

Artificial Kidney and Dialysis

Dual lumen subclavian catheters for haemodialysis

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KEY WORDS

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ABSTRACT

The dual lumen catheter has recently been developed as a subclavian vascular access device for haemodialysis. This paper describes our preliminary experience with two currently available catheters of this design: the Shiley Dual Lumen Catheter, and the Quinton-Mahurkar Dual Lumen Catheter. The performance of both catheters, characterised by high blood flow rate capabilities, low venous resistances and minimal recirculation, is superior to that of other types of subclavian haemodialysis cannula.

INTRODUCTION

Catheterisation of the subclavian vein has become increasingly popular as a method of temporary vascular access for haemodialysis since the original description in 1969 (1). The advantages of the technique are now well recognised. An experienced operator can achieve catheter placement in a short period of time with a low risk of complications. The catheter can be used immediately, and then left in situ between dialysis. Most importantly the technique preserves peripheral vessels for future use as chronic access routes, and does not leave conspicuous scars.

Until recently subclavian haemodialysis catheters were single-lumen devices which require the use of an expensive reciprocating single-needle system (2). Such a system limits effective blood flow rates and hence dialysis clearances, and may also be associated with high recirculation values depending on operator experience. In an effort to overcome these problems, the co-axial or double lumen subclavian catheter (Figure 1(b)) was de-

veloped (3,4). These catheters have low recirculation, and permit the attainment of high blood flow rates, but are associated with unacceptably high venous resistances.

However, the most recent haemodialysis cannula design to become available is the dual lumen subclavian catheter (DLSC). This report describes our preliminary clinical evaluation of two currently available catheters of this design; the Shiley Dual Lumen Subclavian Catheter and the Quinton-Mahurkar Dual Lumen Subclavian Catheter.

MATERIALS AND METHODS

The Shiley DLSC, made of fluorinated ethylene propylene copolymer, has 15.5 cms of usable tubing with an external diameter of French size 12. The Quinton-Mahurkar DLSC, 23.5 cms long with an 11 French outer diameter, is manufactured from polyurethane and is a more flexible device. Both catheter designs are radiopaque.

The basic design of both catheters is shown in Figure 1(a). A central septum divides the cannula into separate, noncommunicating "arterial" and "venous" blood pathways. In the Quinton-Mahurkar design the "arterial" lumen has six access holes located between 3.3 and 4.3 cms from the distal tip, whereas the Shiley catheter has two larger holes between 4.4 and 5.2 cms of the tip. The "venous" lumen returns blood through the tip of the catheter and through two side holes located in the distal 2 cms of the cannula. Each lumen is connected to a luer-locking injection cap by independently occluding tubing segments that are manufactured with the clamps already in position.

The method of insertion of the DLSC is essentially the same as for single lumen subclavian catheters. After appropriate skin cleansing, the catheter is introduced into the subclavian vein by the Seldinger technique via the infraclavicular route. Rotation of the catheter during insertion may be required to overcome subclavicular tissue. After insertion, both limbs of the catheter are flushed with heparinised saline; and the clamps applied. The DLSC is held in place with a single suture and a double layer of sterile transparent adhesive dressing ("OP-SITE")®. A chest x-ray is taken to ensure correct

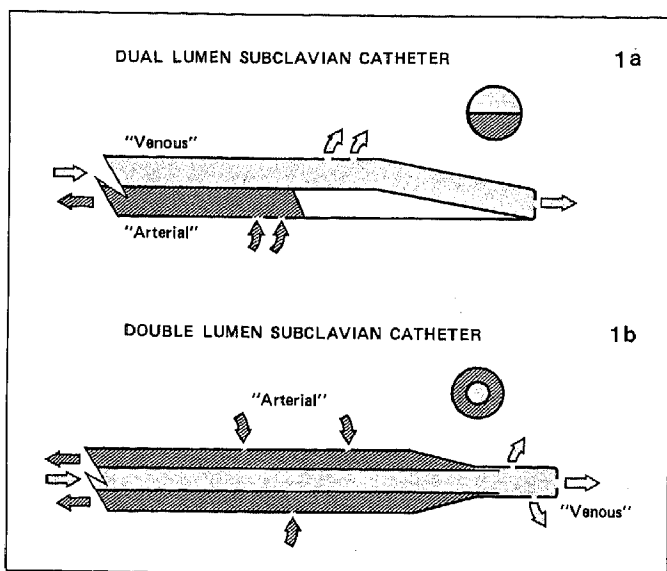


Fig. 1 Design of (a) dual lumen subclavian catheter and (b) double lumen subclavian catheter.

positioning and to exclude complications. If it is intended to commence dialysis immediately, a loading dose of heparin is instilled into the "venous" port, and the "arterial" and "venous" blood lines are attached to their respective colour-coded ports. After the clamps are released, dialysis is begun.

At the termination of dialysis, after the patient's blood is returned, each lumen is flushed with saline. Luer-locking injection caps are fitted to both ports, and 1 cc (Shiley) or 1.5 cc (Quinton-Mahurkar) of 1000 u/cc heparin is injected into each cap.

Patency of the catheters is maintained between dialyses in in-patients by repeating the post-dialysis heparinisation regimen every eight hours under strictly aseptic conditions. In out-patients the heparin concentration is increased to 5,000 u/cc after dialysis, and then left undisturbed, until the solution is withdrawn prior to the next treatment.

Measurements of recirculation were performed on each catheter at a blood flow rate of 200 mls/min during the initial hour of the first ten dialyses, and at every fifth dialysis thereafter. Blood samples were taken simultaneously by three individuals from the "arterial" line (A), the "venous" line (V) and a peripheral venous site (P). Plasma urea and creatinine concentration were measured on a Beckman Astra 8 analyser (Beckman R11C Ltd, Sands Industrial Estate, High Wycombe, Bucks, England). Plasma phosphate concentration was measured by Technicon Autoanalyser All (Technicon-Instrument Co., Tarrytown, New York, U.S.A.). Recirculation values (R) were calcu-

lated from the concentrations of urea, creatinine and phosphate according to the formula:

$$R = (P - A) / (P - V) \times 100. \quad (5)$$

Flow resistance in the venous return of the catheter was measured at the time of every recirculation test. During every fifth dialysis the relationship between blood flow and venous resistance was studied. Blood flow rate was measured and adjusted to the study requirements using bubble transit times determined in triplicate. An accuracy of $\pm 3\%$ is achieved with routine use of this method of measuring blood flow rates in this clinical range (6). Pivipol® blood tubing (Bellco, catalogue reference BL807), was used in all procedures. Venous pressure was measured at 100, 150, 200, 250 mls/min and at maximum flow. The maximum flow rate was taken as either the pump speed at which the flow became insufficient, or that which caused the venous pressure to reach 200 mmHg, whichever ever occurred first.

RESULTS

(a) Clinical observations

The Shiley DLSC was evaluated in 18 patients (9 male, 9 female, age 55.5 ± 9.3 (SD) years) and the Quinton-Mahurkar DLSC in 11 subjects (6 male, 5 female, age 57.5 ± 9.8 years). The reasons for insertion of the DLSC are shown in Table I).

TABLE I - REASONS FOR INSERTION OF DLSC

	Shiley	Quinton-Mahurkar
Acute Renal Failure	3	2
Transfer from CAPD	5	3
ESRF: No time for A-V fistula	9	6
Failure of A-V fistula	1	0
Total	18	11

TABLE II - RECIRCULATION VALUES (\pm SD) AT BLOOD FLOW RATE 200 ML/S/MIN

	Shiley			Quinton-Mahurkar		
	Urea	Creatinine	Phosphate	Urea	Creatinine	Phosphate
First dialysis	5.6 ± 5.4	6.0 ± 5.9	6.5 ± 6.9	5.2 ± 3.9	4.6 ± 5.1	4.2 ± 3.0
All dialysis	5.9 ± 2.6	5.5 ± 3.3	6.4 ± 3.5	7.6 ± 3.2	7.6 ± 4.2	7.0 ± 3.2

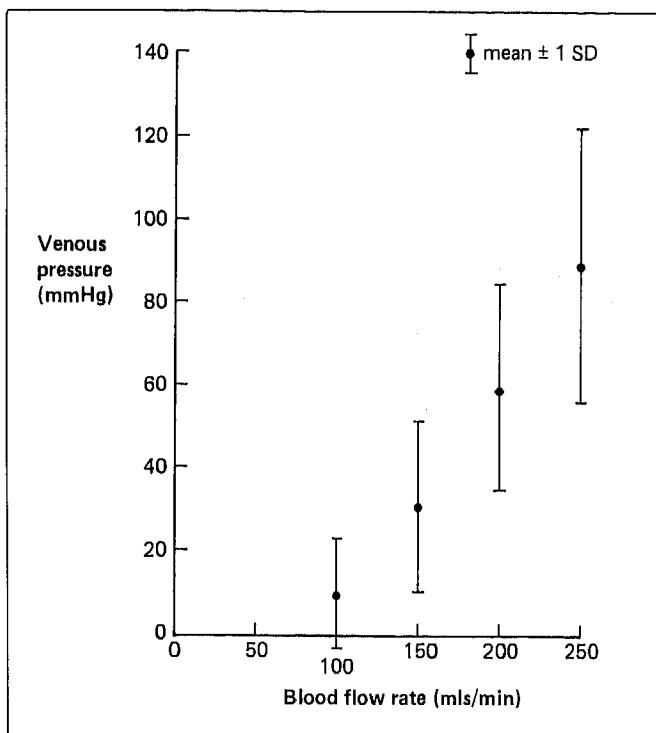


Fig. 2 Shiley DLSC: Relationship between venous resistance and blood flow rate.

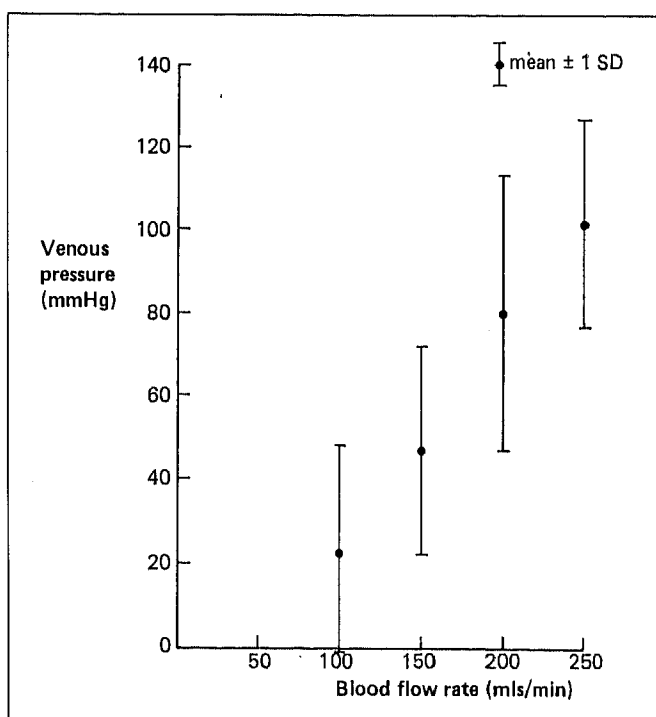


Fig. 3 Quinton-Mahurkar DLSC: Relationship between venous resistance and blood flow rate.

Placement of all catheters was uneventful and no traumatic complications were experienced. The Quinton-Mahurkar catheter proved more difficult to position because of its greater flexibility and percutaneous vessel dilator was required in 4 patients. A dilator was used in only one subject receiving a Shiley DLSC.

One hundred and twenty three dialyses were performed using the Shiley DLSC (471 dialysis hours) and one hundred with the Quinton-Mahurkar device (397 dialysis hours). Each Shiley catheter was in place for 15.7 ± 13.6 days, and provided vascular access for 6.8 ± 5.5 dialyses. The Quinton-Mahurkar catheters were each used for 23.5 ± 12.6 days and 9.1 ± 5.6 dialyses.

Inadequate flow from the "arterial" limb prior to commencement of dialysis necessitated catheter repositioning before 14 of the 123 treatments with the Shiley DLSC (11.4%) and 2 of the 100 dialyses using the Quinton-Mahurkar DLSC (2%). On all occasions easy, unobstructed instillation of saline into the "arterial" port confirmed patency of the "arterial" access holes. Rotation of the catheter, over a guide wire, through 180° overcame this problem and permitted initiation of dialysis

No cannula associated sepsis was noted in our patients. Five of the subjects using the Shiley DLSC experienced a dull, continuous ache related to the insertion site throughout the period of catheter use. This discomfort was relieved on catheter removal. Only one serious complication was directly attributable to a DLSC. A 45 year old developed a radiographically proven subclavian vein thrombosis 18 days after insertion of a Quinton-Mahurkar DLSC. The patient recovered without sequelae on anticoagulant therapy. Four patients died during the study. On each occasion post-mortem examination confirmed that the cause of death was unrelated to the catheter.

Seven Shiley devices were removed because of catheter failure. Two became irrecoverably clotted, and in 5 patients dialysis could not be performed because of insufficient "arterial" flow unresponsive to catheter repositioning. Four Quinton-Mahurkar catheters were taken out for similar reasons. One clotted, one had inadequate "arterial" flow, but two developed problems related to the external portion of the device. One catheter spontaneously leaked at the hub, and the other developed a stricture of the "arterial" clamping segment sufficient to obstruct blood flow.

(b) Catheter haemodynamics

(i) Pressure flow relationship

The relationship between venous pressure and blood flow rate for the two catheter designs is depicted in Figures 2 and 3. As blood flow rate was increased from 100

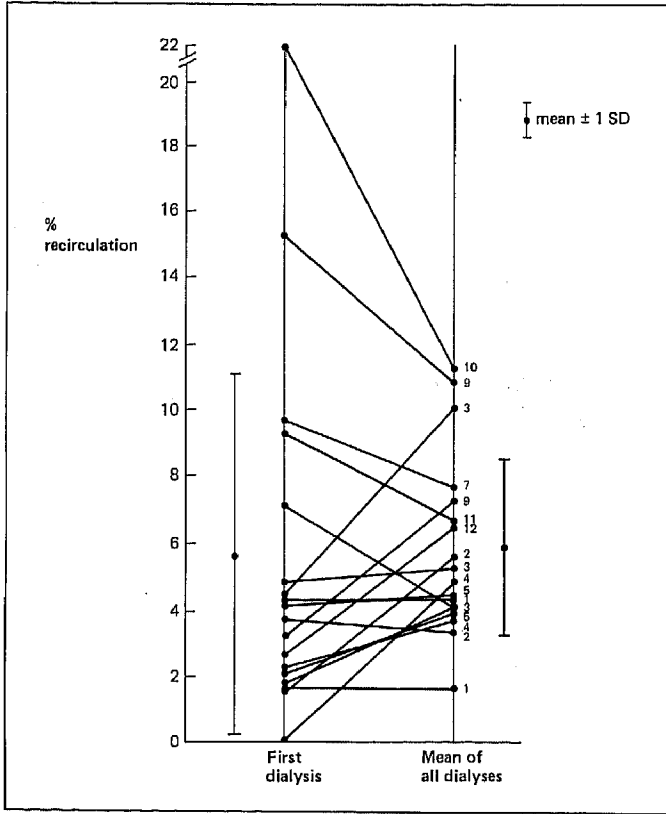


Fig. 4 Shiley DLSC: Change of urea recirculation values with continued use. Figures at right of each line indicate number of dialysis studied with each catheter.

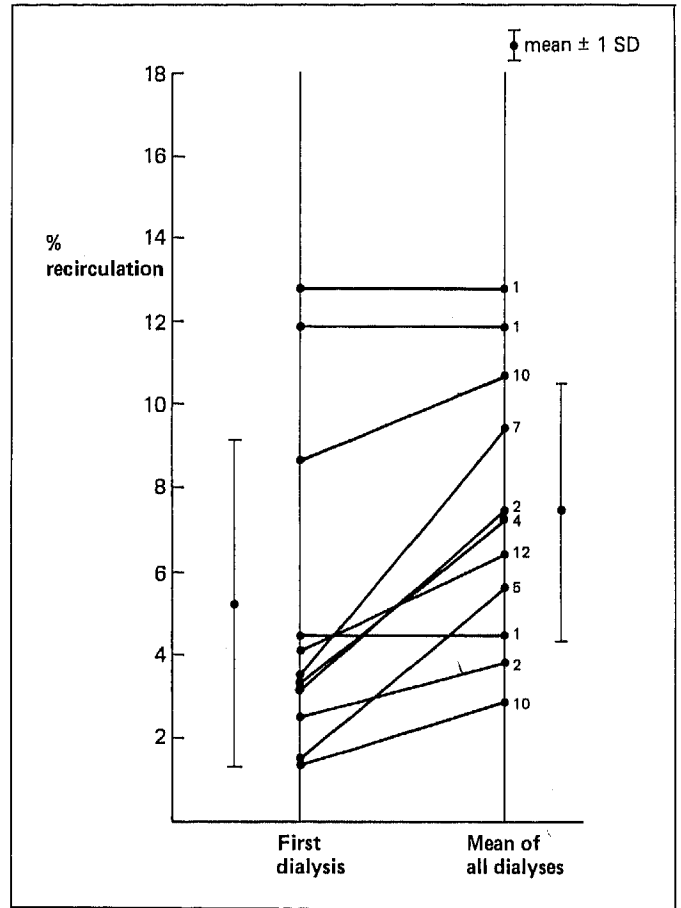


Fig. 5 Quinton-Mahurkar DLSC: Change of urea recirculation values with continued use.

up to 250 mls/min venous pressure increased from 9 to 89 mmHg with the Shiley catheter and from 23 to 102 mmHg with the Quinton-Mahurkar device. At our usual dialysis blood flow rate of 200 mls/min the mean venous pressure for the Shiley DLSC was 59 ± 24 mmHg during the first dialysis with each catheter, and 59 ± 25 mmHg when all treatments were analysed. The Quinton-Mahurkar catheter had a venous pressure of 72 ± 35 mmHg, at a blood flow rate of 200 mls/min, during the first dialyses rising to 80 ± 33 mmHg with continued use.

The maximum flow rate achieved with the Shiley catheter was 362 ± 85 mls/min during the first dialysis, and 369 ± 88 mls/min when all dialyses were analysed. The maximum flow rate of the Quinton-Mahurkar DLSC was 359 ± 83 mls/min during the first dialysis and 329 ± 77 mls/min during all dialysis.

(ii) Recirculation

Mean recirculation values measured during the first dialysis with each catheter design are shown in Table II,

along with the figures for all dialyses. Figures 4 and 5 demonstrate graphically the changes in the urea recirculation of the individual catheters.

DISCUSSION

Percutaneous cannulation of the subclavian vein is now widely accepted as the best method for providing temporary vascular access for haemodialysis. Three types of subclavian catheter are currently available. The most popular device used in the United Kingdom is the single lumen catheter. It is easy to insert and reliable once positioned. However, this catheter necessarily requires a single needle dialysis system since blood must be alternately cycled through the same pathway. Recirculation values as high as 22% (7), obligatory high and often unpredictable ultrafiltration rates, and foaming of the venous drip chamber causing clotting are all potential disadvantages of such a single needle system.

Co-axial or double lumen subclavian catheters overcome some of these problems. Bregman described a recirculation rate of 5% with the double lumen device manufactured by Vas-Cath of Canada Ltd. (4), while Uldall reported zero recirculation with his catheter design (3). However, at blood flow rates of between 190 and 227 ml/min venous pressures of between 160 and 190 mmHg have been experienced, again promoting high obligatory ultrafiltration (3, 4). The need to replace the inner lumen at each dialysis, recommended by certain manufacturers, increases the risk of infection as well as the cost (4).

The recently developed dual lumen subclavian catheter design appears to have clear advantages over both the single lumen and double lumen devices. Haemodynamically both the Shiley DLSC and the Quinton-Mahurkar DLSC function efficiently. While recirculation values are comparable with those reported using double lumen catheters, blood flow/venous resistance characteristics are far superior. The function of the Shiley catheter appears particularly stable with continued use. There was a tendency for the performance of the Quinton-Mahurkar DLSC to deteriorate with time as judged by increasing recirculation values, increasing venous resistance and decreasing maximum blood flow rates.

The insertion, and any subsequent repositioning, of all catheters was performed by one experienced operator (JST). This may explain the absence of traumatic complications and infections related to the use of these catheters. Significant catheter clotting occurred infrequently. It was common to aspirate a small amount of clot whilst preparing the patient for dialysis, but only three cannulae had to be removed because of irrecoverable occlusion by thrombus. Once positioned the dual lumen catheters were generally well tolerated by the patients despite their larger external diameter compared with single lumen devices. However, the use of five Shiley catheters was associated with a continuous dull ache related to the insertion site. Direct pressure by this stiffer device on the periosteum covering the inferior surface of the clavicle may be responsible for this discomfort.

It is mandatory to ensure intravascular positioning of the entire catheter before commencing haemodialysis. Free aspiration of blood from both "arterial" and "venous" ports must be achieved before the haemodialysis blood lines are connected. It is not uncommon to find that blood flow from one pathway of a dual lumen catheter is absent or inadequate when preparing a patient for dialysis. Easy, unobstructed injection of saline down the affected pathway confirms patency of the access holes. In this situation, rotation of the catheter through 180° followed by easy aspiration of blood from the previously affected pathway confirms intravascular positioning. One presumes that close proximity of the vascular en-

dothelium to the "obstructed" holes causes this problem. Attempted aspiration of blood merely sucks the vessel wall into the holes, so occluding them. This is a particular problem of the dual lumen catheter, as the access holes are clustered on opposite sides of the cannula, and not spirally arranged like the ones on single and double lumen subclavian devices. Unfortunately, this problem was insoluble on a number of occasions, and was the commonest cause of catheter failure in this study.

In conclusion, therefore, the haemodynamic characteristics of the dual lumen haemodialysis catheter make its performance superior to other currently available forms of subclavian vascular access device. Our preliminary clinical evaluation of both the Shiley DLSC and the Quinton-Mahurkar DLSC recommends their use in patients requiring acute haemodialysis. Whether to use a single lumen or a dual lumen subclavian catheter is a matter not only of personal preference but also of availability and skill in the use of single needle dialysis machines.

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REFERENCES

1. Erben J., Kvasnicka J., Bastecky J.: Experience with routine use of subclavian vein cannulation in hemodialysis. *Proc. EDTA*, 6, 59, 1969.
2. Uldall P.R., Dyck R.F., Woods F., Merchant N., Martin G.S., Cardella C.T., Sutton D., deVeber G.A.: A subclavian cannula for temporary vascular access for haemodialysis or plasmapheresis. *Dial. Transplant.*, 8, 963, 1979.
3. Uldall P.R., Woods F., Merchant N., Crichton E., Carter

- H.: A double-lumen subclavian cannula (DLSC) for temporary hemodialysis access. *Trans Am. Soc. Artif. Intern. Organs*, 26, 93, 1980.
4. Bregman H., M.: The double-lumen subclavian cannula A unique concept in vascular access. *Dial. Transplant.*, 11, 1065, 1982.
 5. Keshaviah P., Carlson G., Wathen R.: In vitro and clinical evaluation of single-needle dialysis. *Trans. Am. Soc. Artif. Organs*, 22, 367, 1971.
 6. Hoenich N.A., Kerr D.N.S.: Dialysers. In: *Replacement of renal function by dialysis*, 120-122, Drukker W., Martius Nijhoff, 1983.
 7. Raja R., Kramer M., Fernandes J.: Subclavian vein and femoral vein catheterisation for hemodialysis - one year comparison. *Absts. Am. Soc. Intern. Organs*, 11, 37, 1982.