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Original Article

Buttonhole needling of haemodialysis arteriovenous fistulae results in less complications and interventions compared to the rope-ladder technique

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Abstract

Background. The rope-ladder puncture technique, with cannulation along the whole length of the vessel traject, has been very common in haemodialysis patients with autogenous arterio-venous fistula (AVF). Today's dialysis population with AVF may exhibit difficult cannulation, because of a short vein length or a complicated cannulation route. An alternative needling possibility is the buttonhole (BH) technique, which inserts needles at exactly the same location during every dialysis session. The present study was conducted to investigate the effect of both cannulation techniques on the incidence of vascular access (VA) complications.

Methods. A total of 75 prevalent haemodialysis patients with autogenous AVF using the BH technique were compared with 70 patients using the rope-ladder technique. The following parameters were registered: haematoma occurrence, redness, swelling, aneurysm formation, the use of sharp or dull needles, miscannulations, and interventions. Needling pain and fear of puncture were assessed using a verbal rating scale (VRS). The duration of the follow-up was 9 months.

Results. Patients in the BH group had more unsuccessful cannulations, compared with the rope-ladder method ($P < 0.0001$), but the frequency of haematoma ($P < 0.0001$) and aneurysm formation ($P < 0.0001$) was less. In addition, intervention such as angioplasty ($P < 0.0001$) was higher in patients using the rope-ladder technique. A negative outcome of the BH technique was the higher incidence of access infections compared to the rope-ladder method.

Conclusion. This study showed that the BH method is a valuable technique with few complications like haematoma, aneurysm formation and the need for interventions. However, the infections induced by the BH method should not be underestimated. This underlines the importance of an aseptic and correct technique of the buttonhole procedure.

Keywords: arteriovenous fistula; buttonhole technique; cannulation; rope-ladder technique; vascular access

Introduction

Adequate vascular access (VA) is essential for the successful haemodialysis treatment of patients with end-stage renal disease (ESRD). The Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines [1] on VA recommends the autogenous arteriovenous fistula (AVF) as the preferred VA for haemodialysis patients, because of both its longevity and a lower complication rate, as compared to arteriovenous grafts (AVGs) and central venous catheters (CVC). This recommendation has led to an increased number of AVFs, created during the past years.

The demographics of the ESRD population are changing which makes the construction of a functioning and usable AVF more difficult as a consequence. Because the anatomy of the superficial veins may differ from patient to patient, the quality and usability after creation of the fistula are not always predictable. In addition, cannulation of an AVF requires more technical skills than cannulation of an AVG [2]. Lee *et al*. have shown a high incidence of needle infiltrations in patients with autogenous AVF [3], which resulted in numerous revision procedures, as well as prolongation of CVC dependence for dialysis.

Despite the fact that complications caused by cannulation may seriously affect VA outcome [3], there is little evidence about the influence of the cannulation technique on VA outcomes.

Three cannulation techniques are nowadays used: the rope-ladder, with cannulation of the whole access length is the most frequently used technique in Europe and the United States [4]; the area technique with cannulation in the same small vessel area (which may lead to vessel damage and the development of stenoses and aneurysm) [5] and, finally,

the constant-site or BH technique, where the needles are inserted at the same spot during every dialysis session. Few studies have compared cannulation techniques, indicating the benefits of the BH method in terms of diminished pain, less miscannulations and reduction of haematoma formation [5–7]. Although there is a growing conviction/belief that BH cannulation has several advantages compared with other techniques, there is no generally accepted method of cannulating the AVF [1].

Therefore, we conducted a prospective observational study in prevalent haemodialysis patients with an AVF, with the purpose to establish the pros and cons of the rope-ladder and BH cannulation techniques, respectively, with respect to several outcome parameters like the incidence of miscannulation, cannulation ease, haematoma and aneurysm formation, CVC dependence or single needle (SN) dialysis, interventions. In addition, needle pain and fear associated with both cannulation techniques were evaluated.

Methods

Study design

From 1 January 2007 to 1 November 2007, 145 prevalent haemodialysis patients with an autogenous AVF were included from three different centres and prospectively followed up; 75 patients used the BH and 70 patients used the rope-ladder technique. Inclusion criteria were a well-functioning fore- or upper arm AVF, with an access flow of $\geq$500 ml/min, diameter of $\geq$6 mm and the ability to use the AVF, with cannulation of two needles. For all patients, haemodialysis frequency was three times per week. Data were collected from three dialysis facilities. One centre exclusively used the BH technique and included all prevalent patients with an established tunnel track. The two other centres included all prevalent patients using the rope-ladder method. Similar cannulation techniques were already used in these patients, before inclusion into the study.

Baseline data included patient characteristics, comorbidities and medication. VA characteristics include access type and anatomic location, date of creation, AVF duration and a single measurement of vein diameter in millimetre with inclusion, assessed by Duplex ultrasound (Aloka 5500, Tokyo, Japan). During the study period, it was standard practice to monitor the AVF once per 3 months, using the ultrasound dilution technique (Transonic Systems Inc.®, Ithaca, NY, USA).

Longitudinal data were administered, using case record forms (CRF) and a standardized method to register data from each dialysis session. The following variables were registered: cannulation technique, inspection for haematoma, redness, swelling and aneurysm, auscultation, use of local anaesthesia, sharp or dull needles, needle direction and position, number of cannulations, ease of cannulation and years of experience of the dialysis nurse. During each dialysis session, needling pain was assessed using a verbal rating scale (VRS) 10-point scale (1 = no pain, 10 = extreme pain) [8]. Of the arterial and venous needles, the highest pain score was recorded. Fear was documented once a week, using the VRS 10-point scale (1 = no fear, 10 = extreme fear).

The study protocol was approved by the Medical Ethical Committee of the Maastricht University Medical Center.

Fistula cannulation techniques

Cannulation was performed by the trained skilful dialysis staff with experience in the specific cannulation technique. The cannulation procedure is characterized by a learning curve, and regular practice is needed to achieve skills and competence. Therefore, the dialysis staff received proper education and clinical training. During clinical training, the dialysis nurse will be supervised by a qualified nurse until successful cannulation is demonstrated.

For the BH as well as the rope-ladder technique, needle insertion was standardized according to a cannulation protocol. In the group of patients with BH cannulation, dull needles are gently inserted at the same spot through an established tunnel track. [5–7]. The dull bevel of the needle opens the vessel flap at the end of the tunnel. The tunnel tracks were previously established by a minimum number of nurses (maximum three) cannulating with sharp needles into the exact same spot, using the same insertion angle and the same depth of penetration, and this for at least six sessions. Only one arterial and one venous BH were created.

Subsequently, all nurses were allowed to cannulate with dull needles. If there were difficulties placing a dull needle into an established BH, a conventional sharp needle was used.

The skin was disinfected with chlorhexidine 70% before and after scab removal from the puncture site according to the K/DOQI guidelines. The scab was removed with a 19-Gauche sharp needle.

In the rope-ladder group, in every dialysis session two new sites are chosen for needle placement, with a minimum of 2–3 cm between the tip of the needles and avoiding previous sites [1].

A cannulation procedure was judged as successful if the dialysis nurse was able to cannulate two needles, both used for the haemodialysis treatment, without unsuccessful cannulation. Unsuccessful cannulation is defined as the need to insert more than one needle per arterial or venous connection, because of the impossibility to use the previously inserted needle(s). A subcutaneous haematoma of the AVF is defined as an abnormal localized infiltration of blood caused by needle cannulation. Aneurysm formation is defined as a localized dilatation of the vessel [9]. Signs and symptoms of infection such as redness and localized warmth were observed and documented.

A vascular access surveillance programme, which included prevention of access dysfunction by surveillance and pre-emptive intervention, was operational at the participating facilities consistent with the K/DOQI guidelines [1].

Statistical analyses

Statistical analysis was performed using the SPSS software for Windows (SPSS release 12.0, SPSS Inc., Chicago, IL, USA). The Mann–Whitney test was performed to test differences between the rope-ladder and BH groups. Proportions of cannulation practice variables between both groups were tested with the chi-square test. For all comparisons, the level of significance was set to $P < 0.05$.

Results

Patients and arteriovenous fistulae

The baseline data are listed in Tables 1 and 2. The mean age of the patients in the rope-ladder group was 65 years and 67 years in the BH group, respectively. The access characteristics and cannulation characteristics are outlined in Tables 3 and 4. Flow measurement of the AVF, using the ultrasound dilution technique, did not show significant differences between the BH group (1275 ml/min range 320–2500 ml/min) and the rope-ladder group (1053 ml/min range 281–2400 ml/min). For five patients in the BH group, and two patients in the rope-ladder group, it was impossible to measure access flow, due to anatomical reasons (all upper arm AVF). Twenty-one patients (14%) were lost to follow-up due to the following reasons: eight death (5%), five successful kidney transplantation (3%), five AVF failure (3%) and three patients started HD at a non-participating facility (2%). The mean duration of follow-up was $\pm$9 months, covering a total of 13 729 dialysis sessions.

Frequency of cannulation events

Unsuccessful cannulation, defined as the need to insert more than one needle per arterial or venous connection, significantly differed between groups ($P < 0.0001$). Patients in the BH group had more unsuccessful cannulations (Figure 1), but less haematoma formation ($P < 0.0001$)

Table 1. Comparison of demographics and comorbidities of the study population between the rope-ladder and buttonhole techniques and their *P*-value

Characteristics	Rope-ladder ($n = 70$)	Buttonhole ($n = 75$)	*P*-value
Gender			
Female	23 (33%)	31 (41%)	0.28
Male	47 (67%)	44 (59%)	
Age (years)			
≤60 years	22 (31%)	29 (39%)	0.36
>60 years	48 (69%)	46 (61%)	
Causes of ESRD[a]			
Glomerulonephritis	14 (20%)	18 (24%)	0.007
Interstitial nephritis	6 (9%)	–	
Cystic kidney diseases	2 (3%)	11 (14%)	
Other congenital/hereditary kidney diseases	–	2 (4%)	
Renal vascular diseases	24 (34%)	15 (20%)	
Diabetes mellitus	11 (16%)	13 (17%)	
Other multisystem diseases	–	2 (3%)	
Other/unknown	11 (16%)	14 (18%)	
Vintage on HD			
1–12 months	13 (18%)	20 (27%)	0.01
1–5 years	51 (73%)	35 (47%)	
≥5 years	6 (9%)	20 (27%)	
Body mass index[a]			
≤30 kg/m^2	64 (91%)	58 (77%)	0.03
>30 kg/m^2	6 (9%)	16 (21%)	
Tobacco use			
No	58 (83%)	67 (89%)	0.25
Yes	12 (17%)	8 (11%)	

[a]Values were missing for some patients.

Table 2. Comparison of medical history of the study population between the rope-ladder and buttonhole cannulation techniques

	Rope-ladder ($n = 70$)	Buttonhole ($n = 75$)	*P*-value
Medical history			
Peripheral arterial obstructive disease	7 (10%)	11 (15%)	0.39
Coronary artery disease	56 (80%)	46 (61%)	0.46
Cerebrovascular disease	14 (20%)	13 (17%)	0.68
Diabetes mellitus	15 (21%)	20 (27%)	0.46
Hypertension	15 (21%)	27 (36%)	0.08
Medication			
Use of calcium antagonist	17 (24%)	7 (9%)	0.04
Use of anticoagulants	17 (24%)	8 (11%)	0.03
Use of platelet aggregation inhibitor	26 (37%)	46 (61%)	0.01
Use of EPO	68 (97%)	60 (80%)	0.02

Table 3. Comparison of AVF type between the rope-ladder and buttonhole cannulation techniques

Characteristics	Rope-ladder $n = 70$	Buttonhole $n = 75$	*P*-value
Mean duration of AVF use (mo)	31 (1–109)	44 (1–245)	0.74
Access placement			
a. radialis – v. cephalica forearm	42 (60%)	36 (48%)	0.14
a. ulnaris – v. basilica forearm	1 (1%)	1 (1%)	
a. brachialis – v. cubiti upper arm	3 (4%)	10 (13%)	
a. brachialis – v. cephalica upper arm	14 (20%)	25 (33%)	
a. brachialis – v. basilica upper arm	10 (14%)	3 (4%)	
Previous accesses			
No	59 (84%)	51 (68%)	0.02
Yes	11 (16%)	24 (32%)	
Previous catheter use[a]			
No	21 (30%)	33 (44%)	0.30
Yes	41 (59%)	39 (52%)	

[a]Values were missing for some patients.

Table 4. Comparison of cannulation characteristics in percentages, between the rope-ladder and the buttonhole cannulation techniques

Cannulation practice	Rope-ladder ($n = 70$) 6882 dialysis sessions	Buttonhole ($n = 75$) 6847 dialysis sessions
Type of needle used		
Metal sharp	90	44
Metal dull	–	56
Catheter	10	–
Needle Gauche		
14 Gauche	–	7
15 Gauche	100	93
Needle position		
Bevel up	52	99
Bevel down	48	1
Axis rotation needle		
Yes	6	13
No	94	87
Direction arterial needle		
Antegrade	95	76
Retrograde	5	24
Tourniquet use		
Yes	50	73
No	50	27
Sonographic guided cannulation		
Yes	–	–
No	100	100
Experience dialyses nurse		
<3 years	41	32
≥3 years	59	68

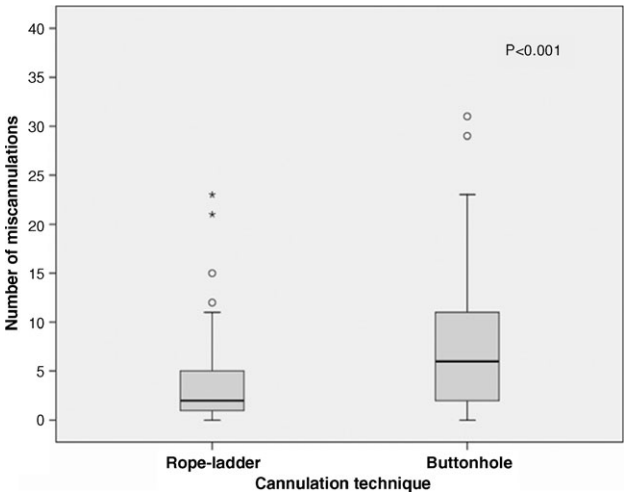

Fig. 1. Comparison of miscannulations between the rope-ladder and buttonhole cannulation techniques. Box indicates 25th and 75th percentiles (thick line is the median value). Capped bars indicate minimum and maximum values including outliers. The mean (SD) number of miscannulations for the rope-ladder technique was 3.7(4.7) and for the BH technique 8.1(7.0).

(Figure 2). Aneurysm formation occurred significantly more often ($P < 0.0001$) in patients using the rope-ladder technique (67%) compared to patients using the BH technique (1%) (Figure 3).

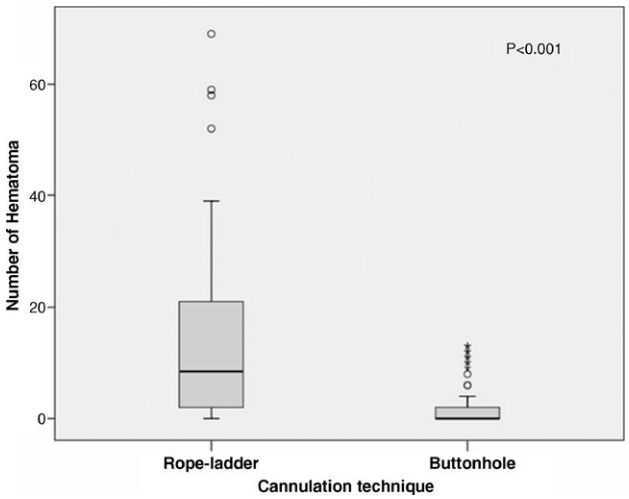

Fig. 2. Number of haemotomas with the rope-ladder and buttonhole cannulation techniques. Box indicates 25th and 75th percentiles (thick line is the median value). Capped bars indicate minimum and maximum values including outliers. The mean (SD) number of haemotomas for the rope-ladder technique was 14.0(15.6) and for the BH technique 2.0(3.7).

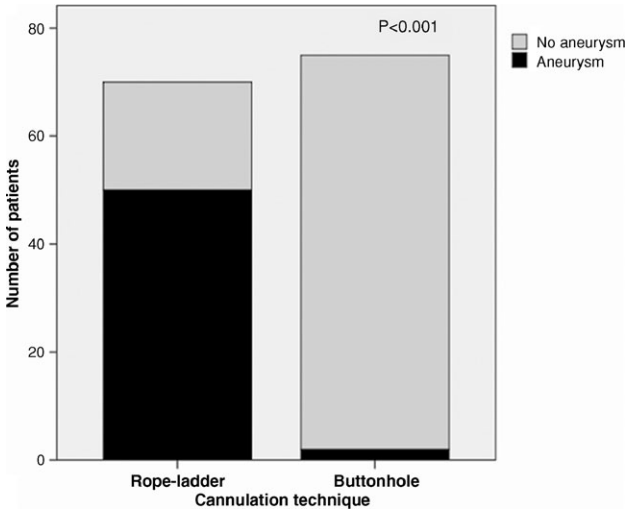

Fig. 3. The number of patients who experienced an aneurysm.

Comparison of cannulation pain and fear

The patients' average pain and fear score, assessed by the 10-point VRS, are outlined in Table 5. Although the mean pain experience level of both groups was mild and not very painful, patients in the BH group experienced more pain ($P < 0.001$) and fear ($P < 0.002$) than patients in the rope-ladder group. However, the need to apply local anaesthetic cream (EMLA = Eutectic Mixture of Local Anaesthetics) was more common in patients using rope-ladder technique than in those using the BH technique ($P < 0.001$) (Table 5).

Frequency of access interventions

During the study period, patients in the BH group required significantly fewer endovascular interventions,

Table 5. Pain and fear with the different cannulation techniques assessed by a verbal rating scale in the various groups

Cannulation practice	Rope-ladder ($n = 70$)	Buttonhole ($n = 75$)	P-value
Age (years)	67 (20–90)	65 (21–87)	0.49
Gender			0.29
Female	33 (23%)	31 (41%)	
Male	67 (77%)	44 (59%)	
Use of local anaesthetic cream	30%	8%	<0.001
Pain score	1.0 (0–5.4)	1.6 (0–5.0)	<0.001
Fear score	0.38 (0–4.1)	0.63 (0–8.2)	<0.002

Table 6. Diagnositic tests and interventions with the different cannulation techniques during 9 months

	Rope-ladder ($n = 70$)	Buttonhole ($n = 75$)	P-value
Patients with diagnostic tests	28	15	
Diagnostic tests	73	24	0.004
Duplex	14	11	
Fistulogram	51	10	
MRA	8	3	
Patients with interventions	21	6	
Interventions	41	10	0.001
Angioplasty	35	2	0.001
Thrombectomy	3	1	0.81
Surgical revisions	3	3	0.55
Antibiotic treatments because of access-related infections	–	4	0.001

(angioplasty) 10 out of 75 patients ($P < 0.001$), as compared with patients in the rope-ladder group, 41 out of 70 patients ($P < 0.001$) (Table 6). The number of thrombectomies ($P = 0.81$) and surgical interventions ($P = 0.55$) were similar in both groups. To maintain the functionality of the AVF, the BH group required 0.2 interventions per patient-year, and patients in the rope-ladder group had 0.8 interventions per patient-year.

However, for the BH group, antibiotic treatment because of access-related infection was more frequently encountered ($P = <0.001$). In the BH group, intravenous antibiotic treatment was necessary in five patients because of access-related infection. Haemoculture results indicated in two patients a Gram-positive *Staphylococcus aureus* infection. Two local infections of the BH site were registered, caused by *S. aureus* and *Clostridium perfringens*. One patient exhibited a Gram positive culture.

No statistically significant difference was seen between the rope-ladder and BH techniques, for as well as CVC use ($P = 0.08$) and SN dialysis ($P = 0.08$) (data not shown).

Discussion

This study shows that, although the BH technique resulted in more miscannulations, haematoma formation occurred significantly less often in the rope-ladder group. An explanation for this observation might be that unsuccessful cannulation with dull needles causes less tissue injury compared to sharp needles. Previous studies have shown that complications associated with cannulation were almost eliminated using BH techniques [7,10–20].

The result of using the rope-ladder technique is only a small dilatation effect over a greater length [5]. We observed a significant number of aneurysms in patients exhibiting the rope-ladder technique. This finding suggests that, although the protocol prescribes the use of the rope-ladder method, the dialysis staff in daily practice may use the area technique.

The present data also demonstrate a significantly lower number of angioplasties in the BH group. This finding supports previous studies that have shown that difficult and complicated cannulation is associated with interventions, access thrombosis and use of CVC as a consequence [3].

A possible explanation for the lower number of interventions in the BH group might be that the BH procedure causes less vessel damage due to the use of dull needles, which are inserted in exactly the same entry point, compared with the rope-ladder technique, where sharp needles have different angles of insertion, which possibly causes more damage, initiating neointimal hyperplasia development resulting in stenoses. To avoid fistula thromboses, stenoses are treated with pre-emptive angioplasty procedures. A negative outcome of the BH technique was the higher incidence of access infections compared to the rope-ladder method. Similar observations [6,21] indicate that although infection rates in AVFs are usually low, the BH cannulation may induce infections. A possible explanation for this observation could be an inappropriate application of the disinfection protocol by the nursing staff and/or the frequently intermittent use of sharp instead of dull needles. Indeed, in the busy in-centre dialysis facility, in order to gain time, nurses did not always respect the contact time of the disinfecting agent and scabs in some cases were not removed properly.

As soon as a bouncing effect was felt and the vessel flap could not be opened immediately with a dull needle, nurses preferred to 're'cannulate with a sharp needle, which was successful in most cases. However, the latter may result in a faulty track cannulation, which can damage and infect the cannulation site. A reinforced disinfection protocol has been implemented, where the scabs and surrounding skin are generously soaked with the disinfecting agent. The importance of thorough scab removal has been highlighted again, together with the advocacy of the use of dull needles.

In addition, the role of primary cannulators has been created. Only the latter are allowed to use sharp needles, after unsuccessful cannulation with a dull needle. A reduction from 48% to <10% use of sharp needles has subsequently been observed with a dramatically improved infection rate in the following months (data not shown).

Surprisingly, the average pain score in patients using the rope-ladder technique was less compared to patients with the BH method. This is not consistent with other studies [5–7,13] in which patients scored less pain with the BH technique. An explanation for this finding might be the fact that other studies have compared pain sensation of both techniques in the same individual patient. In the present study, the individual patient was using only one technique

and, therefore, cannot experience and judge the effect of the other technique. The application of local anaesthetic cream in the rope-ladder group might also have influenced the pain score.

Our study has limitations, as it was an observational, non-randomized study, with a comparison of patient groups and nursing teams, so a specific factor could have been biased. Each cannulation technique demands its own specific skill; therefore, patients had to be included from three different centres.

Some prognostic factors such as vintage on HD, BMI and previous accesses are not equally distributed between the rope-ladder and BH groups. Only based on these factors, the BH group should have worse outcomes. The rope-ladder technique requires a cannulation route of >10 cm to allow for rotation of needle sites and sufficient distance between the needles. This is not necessary for the BH, which is a clear advantage for this technique.

Cannulation of the AVF in the today's population is more difficult and challenging than ever. This study showed that the BH method is a valuable technique with few complications like haematoma, aneurysm formation and the need for interventions. The frequency of cannulation-related complications was significantly lower with the BH technique compared with the rope-ladder method. In addition we may postulate that the BH technique is not only suitable for self-cannulating patients, but also deserves a place in dialysis facilities were the buttonhole sites are cannulated by multiple nurses. Infections induced by the BH method should not be underestimated, and underline the importance of aseptic and correct technique of the BH procedure.

Successful access cannulation requires a high level of awareness and skills of the dialysis nurse, and frequent monitoring, evaluation and education of the needling technique are mandatory to guarantee that patients will receive the highest quality of care.

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