THE SUBCLAVIAN CATHETER IN HAEMODIALYSIS

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Introduction

The main stimulus for the development of an improved method of temporary vascular access for haemodialysis in our hospital arose from the presence of a very active programme of long term peritoneal dialysis. When patients on regular peritoneal dialysis developed peritonitis or required abdominal surgery they had to be transferred at short notice to haemodialysis. Arteriovenous (A-V) fistulae cannot generally be constructed and used immediately, so we were faced with the alternatives of using repeated femoral cannulation or inserting a Silastic-Teflon shunt. It was felt to be barely justified to destroy blood vessels to construct a shunt which would only be required for an average of three weeks. On the other hand, femoral cannulation before each dialysis was often painful for the patient as well as time-consuming for medical and nursing staff. We found that a catheter introduced into the superior vena cava, via the subclavicular approach to the subclavian vein could be left in place for repeated dialyses. The patient could remain mobile and the catheter could be kept patent between one dialysis and the next by instillation of heparin through an injection cap with a rubber diaphragm. When no longer needed the catheter could simply be removed and there would be minimal residual scarring. Since no blood vessels had been destroyed the same technique could be used again in the future if another period of temporary haemodialysis was required. The other alternative, to give every long term peritoneal dialysis patient a fistula in case it should one day be needed, is not really feasible. Many of these elderly patients have poor vessels, a fistula is an unwanted additional strain on already limited cardiac function, and most of the A-V fistulae will never be used anyway.

Subclavian cannulation for haemodialysis was first reported by Erben et al in 1969[1] but is now being widely used all over the world. In our own hospital we now perform about 200 subclavian cannulations yearly for temporary vascular access for haemodialysis, and since the summer of 1977 only one patient with end-stage renal failure has received a Silastic-Teflon shunt. This was after a traumatic and completely avoidable complication from a subclavian catheter. We
have fortunately had no deaths attributable to subclavian cannulation nor any prolonged morbidity resulting from the technique.

Equipment and technique

The catheter designed in this hospital, and presently marketed by the Sorenson Research Company, Salt Lake City, Utah, USA, has evolved by modification of earlier designs. The catheter itself, which is introduced through a subcutaneous tunnel by a modified Seldinger technique is constructed of flexible polyurethane which is tapered to fit over a Seldinger guide wire. It is so flexible that it requires a central stylet or obturator to stiffen it during insertion.

The technique for insertion has been described in detail elsewhere [2, 3]. The points worth emphasising are meticulous sterility, accurate and unhurried placement of the Seldinger-type needle, and advancement of the soft end of the guide wire far enough to be sure that it will guide the tapered tip of the catheter safely into its final position before the guide wire is withdrawn.

Recently we have found that insertion of both the single and double-lumen catheters over the guide wire is made much easier in difficult cases by initial use of an appropriate sized vessel dilator to dilate the track through the tough subclavicular fascia. (8 French for the single and 12 French for the double-lumen catheter.)

We also attach importance to the subcutaneous tunnel which helps to stabilise the catheter on a convenient flat area of the anterior chest wall, provides a longer physical barrier to the entrance of infection, and allows positioning of the special OP-SITE dressing (Smith and Nephew) which is such an essential requirement for long term infection-free attachment of the device. Although there is no evidence from controlled trials of the benefit of a subcutaneous tunnel we have been impressed by the difference it makes to the ease of catheter care and the increased comfort of the patient. We had reason to be grateful for the existence of a tunnel when a patient at home pulled his catheter out in the middle of the night during a bad dream. The skin tunnel collapsed and bleeding was minimal. This was in contrast to a patient reported to us who was found dead in bed at home, having exsanguinated when the connection came off the end of the catheter. Good Luer-lock connections, as well as safety tapes are essential safety precautions.

Maintaining patency of the catheter in the intervals between dialyses can be achieved by instillation of concentrated heparin solution through the Luer-lock injection cap after dialysis is over. This injection should just fill the dead space so that very little heparin escapes into the systemic circulation. The patient can go home and the catheter requires no attention till the next dialysis. If simple aspiration and flushing of the catheter with heparinised saline does not serve to re-establish flow at the start of dialysis, use of the fibrinolytic agent Urokinase injected into the catheter an hour before the start of dialysis is an effective alternative to changing the catheter over a guide wire. The new double-lumen subclavian catheter is supplied with a declotting catheter for removing clot from the inner walls of the outer tube [4].
Subclavian catheters and single-needle machines

From the beginning the disadvantage of having only a single conduit leading to a central vein has been the necessity to use a single-needle machine. Occasionally a venous return needle can be placed in an antecubital vein, especially during the later phases of A-V fistula maturation. But reluctance to master the art of skilled use of single-needle machines leads to unnecessary arm vein damage and premature needling of immature fistulae. There is abundant evidence of the efficiency of subclavian dialysis with single-needle systems when these are properly used [3, 5, 6]. Most experienced users would agree however that the pressure-pressure cycled, double pump single-needle machine made by Bellco is superior to simpler and cheaper machines such as the Vital Assist, if for no other reason than that the stroke volume with the former is much greater and therefore the recirculation of blood in the dead space of the catheter is correspondingly a smaller proportion of the total blood flow. Nevertheless special blood lines and greater expertise are needed for the Bellco machine. The Vital Assist gives entirely adequate results when correctly used [7].

The double-lumen subclavian catheter

The necessity to use single-needle machines, which tend to be an unwanted encumbrance especially when dialysing for acute renal failure in a cluttered intensive care unit, led to a search for a subclavian catheter with two blood pathways. The double-lumen subclavian catheter (DLSC) developed at the Toronto Western Hospital [4, 8], differs from other designs in that the external surface of the catheter which lies in the central vein is completely smooth (Figure 1). The venous return pathway is composed of a central, thin-walled Teflon tube in continuity with the terminal narrow section of the outer tube. The 'arterial' outflow pathway, with separate side holes for entry of the blood through the wall of the outer tube, is the space between the inner and outer tubes. The inner tube can be removed to allow de-clotting to be accomplished and if any sizeable fragments of clot are dislodged from the walls of the catheter, they stay within the confines of the catheter until they are aspirated out.

If the inner tube is damaged or contaminated it can be replaced, since all outer tubes and all inner tubes are compatible with one another. Blood flow rates up to 300ml per minute can be achieved with the DLSC with no recirculation at all. At a standard blood flow of 200ml/min both the arterial negative as well as the venous positive pressures tend to be close to 100mmHg. If these pressures increase, a build-up of fibrin in the catheter should be suspected and this can be dealt with either by mechanical de-clotting techniques or use of fibrinolytic agents such as Urokinase. If necessary, the catheter can be changed over a guide wire in the same way as is done for the single-lumen catheter.

As yet there has been no instance of iatrogenic trauma resulting from use of the DLSC. Long term observation will show whether there is any higher incidence of less serious complication such as infection or subclavian vein thrombosis.
Figure 1. A) Shows the polyurethane outer tube. B) Shows the inner tube with its stylet in place to stiffen it during insertion. C) Shows the inner tube locked into the outer tube so as to provide two separate blood pathways.
Indications for subclavian cannulation

The main reasons for inserting a subclavian catheter in our experience are shown in Table I.

The first four reasons listed in Table I are numerically the most important and require no further explanation except to say that subclavian cannulation for acute reversible renal failure is becoming more common as the population of patients with acute renal failure gets older and more arteriopathic. Frequently the vessels which might have been suitable for construction of a shunt have already been used for direct arterial pressure monitoring, intravenous infusion, or venous blood sampling.

<table>
<thead>
<tr>
<th>TABLE I</th>
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<tr>
<td>1. ESRD not previously diagnosed. (No time to construct an A-V fistula)</td>
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<td>2. Sudden failure of an A-V fistula</td>
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<td>3. Urgent transfer from peritoneal dialysis to haemodialysis [9]</td>
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<tr>
<td>4. Acute reversible renal failure. (Especially in older subjects with poor peripheral vessels)</td>
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<td>5. Sudden failure of a renal transplant</td>
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<td>6. Haemodialysis while waiting for a living donor transplant</td>
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<td>7. Definitive long term method when all else fails</td>
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<td>8. Double-lumen subclavian catheter for continuous slow ultra-filtration</td>
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<td>9. Plasmapheresis for kidney disease</td>
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Paganini and his colleagues [10] have shown the value of a shunt in acute oliguric renal failure for performing continuous slow ultrafiltration to maintain normal hydration at all times despite the administration of large volumes of intravenous fluids including total parenteral nutrition.

We have modified Paganini’s technique to allow us to use it with the double-lumen subclavian catheter as shown in Figure 2. This simple extracorporeal circulation which includes a peristaltic non-occlusive blood pump (Rhone Poulenc), a high permeability hollow-fibre column (Amicon Diafilter 20) and a Renal Systems foam detector, can be set up quickly by the haemodialysis nurse and monitored thereafter by the patient’s own intensive care nurse. It allows fingertip control of fluid removal (mainly salt and water) 24 hours a day. The only disadvantage of the method we have discovered so far is the need for continuous heparin administration with the consequent risk of bleeding.

On occasions we have used subclavian cannulation to provide a few weeks of haemodialysis for patients who expect soon to receive a living donor transplant. It may be hardly justified to construct a fistula if it will only be used for a very short time. Even more rarely we and others have settled for using a subclavian catheter as the permanent method of vascular access in patients who have
unusually severe vascular access problems. If, after several months, a catheter becomes infected it can be removed and placed on the other side in time for the next dialysis.

Finally, we have found the subclavian technique particularly useful in patients who require plasmapheresis. The single-lumen cannula is adequate for use with a cell separator, (only one blood pathway is required) while the double-lumen device is particularly suitable when plasmapheresis is performed by membrane filtration in an extracorporeal circulation resembling haemodialysis. We have found, however, that it is important to use low concentrations of citrate as in ACD-B. The high concentrations found in ACD-A cause an unacceptably high
incidence of arrhythmias when returned close to the heart [11].

The one situation in which we feel that the subclavian catheter is contra-
indicated is when carrying out haemodialysis or haemoperfusion for treatment
of severe poisoning. The danger of accidental pneumothorax in a deeply uncon-
scious patient on a ventilator is a reason for femoral cannulation instead. The
femoral cannula is not a disadvantage in a supine patient who needs only one or
at most two treatments. We now use the double-lumen subclavian catheter in the
femoral site for cases of poisoning because one femoral puncture provides two
blood pathways and a blood flow rate up to 300ml per minute without recircu-
lation.

Complications of subclavian cannulation

The complications we have encountered as well as those which have been reported
by others are shown in Table II. The commonest and least serious of these is
infection. Clinical exit site infection, which can be diagnosed early by observation
through the transparent dressing, usually responds to antibiotics even though the
catheter is left in situ. Blood stream infection, diagnosed by the presence of a
fever and positive blood cultures obtained from distant veins, in the absence of
any other obvious cause must be assumed to be due to the catheter, and is an

<table>
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<th>TABLE II. Subclavian catheter complications</th>
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<td>Infection</td>
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<tr>
<td>Exit site</td>
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<td>Bloodstream</td>
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<td>Trauma</td>
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<td>Pneumothorax</td>
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<td>Subclavian artery puncture</td>
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<td>Superior vena cava perforation</td>
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<td>Haemothorax</td>
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<tr>
<td>Accidental disconnection</td>
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<tr>
<td>Air embolus</td>
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<tr>
<td>Exsanguination</td>
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<tr>
<td>Thrombosis</td>
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<tr>
<td>Subclavian vein</td>
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<tr>
<td>Thrombus adherent to catheter</td>
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<td>Loss of catheter</td>
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<td>into the heart</td>
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<tr>
<td>Spontaneous erosion</td>
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<td>through wall of SVC</td>
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<td>Intrapulmonary haemorrhage</td>
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<td>Haemopericardium</td>
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absolute indication for catheter removal. Hitherto we have also given an anti-
biotic and all these infections have cleared up at once. None has recurred when
the catheter was re-inserted on the opposite side of the chest in time for the next
dialysis. However, the experience of other authors with other central venous
blood lines [12] suggests that antibiotics may not be necessary as long as the
catheter is removed. Initially we practised changing the catheter once a week
over a guide wire [7], the idea being that a clean catheter would not serve as a
nidus for infection. However a prospective randomised controlled trial of chang-
ing versus no changing showed exactly the same infection rate (rather less than
20% of all insertion episodes) in both groups [13]. We therefore abandoned
routine catheter changes and only change the catheter if flow rate is inadequate
due to build-up of fibrin. The use of the fibrinolytic agent Urokinase when
necessary (injected into the catheter an hour before dialysis) has reduced the
need for catheter changes for both the single- and the double-lumen devices.

Traumatic complications of subclavian cannulation are largely avoidable if
insertion and handling is restricted to well trained and supervised doctors and
nurses [3]. In our experience the only life-threatening complications (haemo-
thorax in both cases) occurred during dialysis when the dialysis attendant
tried, against prescribed advice, to push a subclavian cannula back in when it was
slipping out [7]. Everybody in every haemodialysis unit must be warned NEVER
to try to do this.

Subclavian vein thrombosis is an uncommon complication which responds
well to removal of the catheter and anticoagulation if it is diagnosed early.
Occasionally thrombosis is silent and only discovered weeks or months later. It
is then too late to produce recanalisation but the presence of good collateral
venous drainage in the arm prevents any long term disability.

Recently Ratcliffe and Oliver [14] have found a disturbingly high incidence
of thrombus adherent to the catheter in the superior vena cava and suggested
that endothelial damage, caused by oscillation of the catheter under the influence
of the single-needle machine, may be the cause. Despite this finding, pulmonary
embolus from this source does not seem to be a common or important problem.
We have seen no proven case among some 900 episodes of subclavian insertion.

Loss of the catheter into the heart was reported by a number of users of
Teflon catheters. Apparently the fatiguability of this material causes it to buckle
and crack and finally break, especially in restless patients. The polyurethane
material from which the new generation of catheters is made, should prevent
this complication. We ourselves lost a catheter into the heart during a catheter
change [7] and retrieved it through the femoral vein by means of a Dotta
basket. This incident taught us that catheters should never be divided distal to
the Silastic section during the changing procedure, but rather through the Silastic
itself.

The most disturbing complication of subclavian dialysis is that of spontaneous
migration of the tip of the catheter through the wall of the superior vena cava.
If this happens with the single-lumen catheter during dialysis with a single-needle
machine blood can still be withdrawn into the extracorporeal circulation through
the side holes and ejected through the end of the catheter into the thorax. Fine
and his colleagues [15] reported a fatal case of cardiac tamponade caused by
penetration of a single-lumen Teflon catheter through the wall of the superior vena cava into the pericardial cavity. Catheters introduced from the left side have also penetrated the right lung and thoracic cavity (Meierhoffer, personal communication) and we ourselves have seen a case of right intrapulmonary haemorrhage from this cause.

The mechanisms proposed by Ratcliffe and Oliver [14] to explain thrombus development may also play a role in vein wall penetration. Theoretically the softer, more flexible polyurethane, and the double-lumen catheter with its smooth continuous blood flow, should both be less likely to produce endothelial damage. Nevertheless this phenomenon of spontaneous penetration merits further study and ways must be found to ensure that it does not happen.

**Conclusion**

The subclavian catheter has become the standard instrument for providing temporary vascular access for haemodialysis and plasmapheresis in many renal centres. The advantages it has over Silastic-Teflon shunts and repeated femoral cannulation are evident and generally recognised. Nevertheless this technique is potentially dangerous especially in unskilled and untrained hands. Deaths have been caused by complications which were not foreseen and in some cases not recognised until it was too late. As practising nephrologists we have an obligation now to try to make the technique safer.

**References**

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