

Radiological Placement of 211 Central Venous Catheters: Outcome and Complications

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Abstract

A prospective study of 211 central venous catheters consecutively placed in 186 patients under radiological guidance was conducted over an 18-month period. The majority (64%) of our patients were at risk for acute complications or failure. These risks included bleeding tendency, distorted anatomy, or previous complicated lines and failed "blind" percutaneous attempts. We employed the subtraction angiographic technique for venous mapping or ultrasound localisation to guide our initial puncture. The accumulated catheter experience was 15,295 days and the median catheter survival time was 166 days. The success rate was 100%. Our acute complications included 1 case of arterial puncture (0.5%), 2 pneumothoraces (1.0%), and 13 patients (6.1%) with haematoma or prolonged oozing at the puncture site. The calculated infection rate was 0.25 episodes per 100 catheter days at risk. These results are comparable to those reported in the literature. We conclude that central venous catheterisation using imaging guidance is accurate and safe, and should be the method of choice especially in high-risk patients.

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Introduction

Long-term central venous access is an important part of modern medical practice, especially in the haematology and oncology units. Central venous (CV) catheters are used for the administration of anti-neoplastic agents, immunosuppressive drugs, antibiotics, blood components, hyperalimentation, for frequent blood sampling, and for acute and temporary haemodialysis prior to creation and maturation of arteriovenous grafts/fistulas.^{1,2} Traditionally, these catheters are inserted via a venous cutdown technique or "blindly" using only surface landmarks via a percutaneous route, usually by surgeons in the operating theatre and under general anaesthesia. The cutdown technique has the disadvantages of risk of venous damage, long operating time and a low success rate of 75%.³ The percutaneous "blind" puncture relies on the assumption of patent veins with normal anatomy. Complications that can occur include inadvertent arterial puncture, haemothorax, pneumothorax, nerve injury and catheter malposition. The success rate improves to 96%,³ and the puncture related

complication rate varies from 1% to 7%.³⁻⁵ Over the last few years, there is growing evidence from Europe and North America in favour of imaging guided placement of CV catheters by interventional radiologists in the angiography suites.⁶⁻¹² However, there is a paucity of literature on radiological placement of CV catheters from the Asia Pacific region.

We undertook a prospective study of CV catheters inserted using imaging guidance over an 18-month period in the angiography suite. The objectives of this work were to report our local experience, document the outcome and complication rates, and evaluate the feasibility of such a service in a busy Radiology unit.

Materials and Methods

Patient Group

Between October 1995 and March 1997, 211 catheters were placed in 102 male and 84 female patients, aged between 12 and 81 years (median 41 years). Twenty-one patients needed a second catheter insertion and 2 required 3 catheter insertions. The 186 patients were fol-

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lowed up through March 1998. Except for 11 patients who were lost to follow-up, complete life cycles of all the catheters were available, i.e. no catheter was still *in situ* at the time of writing.

Eighty-four per cent of our referrals came from the haematology (119), oncology (30) and renal (29) departments (Table I). Chemotherapy (64%) was the predominant indication for catheter placement (Table II). One hundred and thirty-five patients (64%) in our cohort were at risk of acute complications or failure of CV catheterisation (Table III). The major risk factor was bleeding tendency (38.9%), due to thrombocytopaenia (less than $140 \times 10^9/L$ platelets) and/or coagulopathy (prothrombin and thromboplastin time out of normal range). The others included distorted anatomy from previous mastectomy, radiotherapy, lymphoedema or mediastinal lymphadenopathy, restricted venous access due to previous CV line complications (sepsis, thrombosis), and previous failed attempts at "blind" percutaneous punctures by the physicians.⁵

TABLE I: PATIENT DIAGNOSIS

Diagnosis	Number	%
Haematological disorders	119	64.0
Leukaemia	84	
Lymphoma	20	
Multiple myeloma	8	
Aplastic anaemia	7	
Solid malignancies	30	16.2
Breast carcinoma	14	
Sarcoma	6	
Gastrointestinal carcinoma	5	
Hepatoma		
Nasopharyngeal carcinoma		
Neuroendocrine tumour		
Primitive neuroectodermal tumour		
Melanoma	1	
Chronic renal failure	29	15.6
Chronic infections	4	2.1
Septic arthritis	2	
Liver abscess		
Meningitis	1	
Gastrointestinal disorders	4	2.1
Crohn's disease	2	
Intestinal lymphangiectasia		
Short bowel syndrome		

TABLE II: INDICATIONS FOR CV CATHETER PLACEMENT

Indication	Number	%
Chemotherapy	135	64.0
Bone marrow transplant	30	14.2
Plasmapheresis	6	2.8
Haemodialysis	30	14.2
Long-term antibiosis	5	2.4
Total parenteral nutrition	5	2.4

Procedure

All patients with thrombocytopaenia and/or coagulopathy were given platelets and/or fresh frozen plasma before and/or during the procedure. It was not our routine practice to administer prophylactic antibiotics or sedation. The catheters were inserted under local anaesthesia and aseptic conditions by staff radiologists in our angiography suites. The procedure generally took 20 to 40 minutes.

Radiological guidance for the initial puncture was in the form of a venous map using digital subtraction angiographic technique or ultrasound localisation. For fluoroscopic guidance of the initial puncture, a digital vein over the dorsum of the hand was cannulated with a 21-gauge butterfly needle. Twenty ml of 300 mg/ml non-ionic low osmolar contrast medium was injected to obtain an angiographic road map of the subclavian vein and superior vena cava. The subclavian vein was assessed for patency and anatomic variations, and the surface marked with a paper clip placed over the patient's infra-clavicular fossa (Fig. 1). A more lateral puncture site was chosen at 2 cm below the junction of the middle and the lateral thirds of the clavicle. For ultrasound guidance, a 7.5 MHz linear array transducer was employed (Fig. 2). The relation of the smaller and pulsatile artery to the vein was identified so as to avoid inadvertent arterial puncture. The access needle was directly visualised in the transverse plane in real-time ultrasound during venous puncture.¹³

The venepuncture site was infiltrated with 2% lignocaine and a small stab incision made. A fine bore 21-22 gauge Chiba needle was used for the initial puncture during fluoroscopic guidance, whilst an 18-gauge needle was used during ultrasound guidance. Upon withdrawal of venous blood, a guidewire was introduced through the venepuncture needle under fluoroscopy and manipulated into the IVC. Utilising the coaxial system and graded dilators, the tract was successively dilated before the appropriate peel-away sheath was

TABLE III: RISK FACTORS FOR CV CATHETER INSERTION

Risk factors	Number	%
Bleeding tendency	82	38.9
Thrombocytopaenia, platelet<100*	62	29.4
Thrombocytopaenia, 100*<platelet<140*	12	5.7
Coagulopathy only		0.5
Coagulopathy and platelet<100*	6	2.8
Coagulopathy and 100*<platelet<140*	1	0.5
Distorted anatomy	4	1.9
Restricted access	15	7.1
Previous failed attempts	34	16.1
Total	135	64.0

* $\times 10^9/L$

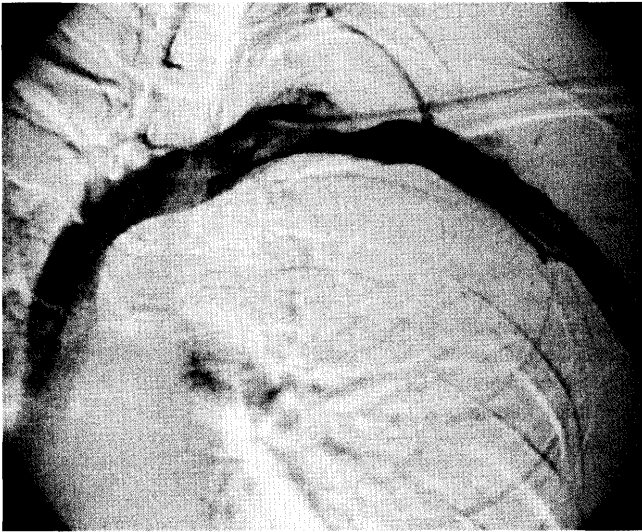


Fig. 1. Paper clip placed over the course of the left subclavian vein, opacified by contrast injected into a digital vein, and demarcating the region of proposed puncture point.

inserted over the guidewire into the vein. The respective catheter was trimmed to the desired length when necessary, by direct measurement of the guide wire. Through the peel-away sheath, the catheter was then fed into the SVC and the catheter tip accurately positioned under fluoroscopy. The desired position of the catheter tip was at the junction of the superior vena cava and the right atrium, the specific position varying between different patients depending on individual anatomy. For tunnelled lines, a skin incision representing the final catheter exit site was chosen just lateral to the sternum or nipple. After infiltration with local anaesthetic, a gently curved subcutaneous track was created over the anterior chest wall using a plastic or metal tunnelling instrument provided with the tunnelled catheter kit. The catheters were secured to the skin using non-resorbable anchoring sutures, and the venotomy incisions in tunnelled lines closed with sutures.

A post procedure chest radiograph was mandatory to confirm the final position of the catheter tip and to exclude any immediate complications, such as haemothorax or pneumothorax that had been missed on fluoroscopy.

Follow-Up

Patients were instructed and trained to care for the catheter by the haematology/oncology/haemodialysis division nurse. The physicians followed up the patients. We reviewed the clinical records at regular intervals, and called up patients and physicians for clarification where necessary, to determine the outcome of the catheters and occurrence of complications.

Infection was divided into local and systemic categories. Local infection comprised exit site and tunnel sepsis. Exit site infection was diagnosed when new erythema,

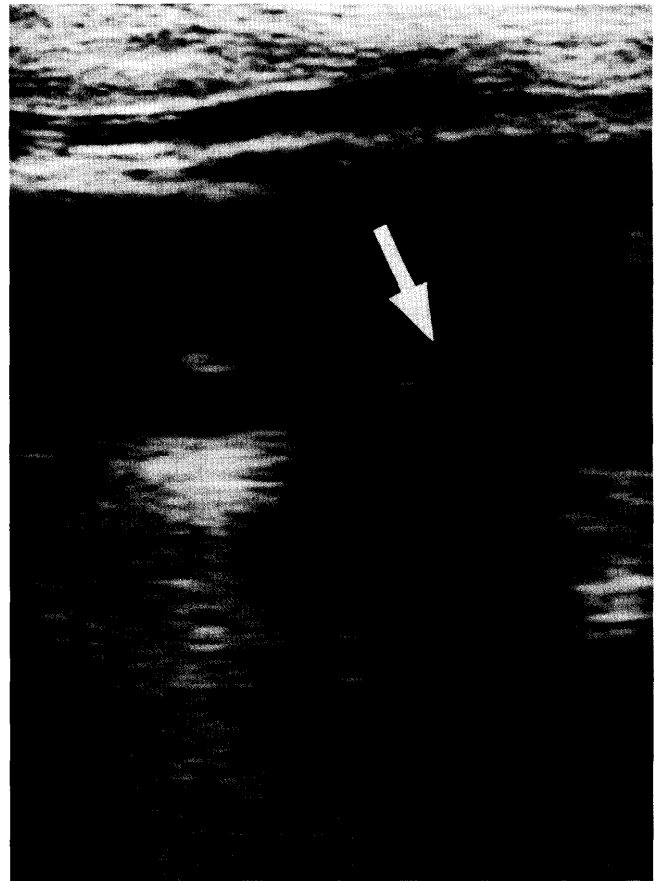


Fig. 2. Sonogram at the infraclavicular fossa showing successful puncture, with the echogenic access needle tip (white arrow) within the hypoechoic subclavian vein.

tenderness, induration and inflammation were seen within 2 cm from the skin exit of the catheter, with or without purulent discharge. Tunnel infections referred to similar findings noted along the subcutaneous tract of tunnelled catheters, more than 2 cm from the skin exit site. Catheter-related septicaemia included all cases of positive or sterile blood cultures in a febrile patient, with no other source of sepsis. The catheters in all these instances were categorically removed according to the standard practice of the referring physicians in our institution, with due consideration of the often immunosuppressed state of these patients.

Catheter thrombosis was clinically diagnosed when difficulty was encountered with aspiration of fluids. Attempts to restore patency using a single 2 ml bolus of 5000 U urokinase into the blocked catheter were made before these catheters were condemned.

Plots of cumulative probability of catheter survival, and freedom from infection [including the 95% confidence interval (CI)], were determined by means of Kaplan-Meier life-table methods, using the SPSS statistical program. Catheters that were lost to follow up, in situ when the patient died, or electively removed, were considered censored events in the computation of catheter survival.

Results

All the 211 catheters were successfully inserted under radiological guidance. Ultrasound guidance was employed in 54 CV catheterisation (25.6%). The right subclavian vein was used for placement of 134 catheters (63.5%) and the left for 41(19.4%). Twenty-seven catheters were inserted via the right internal jugular vein (12.8%), 7 via the left internal jugular vein (3.3%), one via the right femoral vein at the groin and one via a translumbar approach into the inferior vena cava. A variety of single and double lumen CV catheters were placed, of which 41 (19.4%) catheters were tunnelled. There were 14 (6.6%) Groshong (Bard, Salt Lake City, Utah, USA), 54 (25.6%) Central Venous (Cook, Bloomington, Indiana, USA), 84 (39.8%) Hickman (Bard, Salt Lake City, Utah, USA), 20 (9.5%) Hohn (Bard, Salt Lake City, Utah, USA), 12 (5.7%) Mahurkar (Quinton, Bothell, WA, USA), 8 (3.8%) Permcath (Quinton, Bothell, WA, USA), and 19 (9%) Vascath dialysis (Vascath, Mississauga, Ontario, Canada) catheters.

Acute Complications

These were related to the venepuncture. A thrombocytopaenic patient developed haematoma from inadvertent arterial puncture (0.5%) early in our study. This necessitated catheter placement on the contralateral side. Three other patients had haematoma at the puncture site (1.4%) secondary to thrombocytopaenia. Prolonged oozing of blood at the puncture site was seen in 10 (4.7%) patients, 7 of whom again had abnormal platelet counts. The bleeding resolved after prolonged compression and pressure bandage in all patients. There were 2 cases of pneumothorax (1.0%). One patient with 20% pneumothorax was treated with needle aspiration alone. The second patient had bilateral pneumothoraces 20% and 15% in size, treated by chest tube drainage. Multiple failed attempts at "blind" punctures were made just before successful insertion under ultrasound guidance in this patient. Hence, we felt that the pneumothorax was unlikely to have been created during radiological placement. Besides, it would not explain the pneumothorax present on the contralateral side, where only "blind" punctures were attempted. No instance of venous perforation, mediastinal haematoma, haemothorax, air embolism or catheter malposition was encountered.

Catheter Outcome (Table IV)

Fifty-eight patients died with their functioning catheters *in situ*, 11 were lost to follow-up, 71 catheters were electively removed upon completion of therapy, and another 71 were removed for complications. The 11 catheters for which final outcome of catheter was not available belonged to non-resident patients, who returned to their native countries upon stabilisation of

TABLE IV: CATHETER OUTCOME

Outcome	Number of catheters	% of all catheters placed	% of all catheters removed
Lost to follow up	11	5.2	
Patient died with catheter <i>in situ</i>	58	27.5	
Catheter removed:	142	67.3	100.0
Electively	71	33.6	50.0
From complications:	71	33.6	
*Infection	39	18.5	27.5
*Accidentally dislodged	20	9.5	14.1
*Catheter migration	4	1.9	2.8
*Leaking catheter	4	1.9	2.8
*Catheter thrombosis	3	1.4	2.1
*Prolonged bleeding from exit site	1	0.5	0.7

their condition. These catheters lasted 12 to 132 catheter days (median 72 days; mean 74 days) without complications.

The 211 catheters were in place 1 to 408 days (median 58 days; mean 74 days), and made up a total of 15,295 catheter days at risk. The cumulative probability of catheter survival (Fig. 3) was 0.67 at 3 months (95% CI, 0.60-0.75), 0.41 at 6 months (95% CI, 0.29-0.54), and 0.26 at 1 year (95% CI, 0.10-0.42). The median catheter survival time was 166 days or 5.4 months (95% CI, 132-200). The diverse indications for catheter placement, their implication on duration of use, and small numbers of some catheter types made meaningful correlation between catheter type, outcome and complications difficult.

Catheter Infection

A total of 39 infective episodes occurred in 38 (20.4%) patients and 39 catheters (18.5%), all of which were removed. There were 7 cases of local infections (3.3%) in

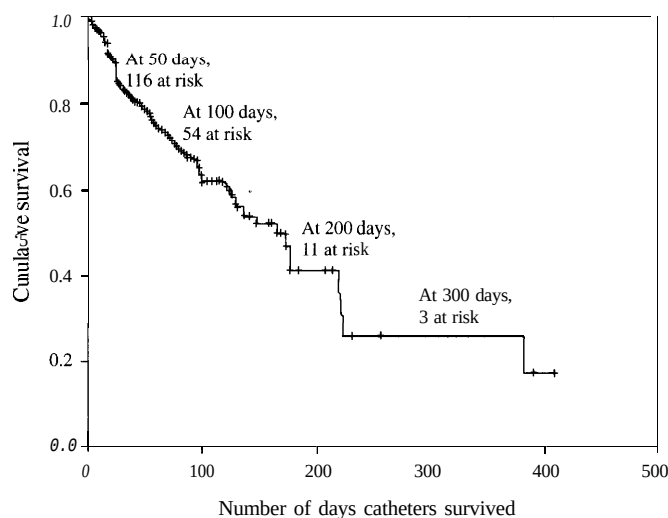


Fig. 3. Kaplan-Meier overall cumulative survival plot.

7 patients (3.8%). Only 2 of the 6 catheters removed for exit site infection (2.8%) were culture positive for microorganisms. One case of tunnel sepsis (0.5%) with abscess formation necessitated incision and drainage as well. Catheter-related septicaemia accounted for 32 infective episodes (15.2%) in 31 patients (16.7%). Nine cases (4.3%) were culture negative for microorganisms, 19 (9%) blood culture positive, and only 4 (1.9%) had positive catheter tip cultures. The more commonly implicated microorganisms were coagulase-negative staphylococci (3 cases), methicillin-resistant *Staphylococcus aureus* (3), *Enterococcus* (2), *Pseudomonas* species (5), *Klebsiella* species (2), *Enterobacter* species (2) and *Candida* species (5).

The calculated infection rate was 0.25 episodes per 100 days at risk overall, and 0.05 episodes per 100 days at risk for local infection. The time to infection was 8 to 224 days (median 31 days; mean 67 days) overall, and 11 to 121 days (median 17 days; mean 32 days) for local infections. Two cases of local infection occurred less than 14 days from catheter placement.

Life table analysis (Fig. 4) demonstrated the probability of freedom from infection to be 0.82 at 3 months (95% CI, 0.75-0.88), 0.60 at 6 months (95% CI, 0.45-0.74), and 0.43 at 1 year (95% CI, 0.20-0.65). Fifty per cent of the catheters were free from infection up to 224 days or 7.3 months (95% CI, 161-287).

Catheter Thrombosis

Twelve catheters were clinically thrombosed (5.7%). Single bolus urokinase therapy declotted 7 catheters and was unsuccessful in 3 (1.4%). These had to be removed or exchanged over the guidewire. Concomitant infection and catheter leakage required removal of 2 catheters. One catheter, blocked after 1 day, had an uneventful radiological placement preceded by several failed attempts at "blind" puncture of the same vessel by the

physicians. The time to catheter thrombosis varied from 1 to 195 days (median 23.5 days; mean 44 days).

Others

Accidental catheter dislodgement occurred in 20 catheters (9.5%) due to the exposed end catching on external structures (e.g. drip stands) or the patients pulling the lines out during confused or delirious states. Only one of these dislodged catheters was tunnelled.

Spontaneous catheter tip migration was noted in 5 cases on follow up chest radiographs; 4 (1.9%) were removed, and 1 catheter which migrated three days after insertion was successfully relocated under fluoroscopy. These cases occurred with subclavian lines commonly in large patients, and the catheter tips tended to flick into the internal jugular vein. The time to catheter tip migration ranged from 3 to 66 catheter days (median 12 days; mean 29 days).

Catheter cracks with fluid leakage resulted in removal of 4 catheters. One patient had bleeding from the exit site on day 5 due to progressive thrombocytopaenia (platelet count dropped from 139 to $66 \times 10^9/L$ from day 0 to 5), leading to catheter removal.

Discussion

Our results attest to the value and safety of radiological guidance in the placement of CV catheters.^{6,12,14} The high incidence of "at risk" patients (64%) in our series must be emphasised. We tabulated our results against those of a surgical series of 121 patients conducted in our institution (Kwek et al, unpublished data) using the "blind" percutaneous technique (Table V). They reported a median catheter survival time of 120 days.

Besides facilitating a more rapid and confident venous puncture, imaging guidance allows the subclavian vein to be punctured at a more lateral site. This is important, since the chance of the needle traversing the pleural space is lowered and the "pinch-off syndrome"¹⁵ is avoided. Page et al⁷ used a 14 G for the initial venous puncture, under guidance of a venous map, and reported no increase in acute complication rate. However, the use of fine bore needles^{6,9,11} probably reduces the risk

TABLE V: COMPARISON WITH RESULTS FROM OUR SURGICAL COLLEAGUES¹⁵

Results and complications	Chan et al	Kwek et al ¹⁵
Success rate	100	95
Arterial puncture	0.5	4
Pneumothorax	1	2
Catheter malposition	0	3
Catheter infection rate	18.5 (0.25)*	15 (0.48)*

* Number of infective episodes per 100 days at risk.
All other figures are percentages.

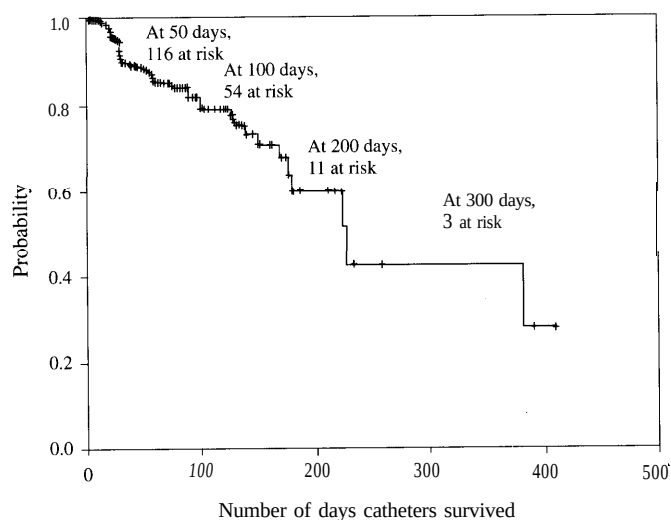


Fig. 4. Plot of probability of freedom from infection.

of catastrophic haemorrhage in the event of arterial puncture, and we preferred the 21-22G needles especially in our large population of thrombocytopaenic patients. The coaxial system allows for fine punctures to gradually increase in size to that required of the catheter.

The main difficulty with the infra-clavicular catheterisation technique lies in pushing a large bore catheter between the clavicle and first rib, with risk of vascular perforation. Gradual and careful dilatation with graded dilators over the Mandril wire and sometimes elevating the upper limb are ways that we found useful to overcome this problem. Insertion of the subclavian catheter may be difficult with kinking of the peel-away sheath. A left-sided approach makes kinking of the peel-away sheath less likely,⁹ but a significant number of our patients had previous complicated lines or previous failed attempts and the numbers of right subclavian placements in our series are therefore comparatively high. Constant monitoring under fluoroscopy ensures accurate final positioning of the catheter tip and any malposition promptly recognised and corrected, minimising repeat insertion attempts.

It is difficult to compare infection rates in different series as the risk varies with the different characteristics of the study population, placement technique, as well as definition and guidelines for clinical management of infective episodes. We gave due reference to the importance of the duration of catheter cannulation in the expression of infection rate.^{11,16-18} All the infective episodes in our series resulted in catheter removal. This reflects the clinical practice in our institution. As many of these patients were receiving chemotoxic or immunosuppressive therapy for malignancies or bone marrow transplant, the physicians preferred to remove the catheters. However, exit site infections have been treated without catheter removal using antibiotics alone even in bacteraemic patients.¹⁷⁻¹⁸ There are also reports of successful treatment of bacteraemic patients without an obvious source of infection, with antibiotics and catheter exchange using the same access tract.¹⁹ Perhaps the interventional radiologists could play a more active role by assisting in the subsequent management of infections related to catheters. We note that the use of prophylactic antibiotics is reported to be associated with a lower rate of local infection.^{6,7} Nevertheless, our infection rate of 0.25 episodes per 100 days at risk is comparable to the figure of 0.2 to 0.32 quoted in the literature,^{9,11-12} and favourable to the figure of 0.48 reported by our surgical colleagues (Kwek et al, unpublished data). These results and others in the literature^{6,14} show that doubts about the sterility of the angiography suite are unfounded.

Our catheter thrombosis rate is within the 3.7% to 10% reported.² Accurate catheter tip placement under direct fluoroscopic guidance, patient motivation, education and training by a dedicated team are important factors

in ensuring a good patency rate. Clinically thrombosed catheters failing urokinase therapy would probably benefit from routine catheter venogram. Besides being diagnostic, it would demonstrate the presence and extent of any venous thromboses, and allow catheter exchange where possible. This is especially important in those patients plagued by limited vascular access sites.

Catheter dislodgements could be reduced by improved suturing technique, vigilant care of the sutured grommet, and increased use of tunnelled catheters, which provide additional anchorage with the Dacron cuff.²

Radiological placement of CV catheters offers other advantages including a more flexible scheduling, increased patient comfort with shorter procedural time and reduced reinsertion attempts, and lower cost for room use. In addition, with their familiarity with guidewire techniques and access to good quality fluoroscopic equipment, interventional radiologists are the ideal people to perform this procedure. Our experience demonstrates that insertion of CV catheters under imaging guidance is associated with high technical success and very low complication rates. We would advocate that this should be the preferred method of choice, especially in high-risk patients.

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