Factors affecting long-term survival of tunnelled haemodialysis catheters—a prospective audit of 812 tunnelled catheters

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Abstract

Background. In 2001, in the US, 23% of haemodialysis patients were dialysing through tunnelled venous catheters (TVCs), and in the UK (2006) there were 28% of prevalent patients using catheters. It is unlikely that numbers will significantly decrease.

We present the results of a prospective audit of the survival of 812 TVCs placed in 492 patients at our institution over a 6-year period (comprising 212 048 patient catheter days or 7068 patient catheter months of follow-up). Four different designs of catheter were studied: Split-Cath III (Medcomp), HemoSplit (Bard), Tesio twin catheter (Medcomp) and Permcath (Quinton).

Methods. We used Kaplan–Meier survival analysis with log-rank test, to compare the effect of different parameters on catheter survival. The relative importance of significant parameters was determined by Cox regression analysis.

Results. We have shown a significant catheter survival advantage of first catheters over second and subsequent insertions, of right internal jugular site over left internal jugular and thereafter over femoral site, and of non-diabetic over diabetic patients. Patient age, sex and operator (physician in ward-based procedure room under ultrasound control or surgeon in operating theatre under fluoroscopic assistance) did not significantly affect survival. The Permcath design demonstrated inferior survival in all but first catheter insertions in catheter-naïve patients. The HemoSplit and Tesio twin catheter designs demonstrated best survival overall.

By Cox proportional hazard modelling the design and the position of the TVC seemed to be the most significant independent survival factors.

Conclusions. Clinicians need accurate data regarding catheter survival, mode of insertion and design, to inform practice.

Keywords: catheters and catheterization; catheter survival; central veins; haemodialysis; tunnelled venous catheter; vascular access

Introduction

Haemodialysis requires repeated, secure access to the bloodstream whilst ensuring an adequate rate of blood flow. The arterio-venous fistula (AVF) represents the optimal means of providing such access [1], but arterio-venous grafts (AVGs) and cuffed tunnelled central venous catheters (TVCs) may be required where formation or maturation of a fistula is awaited, AVF formation is not possible for medical or personal reasons, or when other routes of access have failed. Particularly in the latter group of patients, TVCs are relied upon to provide a means of permanent vascular access, and they do have a number of advantages in this respect. TVC placement is straightforward and can be performed by nephrologists, radiologists or surgeons, they can be used immediately once inserted, connection to the dialysis circuit is straightforward and needle free, and catheters provide sufficient blood flow to allow adequate haemodialysis [2–4]. They do, however, suffer from a number of disadvantages, particularly catheter-related bacteraemia and sepsis [5], blockage and dysfunction (either by thrombus or fibrin sheath) [6,7], malposition and/or migration [8], an increased risk of central venous stenosis [9,10] and eventual device failure. There is also an association between TVCs and an increased risk of mortality, when compared to AVFs [11]. Despite these problems, a combination of under-provision of vascular access surgery in the UK, late referral and comorbidity means that a considerable number of our patients still utilize TVCs in the medium- to long-term—28% from the
most recent UK Registry data [12], and will continue to do so for the foreseeable future.

Since their first description by Schwab et al. in 1988 [13], a number of differing designs of TVC have evolved to try and minimize some of the problems associated with their use [14]. Separation of the two intravascular tips of the device (‘split-tip’) is reported to reduce fibrin sheath formation, catheter thrombosis and hence late malfunction—as well as recirculation [14,15], the design of the lumens and pattern of holes at the end of the catheter have been modified to improve blood flow and reduce recirculation, and catheters are now available in a variety of pre-curved lengths to aid placement and avoid kinking. Although the development of TVCs has revolutionized the management of patients requiring renal replacement therapy, their frequent complications present nephrologists with a classical ‘double edged sword’—as one review recently put it, we ‘hate living with them, but can’t live without them’ [16]. Given this technological Faustian pact, use of TVCs should be informed and guided by knowledge of their complications, and an insight into their longevity and limitations. When it comes to TVCs, ‘there are many questions, but few answers’ [17].

In this study, we present the results from an audit of all tunnelled catheter insertions performed at our institution over a 6-year period. We have assessed the type of TVC used, whether site of insertion (right or left internal jugular vein or femoral vein) may have implications for longevity, and whether the performance of a patient’s first TVC may be different to that of subsequent lines.

### Subjects and methods

#### Setting—Lister dialysis programme

The Lister Renal Unit comprises three dialysis units providing renal replacement therapy to a population of approximately 1.2 million people. Throughout the period of study the units were treating between 300 and 400 haemodialysis patients.

Our patients use high-flux biocompatible membranes (predominantly polysulphone). Microbiological water purity is checked monthly to ensure compliance with tight chemical and microbiological standards (<0.1 cfu/ml and <0.03 EU/ml). Bicarbonate was used exclusively as buffer. On-line post-dilution haemodialfiltration (HDF) is the preferred modality for patients with minimal residual renal function (KRUs <1 ml/min) and above average body weight. Between 60% and 70% of the patients dialysed through an AVF with the majority of the remainder using tunnelled lines.

Dialysis prescription is individualized using a two-pool kinetic model to ensure a total $K_t/V$ (residual renal function + dialysis) of 1.2 per session for thrice-weekly dialysis, as described previously [18].

#### Data collection: (Table 1)

Data of 812 TVCs undertaken in 492 patients was prospectively collected. The catheters were inserted between 13 January 2000 and 28 December 2005 (6 years) with a minimum follow-up of 1 year. We evaluated the outcomes and complications of four different catheters:

(i) Split-Cath® III™ (Medcomp)—dual-lumen catheter with end and side ports.

(ii) HemoSplit™ (Bard Access Systems)—pre-curved dual-lumen catheter with end and side ports.

(iii) Tesio twin catheter (Medcomp)—two entirely separate catheters, with end and side ports.

(iv) PermCath™ (Quinton Instruments)—dual-lumen catheter with end ports only.

One hundred and eighty-one Split-Cath catheters were inserted, 395 Tesio catheters, 109 PermCaths and 127 Hemosplit catheters. 314 TVCs were inserted in women (39%) and 498 in men (61%); average age was 62.6. 211 patients were diabetic (26%). In total, the study comprised 212,048 patient catheter days (7068 patient catheter months). In 380 cases, the tunnelled dialysis catheter was the first TVC the patient had received and in 432 cases the patient had received one or more previous TVCs.

TVCs were placed in the right internal jugular vein on 516 occasions, the left internal jugular in 165 occasions, the femoral veins (right or left) in 120 occasions and the subclavian veins (right or left) in 11 cases.

In 358 cases, the TVCs were inserted in an operating theatre setting, by a surgeon, almost exclusively using fluoroscopic guidance. Of the 454 non-surgical cases the vast majority of TVCs were inserted in a dedicated procedures room on the acute nephrology ward, with monitoring (blood pressure, pulse oximetry and electrocardiography) but no fluoroscopic guidance. In the remaining cases ($n = 34$) the catheters were inserted under fluoroscopic guidance by a physician in the radiology angiographic suite.

Choice of TVC design reflected the preference of the operator, the availability on the ward or in theatre, and in a few patients there were considerations of size. Ward lines were predominantly inserted by three physicians (A.C.F., J.S. and P.W.), and theatre lines by four surgeons (including S.S. and H.H.T.).

<table>
<thead>
<tr>
<th>Table 1. Patient and TVC study data</th>
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<tbody>
<tr>
<td><strong>Tunnelled lines</strong></td>
</tr>
<tr>
<td><strong>Patient numbers</strong></td>
</tr>
<tr>
<td><strong>Mean age (years)</strong></td>
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<tr>
<td><strong>Sex—Male:Female (%)</strong></td>
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<tr>
<td><strong>Diabetic (%)</strong></td>
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</table>

### Insertion site

- **RIJ catheters (%)** 516 (64)
- **LJ catheters (%)** 165 (20)
- **Subclavians catheters (%)** 11 (1)
- **Femoral catheters (%)** 120 (15)

### TVC design

- **Tesio catheters (%)** 395 (49)
- **Split-Caths (%)** 181 (22)
- **Hemosplits (%)** 127 (16)
- **PermCaths (%)** 109 (13)
Factors affecting long-term survival of TVCs

**TVC—care protocols**

Sepsis. Suspected exit site infections were swabbed and treated according to antibiotic sensitivities. Patients with suspected bacteraemias were treated empirically with a 2-week course of post-dialysis vancomycin (corrected to body weight), pending results of blood cultures. If the patient was clinically unwell, or if the bacteraemia recurred after a course of treatment, then usually the TVC was removed, and the patient left catheter free for 24 to 48 h before a subsequent catheter was re-inserted. Thereafter, if there was evidence of ongoing sepsis (persistence of fever or persistently raised CRP) then the patient was dialysed using temporary femoral catheters, until the sepsis had settled and a new TVC could be re-inserted. On rare occasions, in patients with ‘difficult’ vascular access, further courses of antibiotics would be used, or the TVC changed ‘over a wire’.

**TVC dysfunction.** Lines were locked with heparin 10 000 units per lumen. When flow was insufficient for dialysis, standard policy was to instil 10 000 units of urokinase as a lock. If the flow still proved insufficient, then the urokinase was withdrawn (as much as was possible) and the TVC brushed with an endoluminal brush. If the TVC remained occluded then the catheter was removed, and a new catheter inserted either over a guide-wire or in an alternate site (after a sufficient interval for the urokinase to wear off). More recently we have started to use infusions of urokinase or rtPA, but these were not routinely in use during the course of the study.

**Statistics.** Kaplan–Meier survival plots (curve generated as a staircase line with symbols at censored observations) were obtained using the program GraphPad Prism® 4, and curves compared using the log-rank test. The relative importance of parameters, found to have a significant effect on line survival by this method, was determined by Cox regression analysis (SPSS).

**Results**

**Indications for insertion**

In 150 cases (18%), TVCs were inserted in patients presenting with acute renal failure. In 133 cases (16%), patients were classified as having chronic renal failure; these patients had been followed up for a minimum of 3 months. One hundred and nineteen (15%) patients had catheter insertions following withdrawal from peritoneal dialysis, and 119 (15%) after failed (predominantly clotted) AVFs. The commonest indication for TVC insertion was re-insertion after previously placed catheters had failed and been removed \( n = 291, \text{ 36}\% \).

**Reasons for failure of line**

In 17 cases (5%), TVCs were unable to be inserted for technical reasons, in 22 cases (6%) the TVCs never functioned because of malposition or kinking of the catheter (counted as an immediate failure). 147 TVCs (43%) were removed after they became irreversibly blocked, and 111 (32%) after infection. Forty lines (12%) were accidentally pulled out or fell out. Five (1%) were removed after developing a hole in one of the catheters.

The remaining 470 TVCs were censored, for the following reasons:

- TVC removed, no longer required—functioning AVF—174 (37%)
- TVC removed, no longer required—functioning Tenckhoff catheter—26 (6%)
- TVC removed, no longer required—functioning renal transplant—28 (6%)
- TVC removed, no longer required—recovered native renal function—15 (3%)
- Patient died with functioning TVC—170 (36%)
- TVC still working at time of completion of audit (31 December 2006)—44 (9%)
- Patient lost to follow-up (moved out of area)—13 (3%)

**Survival curves**

Figure 1 shows the censored survival of all TVCs inserted in all sites. Median survival is 506 days (~17 months).

Figure 2 reveals that there is a significant difference in survival between the first and any subsequent TVC insertion (median survivals 647 and 403 days, respectively, ~22 and 13 months).

Figure 3 demonstrates that the operator does not appear to affect overall TVC survival. Equally, neither age nor sex of patient demonstrated a significant effect on TVC survival. Diabetic status (Figure 4) however did have a significant negative influence on survival \( P = 0.0113 \).

Figure 5 explores the influence of insertion site on all TVCs. The internal jugular route is most favourable, and significantly better than left internal jugular route, which in turn is significantly better than the femoral route (median survivals of 633, 430 and 116 days, respectively).

Although this is not a randomized study, we explored the influence of catheter design on survival. Initial analysis (Figure 6) shows that overall the Hemosplit and Tesio catheters survived significantly longer than the Perm cath and Split-Cath, but when we removed the influence of insertion site, by comparing just right internal jugular catheter survival (Figure 7), there was no significant difference between the Hemosplit, Tesio and Split-Cath, but all three survived longer than the Perm cath (\( P = 0.003 \)). This difference was not apparent when a sub-analysis of only the first right internal jugular catheters was undertaken but reappeared on the sub-analysis of second and subsequent catheters, and a separate analysis of left internal jugular lines (Figure 8).

An analysis of all femoral lines \( n = 120 \), showed a significant survival benefit of Tesio catheters over Split-Caths and Perm caths (Figure 9).
Cox regression analysis (backwards LR) (SPSS)

In the Cox proportional hazards model (backwards LR), survival and risk are calculated with respect to one of the factors, which is assigned a unitary risk of 1. For example, failures of all designs were compared to Split-caths, which are therefore not listed (unitary risk of 1). Therefore, Hemosplit catheters [Exp (B) score 0.59] were less likely to fail by 41%, and Permcaths [Exp (B) score 1.57] were 57% more likely to fail than Split-Caths. Equally, regression analysis of route of insertion is compared to the right internal jugular route, which is not listed, and is given the unitary risk of 1.

In a Cox proportional hazards model (Table 2), the design of TVC, its position, whether it was the first
or a subsequent catheter, and whether or not the patient was diabetic, were all significant independent predictors of line survival.

Hemosplit catheters (by 41%) and Tesio catheters (by 33%) were less likely to fail and Permcaths 57% were more likely to fail than Split-Caths.

TVCs in the left internal jugular vein (by 54%), femoral vein (by almost three times more) and in the subclavian vein (by approximately two times more) were all more likely to fail than lines in the right internal jugular vein.

Discussion

Patients on haemodialysis via TVCs for 3 years demonstrate a 47% increased mortality compared with matched controls using AVFs [19]. Indeed, central venous access is considered to be the most important risk factor for infection and death in patients receiving renal replacement therapy [1]. TVCs significantly increase the risk of vascular stenosis and occlusion, and compromise maturation and patency of subsequent AVFs and AVGs [20]. It is entirely appropriate therefore that the Dialysis Outcomes Quality Initiative put forth by the US National Kidney foundation (NKF) has recommended that <10% of all chronic maintenance haemodialysis patients should use dialysis catheters for >3 months in the absence of a maturing definitive vascular access [21]. There is a disappointing progress towards this target. In the US, 23% of haemodialysis patients were dialysing through catheters (a review published in 2002) [22], and in the UK in 2005, there were 29% of prevalent patients using catheters [23].

As a result of shortages of surgical theatre lists, the prevalence of catheters in our units in recent years has varied between 30% and 40%. This results in a steady stream of failed catheters requiring replacement; which was the commonest indication of catheter insertion (36%). A further 16% of TVC patients had been followed up for a minimum of 3 months. Some of these patients had undergone AVF surgery but the fistula had failed or had not sufficiently matured for use, others had changed preference of dialysis modality with insufficient time to fashion an AVF, and in a few, lack of definitive access surgery reflected failings in timely referral to, or delays in, surgery. A total of 18% of the TVC patients presented sufficiently late to preclude fistula creation.

Table 2. Cox proportional hazards model (backwards LR)

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>SE</th>
<th>Wald</th>
<th>df</th>
<th>Sig.</th>
<th>Exp(B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diabetes</td>
<td>0.363</td>
<td>0.120</td>
<td>9.197</td>
<td>1</td>
<td>0.002</td>
<td>1.438</td>
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<tr>
<td>Subsequent line</td>
<td>0.328</td>
<td>0.132</td>
<td>6.160</td>
<td>1</td>
<td>0.013</td>
<td>1.388</td>
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<tr>
<td>TVC design</td>
<td>35.857</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
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<tr>
<td>Tesio</td>
<td>-0.399</td>
<td>0.144</td>
<td>7.690</td>
<td>1</td>
<td>0.006</td>
<td>0.671</td>
</tr>
<tr>
<td>Permcath</td>
<td>0.448</td>
<td>0.172</td>
<td>6.741</td>
<td>1</td>
<td>0.009</td>
<td>1.565</td>
</tr>
<tr>
<td>Hemosplit</td>
<td>-0.527</td>
<td>0.216</td>
<td>5.956</td>
<td>1</td>
<td>0.015</td>
<td>0.590</td>
</tr>
<tr>
<td>TVC Position</td>
<td>40.242</td>
<td>&lt;0.0001</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Left IJ</td>
<td>0.432</td>
<td>0.145</td>
<td>8.849</td>
<td>1</td>
<td>0.003</td>
<td>1.540</td>
</tr>
<tr>
<td>Femoral</td>
<td>1.079</td>
<td>0.171</td>
<td>39.764</td>
<td>1</td>
<td>0.000</td>
<td>2.942</td>
</tr>
<tr>
<td>Subclavian</td>
<td>0.725</td>
<td>0.424</td>
<td>2.922</td>
<td>1</td>
<td>0.087</td>
<td>2.066</td>
</tr>
</tbody>
</table>
The commonest cause for catheter failure necessitating removal was irreversible blockage (43%), predominantly thrombosis and fibrin sheath formation. Infection resulted in removal of 32% of catheters. A surprisingly high proportion of TVCs (12%), were accidentally pulled out or fell out. We believe repeated traction, either by accidental snagging of the catheter when changing clothes, or by injudiciously placed dialysis lines, were responsible.

Modern tunneled dialysis catheters demonstrate reasonable survival, albeit often inferior to native AVFs. Duncan et al. [4], in an impressive study of 623 Tesio-Caths inserted in 435 patients, demonstrated a censored functional catheter survival of 77.8% at 1 year and 44% at 3 years. Wang et al. [24] followed up 303 first Tesio catheters in 200 patients, demonstrating a catheter survival of 60% at 1 year and 51.5% at 3 years. In contrast, Cetinkaya et al. [25], studying 92 Ash-Split catheters in 85 patients, demonstrated a median survival of only 289 days. In addition, some outstanding survival figures have been reported. Di Iorio et al. [26], studying a mix of 98 dialysis catheters (predominantly Vas Cath Soft Cell catheters, Bard), has reported an 82% catheter survival at 84 months. Tesio et al. [27], following up 108 Tesio catheters inserted in the early 1990s reported a 93% 1-year, 82% 5-year and 32% 7-year catheter survival. In our study, the median survival of all lines was 506 days (1-year survival 61%, 3-year survival 22%).

The very first tunneled catheters, inserted into TVC-naïve patients, demonstrate the best longevity (median survival of 647 vs 403 days, first vs subsequent lines). Subsequent TVCs were 39% more likely to fail on Cox proportional hazards modelling.

There has been a paucity of data regarding survival of different catheter designs. Richard et al. [30], in a randomized prospective evaluation, compared the performance of 36 Tesio, 38 Ash Split (similar to Split-Cath) and 39 Opti-flow catheters, but given the relatively small numbers, were unable to demonstrate a significant difference in survival. Trerotola et al. [15], comparing 132 Ash-Split and Opti-flow catheters, were able to demonstrate a significant survival advantage for the Ash-Split ($P = 0.02$) [15].

We compared the performance of four types of commercially available tunneled catheter. Two catheter designs—the HemoSplit and the Tesio twin catheter—performed significantly better than the Split-Cath III and Perm cath (median survival 727, 608, 308 and 286 days, respectively. There was no significant difference between the Hemosplit and Tesio survival). Using Cox Proportional Hazard modelling, the design of the TVC was confirmed as an independent predictor of line survival, and the Hemosplit and Tesio designs again demonstrated best survival.

In patients with their first right internal jugular catheter, the differences in survival disappear, all catheters performing relatively well. The differences in performance become apparent again when assessing survival of second and subsequent right internal jugular catheters. In this subgroup, all catheters significantly outperformed the Perm cath; the Hemosplit seemingly surviving the best, although this did not reach statistical significance. Similar findings were observed in patients with left internal jugular catheters. In the femoral site, the Tesio catheter performed best, significantly better than the...
References


Received for publication: 1.4.07
Accepted in revised form: 31.7.07