Confirmation of the safety of central venous catheterisation in critically ill infants and children — the Baragwanath experience

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Objective. To evaluate, in critically ill children, the safety and effectiveness of routine central venous catheterisations (CVCs) performed by residents from all disciplines.

Design. Prospective audit of all CVCs over a 24-month period.

Setting. Multidisciplinary intensive care unit at Baragwanath Hospital, Soweto.

Patients. All critically ill patients 12 years of age or younger requiring CVC. All percutaneous sites (subclavian, internal jugular and femoral) were used; these were selected by the attending doctor and not influenced by the audit.

Results. There were 272 catheterisation attempts, of which 241 (88.6%) were successful. Patient age and size but not disease severity influenced incidences of both catheterisation failure and minor bleeding. The latter was the commonest early complication, occurring in 63 (23.2%) successful catheterisations. There were 7 major complications — 3 pneumothoraces, 2 tachyarrhythmias and 2 major bleeds, all with subclavian vein catheterisation. Catheter-related infections (CRIs) occurred in 85 (51.2%) of 166 lines and catheter-related septicaemia (CRS) in 10 (5.7%) of 175 lines where there were sufficient data for evaluation. No patient or line factor, including duration of insertion, influenced CRI or CRS. In CRI, *Staphylococcus epidermidis* was the commonest organism. Other common CRI isolates were *Enterococcus faecalis, Klebsiella* spp. and *Candida albicans.* Six different organisms were implicated in CRS.

Conclusions. CVC is a safe procedure with a high success rate. The femoral vein is the recommended percutaneous site of choice as it carries no great risk of sepsis and does not expose the patient to the hazard of intrathoracic complications.

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Central venous catheterisation (CVC) is an invasive procedure commonly performed in intensive care units (ICUs). Its safety and efficacy are well established in adults.[1-4] As paediatric patients are smaller, CVC is more difficult and is therefore regarded as a hazardous procedure. Consequently, central venous lines (CVLs) have been under-used in children. Critically ill children frequently require a CVL for the administration of inotropes or parenteral nutrition or for haemodynamic monitoring. Thus CVC is an essential technique for physicians working with such patients. Paediatric residents can be trained to perform the procedure with a high degree of success,[5,6] but supervision may not always be available.

The complications of CVC can be early or late, the former occurring during catheterisation.[5,6,8] Catheter-related septicaemia (CRS) is the most serious late complication.[6-9] The percutaneous site of catheter placement may affect the infection rate; the femoral area is thought to carry the greatest risk. However, femoral vein catheterisation offers advantages over the subclavian and internal jugular routes by avoiding the risk of pneumothorax, haemothorax, thoracic duct trauma and cardiac arrhythmias.[10]

This report describes our experience with routine CVC. We evaluated the safety and effectiveness of insertion of CVL by doctors from many disciplines and with widely varying experience, and recorded early and delayed mechanical complications and line sepsis.

Subjects and methods

Subjects

After institutional approval, we prospectively studied all CVC attempts in children 12 years of age or younger in the 2-year period from June 1991. The insertion site was chosen by the attending doctor, independently of the audit.

Setting

This study was performed in a multidisciplinary intensive care unit which admits paediatric and adult medical and surgical patients and is staffed by residents of all disciplines. Their experience varies from first year post-internship to senior residency.

Catherisation technique

All catheters were inserted percutaneously using the modified Seldinger technique.[11-13] The subclavian, internal jugular and femoral sites were used.

Aseptic techniques including masks, surgical hand washing, sterile gloves, gowns and drapes were routinely used for all insertions. The insertion site was cleaned with

10% povidone-iodine before insertion and the field was surgically isolated. A semi-permeable adhesive plastic dressing (Opsite; Smith and Nephew) was placed on the insertion site. After insertion of chest lines, i.e. subclavian or internal jugular, a chest radiograph was performed to ensure correct placement of the catheter tip[14,15] and to exclude any intrathoracic complications. All femoral catheter tips were in the inferior vena cava within the abdomen.

Data collection

The following data were collected at the time of CVL insertion: age, weight, sex, and haemodynamic and respiratory status of the patient; catheter type and size, percutaneous site, number of catheterisation attempts, success or failure, and any early complications.

Following CVC, patients were examined daily, until removal, for any late complications including local sepsis, fluid extravasation into tissues, catheter leakage, limb swelling or ischaemia (femoral CVCs only), or vascular thrombosis. Catheter blockage and accidental removal were also noted.

Each skin puncture was regarded as an attempt and catheterisation was considered to be successful when the vein was cannulated. Haemodynamic status was assessed clinically. Respiratory status was classified as not intubated, or intubated with ventilation (with or without paralysis). Complications were classified as minor or major, with the latter requiring treatment.

Catheters were removed when no longer required or when late complications were suspected. At removal, blood samples for culture were drawn from the catheter and a peripheral vein. Catheter tips were aseptically removed and cultured.[16] CRS was defined as a catheter tip or blood culture yielding the same organism as the peripheral culture, and catheter-related infection (CRI) as a catheter tip or blood culture with a negative peripheral blood culture.[17]

Statistical methods

Comparisons of categorical variables were made with the chi-square statistic, and continuous variable comparisons were performed using the Wilcoxon test. A probability value of < 0.05 was accepted as significant.

Results

Patients

Our survey covered 272 CVC attempts (in 155 patients), 241 (88.6%) of which were successful. The mean patient weight was 10.3 kg (range 2 - 40 kg); in 173 cases (63.6%) the patient weighed ≤ 10 kg. Patient disease severity was assessed on admission using the PRISM scoring for predicted mortality.[18] The mean predicted mortality rate was 30.5%.

The haemodynamic status was normal in 171 (62.9%) cases. Patient respiratory status was as follows: 23 (8.5%) CVCs, patients were not intubated; 116 (42.4%) patients were ventilated without paralysis and 133 (49.1%) with paralysis.

Central venous lines

The mean duration of catheterisation was 5.8 days (range 1 - 21 days). Catherisation was performed using Arrow catheters, of which 7 (2.6%) were single, 234 (86%) double and 31 (11.4%) triple lumen. Percutaneous sites used in catheterisation are shown in Table I. The indications for catheterisation were: (*i*) haemodynamic monitoring in 172 patients (63.2%), of whom 130 also received inotropes; (*ii*) intravenous alimentation in 41 patients (15.1%); and (*iii*) lack of peripheral access in 59 (21.5%). Central venous pressure measurements for haemodynamic monitoring were taken irrespective of catheter site, i.e. whether femoral or non-femoral.[19]

Table I. Percutaneous sites of CVC attempts

Percutaneous site	No.	%
Right subclavian	49	18.0
Left subclavian	45	16.5
Right internal jugular	48	17.6
Left internal jugular	8	2.9
Right femoral	78	28.7
Left femoral	44	16.2

Non-infectious complications

Early. The non-infectious complications are listed in Table II. The commonest early complication was bleeding at the insertion site. Most of these were minor bleeds which resolved with pressure on the puncture site. In two instances, the catheter had to be removed from the subclavian site because of intractable bleeding. Haematoma formation occurred in 18 patients, of whom 13 also had minor bleeding. Arterial puncture was recorded in 11 cases with no percutaneous site predilection. Catheter malpositioning occurred with 8 non-femoral lines (7 subclavian, 1 internal jugular); in all instances the catheter was in the jugular vein towards the head — 7 were right-sided. Major complications occurred only with subclavian catheters; except for 1 case of pneumothorax, all the catheters were right-sided.

Table II. CVC — non-infectious complications

Complication	No.	%
Early (N = 272)		
Failure	31	11.4
Bleeding		
Minor	63	23.2
Major	2	0.7
Haematoma	18	6.6
Arrhythmia	2	0.7
Pneumothorax	3	1.1
Arterial catheterisation	11	4.0
Malpositioning	8	2.9
Late (N = 241)		
Local swelling	3	1.2
Fluid extravasation	5	2.1
Obstruction	7	2.9
Removal	8	3.3

Delayed. All the delayed non-infectious complications were minor, with no cases of vascular thrombosis, limb swelling or ischaemia. These complications occurred at all percutaneous sites, although accidental removal occurred more commonly with internal jugular CVLs — 4 of 8 catheters which 'fell out' were internal jugular catheters.

Factors influencing complications. Failure of catheterisation was not influenced by patients' haemodynamic or ventilatory status, catheter size or percutaneous site. However, success of catheter placement was affected by patient age and weight (Table III). Similarly, the incidence of minor bleeding was not influenced by ventilatory or haemodynamic status, or the site or size of the CVL, but was more common in the younger ($P = 0.02$) and smaller ($P = 0.04$) children. Minor bleeding was also associated with a greater number of cannulation attempts ($P < 0.0001$); the mean (± SD) numbers of attempts in patients with and without bleeding were 3.7 ± 2.7 and 2.4 ± 2.1, respectively.

Table III. Factors influencing catheterisation failure

Patient factor	Success	Failure	*P*-value
Age (mo.)	12 (0 - 132)	4 (0 - 84)	0.03
Weight (kg)	8 (2 - 40)	6 (2 - 28)	0.0001

Results expressed as median (range).

Infectious complications

Culture results were available in 166 (68.9%) cases for assessment of CRIs and in 175 (72.6%) cases of CRS evaluation. In 9 cases where peripheral blood cultures were negative, catheter blood or tip cultures were not available. CRIs were present in 85 (51.2%) and CRS in 10 (5.7%) patients. These complications were not associated with the duration of catheterisation or the clinical condition of the patient. CRIs were more common in catheters inserted in the internal jugular site (64.5%) than the femoral (47.3%) or subclavian (50.8%) sites. However, these differences were not significant.

The organisms isolated in cases of CRI are shown in Table IV. The commonest isolate was *Staphylococcus epidermidis*, which occurred more than twice as frequently as the next most commonly cultured micro-organisms — *Klebsiella* spp., *Candida albicans* and *Enterococcus faecalis*. The distributions of Gram-positive and Gram-negative organisms in femoral and non-femoral sites are shown in Table IV. These did not differ, as Gram-negative organisms represented 35.4% of femoral and 35.3% of non-femoral isolates. In CRS, 6 different organisms were implicated, with 3 cases each of *S. epidermidis and Klebsiella* spp. (Table V).

There were no deaths attributable to either non-infectious or infectious complications of CVC.

Table IV. Organisms isolated in cases of CRIs in non-femoral and femoral catheters*

	Non-femoral		Femoral	
Organism	No.	%	No.	%
Gram-positive organisms	37	31.9	25	21.6
S. epidermidis	23	19.8	12	10.3
S. aureus	5	4.3	3	2.6
E. faecalis	7	6.0	6	5.2
Other Gram-positive organisms	2	1.7	4	3.4
Gram-negative organisms	24	20.7	17	14.7
Klebsiella spp.	11	9.5	4	3.4
Enterobacter spp.	3	2.6	4	3.4
Acinetobacter spp.	4	3.4	3	2.6
Pseudomonas aeruginosa	3	2.6	3	2.6
Other Gram-negative organisms	3	2.6	3	2.6
C. albicans	7	6.0	6	5.2

* 2 organisms isolated in 25 cases and 3 in 3 cases.

Table V. Organisms isolated in cases of CRS

Organism	No.
S. epidermidis	3
S. aureus	1
E. faecalis	1
Klebsiella spp.	3
Acinetobacter spp.	1
C. albicans	1

Discussion

Recent series of CVC in children have reported rates of successful catheterisation ranging between 86% and 97%,[5,6,10,20] and in younger and smaller children rates of about 80% have been reported.[5,20] These investigators also showed that success was not influenced by disease severity[5] or operator experience.[5,18] We had a similar success rate of 89% and also found patient age and size but not disease severity to be significant influencing factors. We did not determine the influence of operator experience, but because of the heterogeneous nature of our unit many of these have limited experience of paediatric CVC.

Major early complications are rare. We had 3 cases (1.1%) of pneumothorax, none of haemothorax; in two instances tachyarrhythmias (0.7%) necessitated line withdrawal. Our results are comparable with those of other series.[5,6] Casado-Flores *et al.*[6] reported 2 instances of haemothorax in subclavian lines of patients with pre-existing alterations in coagulation. We would consider this a relative contraindication to subclavian or internal jugular CVC, and in such a situation would select the femoral percutaneous site as any bleeding would be more clinically evident and could potentially be controlled by direct compression.

We report a high incidence of minor bleeding with CVC, but these cases were all stopped by pressure at the insertion site. Minor bleeding was more common in smaller and younger patients and was associated with more cannulation attempts. In small individuals, where catheterisation is more difficult, as evidenced by greater failure rates, multiple cannulation attempts are often necessary.[21] These cases of minor bleeding are possibly over-reported, as one would expect some oozing from a skin site where there have been many puncture wounds.

Catheter malposition occurred predominantly with subclavian catheterisations. As experienced by others,[6] these were in most cases associated with right-sided catheterisation. This finding is attributed to the anatomical position of the brachiocephalic trunk which facilitates the upward direction of the catheter tip.[6]

Delayed non-infectious complications were all minor. There were no cases of vascular obstruction or clinical evidence of venous thrombosis. Routine fluoroscopic investigations to detect subclinical venous thrombosis simply to document their presence more accurately are not justified.[10]

As most series report few serious non-infectious late complications, the most common and most serious late complication associated with CVC is CRS. Although recorded as the most common complication, the incidence is still low and has variously been reported to be between 1.4 and 5.8 per 100 cases.[5,13,20] Therefore, in most studies the actual number of cases is too small to draw any meaningful conclusions about predominant organism type and possible associated factors. For example, in a recent large series,[6] there were 6 cases of CRS in which 5 organisms were isolated, 2 cases of *S. epidermidis* and 1 each of 4 other organisms. Similarly in the earlier series of Smith-Wright, *et al.*[8] in 11 cases of CRS, 8 different organisms were isolated. In our series we documented 10 cases of CRS and identified 6 different organisms of which there were 3 cases each of *S. epidermidis* and *Klebsiella* spp. The finding that *S. epidermidis* predominates is in keeping with other experience.[22] The high incidence of *Klebsiella* spp. is well documented in critically ill patients in ICUs.[23,24] No patient or catheter variable, including duration of catheterisation, influenced the incidence of CRS.

CRI occurred in just over 50% of cases where sufficient culture data were available. The most common organisms were the same as those associated with CRS, although *Enterococcus* and *C. albicans* also occurred frequently. Coagulase-negative staphylococci and *C. albicans* have previously been recognised as the organisms most often responsible for CRI.[22] The rate of CRI was also not associated with any patient or catheter variables, although it did occur slightly more commonly with catheters placed in the internal jugular vein. A possible explanation is the greater difficulty of both securing catheters and applying a sealed dressing experienced in the neck compared with the chest or groin. These findings confirm those of Stenzel *et al.*,[22] and further dispel the myth that the femoral region is a dirty area contaminated by the perineum, which must be avoided when a site for percutaneous CVC is selected. Furthermore, as CVC in the femoral area does not expose the patient to the major intrathoracic complications and avoids the need for recurrent chest radiographs to confirm catheter tip position,[14,15] it would appear to be the site of choice for CVC in children.

Conclusions

In our experience, CVC in critically ill children has a low complication rate with limited morbidity and no mortality. Although to be skilled in this technique is a desirable goal for doctors managing these patients, it can still be performed by less experienced medical staff without increased risk. The femoral vein is the percutaneous site of choice.

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