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The salvage of aneurysmal fistulae utilizing a modified buttonhole cannulation technique and multiple cannulators

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Abstract

We describe the St Michael's Hospital (SMH) modified buttonhole (BH) cannulation technique as a method that offers a solution for fistulae with aneurysmal dilatation due to repetitive cannulation in a restricted area. This is a prospective cohort study of 14 chronic hemodialysis (HD) patients with problematic fistulae (marked aneurysmal formation and thinning of the overlying skin, bleeding during treatment, and prolonged hemostasis post-HD) because of repetitive, localized cannulation. Each patient was followed for 12 months. The protocol was as follows: creation of tunnel tracks by 1 to 3 experienced cannulators per patient, using sharp needles. After the tunnel tracks were established and cannulation was easily achieved with dull needles, additional cannulators were incorporated with the guidance of a mentor. Bleeding from cannulation sites during dialysis ceased within 2 weeks and skin damage resolved within 6 months in all patients. Hemostasis time postdialysis decreased from 24 to 15 min. Cannulation pain scores decreased significantly. Access flows and dynamic venous pressure measurements remained unchanged. No interventions were required to maintain access patency. In 2 cases, the aneurysms became much less evident. Complications included one episode of septic arthritis and one contact dermatitis. A third patient developed acute bacterial endocarditis 9 months following completion of her follow-up. The SMH modified BH cannulation technique can salvage problematic fistulae, prevent further damage, and induce healing of the skin in the areas of repetitive cannulation. This technique can be successfully achieved by multiple cannulators in a busy full-care HD unit.

Key words: Problematic fistulae, buttonhole cannulation, arterio-venous fistula, hemodialysis access, hemodialysis access aneurysm, hemodialysis access salvage

INTRODUCTION

The "Constant Site Method" of hemodialysis (HD) needle insertion was first described by Twardowski et al.[1] in the Polish literature and 2 years later was reported in the English literature.[2] This technique was serendipitously developed in the course of cannulating the fistula of a patient in whom there was an inadequate length of fistula to achieve the rope ladder cannulation approach. In this constant site cannulation technique, the identical cannulation track was used, resulting in a simplified painless access to the dialysis fistula. This technique was renamed the "Buttonhole Puncture Technique" in 1984 by Krönung.[3] While the initial experience with the buttonhole (BH) technique was very positive,[3–8] its use has not become widespread, particularly in North America, probably because the application of this technique has been primarily limited to the population of patients in which a single cannulator achieves access for HD (home or self-care HD).[8–10] Indeed, the current rebirth of the BH

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technique is still focused upon the single cannulators with ideal fistulae.[8]

A common problem in fistulae with a limited area available for cannulation is the development of marked aneurysmal dilatations and thinning of the skin at the sites of repetitive cannulation. We considered the use of a modified BH technique in these problematic fistulae as a potential solution, as it addressed the pathogenesis of these aneurysms.[3] Whereas the classic BH cannulation is usually achieved by a single cannulator using an ideal fistula, our situation required several modifications to the standard BH cannulation technique: the fistulae were clearly not ideal, but in fact had aneurysms at the cannulation sites and in a full-care dialysis unit, it was necessary to involve multiple cannulators. It was also important to ensure that this cannulation method did not have an adverse effect on fistula performance or morphology. With a structured approach, BH cannulation for aneurysmal fistulae was successfully introduced into our large and busy HD unit. We were able to create buttonhole accesses in patients with aneurysmal dilatation of their fistulae because of repetitive cannulation in a restricted area, with resultant healing of the vessel and skin. This modified buttonhole technique accommodates multiple cannulators, in the creation and cannulation of the tunnel tracks.

METHODS

Study design

This prospective cohort study evaluated the impact of the SMH modified BH cannulation technique, on fistulae with aneurysmal dilatation and damaged skin and its implementation by multiple cannulators. The patients were each followed for 1 year.

Patient population

Of 200 prevalent in-center chronic HD patients, 14 patients with problematic fistulae because of marked aneurysm formation and thinning of the overlying skin in the cannulation areas were identified. All patients agreed to undergo BH cannulation in an attempt to improve their problem. There were no exclusion criteria. All patients had restricted areas for cannulation. Six had oozing of blood during HD and prolonged hemostasis post-HD without central venous stenosis confirmed by angiogram.

Nurse population

Of 63 HD nurses, an initial team of 7 experienced nurses was established on the basis of their expertise with conventional cannulation; they are referred to as the "tunnel track creators" (TTC). They were trained by an experienced BH cannulator (team leader). Six months later, a second team of 7 nurses, designated as the buttonhole cannulators (BHC), was recruited and certified in the same way as the first group. These nurses did not create buttonhole tracks; however, they cannulated the mature buttonhole accesses.

Protocol

Cannulation site selection

The sites for the buttonhole tunnel tracks were selected in areas of maximum skin integrity and least skin hematoma, also avoiding any intra-aneurysmal thrombus with the use of the bedside ultrasound (Site-RiteII Ultrasound System Dymax Corporation, Pittsburgh, PA, U.S.A.). Cannulation was performed at the base of the aneurysm in all cases.

Buttonhole creation and first 6 months of BH cannulation

For each patient, the TTC team was further divided into 2 groups. The first group consisted of 2 nurses (designated as the primary cannulators), who created the tunnel tracks, periodically being replaced by the team leader, if a primary cannulator was not available. Tunnel tracks were created using 15 G sharp needles, with backeye (Hemodialysis Fistula Set M9-7005 MG, Medisystems Corporation, Seattle, WA, U.S.A.) for approximately 2 weeks (or 6–8 cannulations). All cannulations were carried out antegrade, and local anesthetic was never used. When the needle slid effortlessly into the vessel, the cannulator would attempt to cannulate with dull needles, with backeye (ButtonHole Needle Set BH-7005 Medisystems Corporation) at the next dialysis. If the dull needle met resistance, it was withdrawn and a sharp needle was used. Dull needles were again tried at the next treatment. If dull needle cannulation was easily achieved, this was considered as a successful dull needle insertion. Thereafter, once dull needles were being used without difficulty (an additional 2 weeks), the second group, which consisted of the remaining 5 nurses in the TTC group (referred to as secondary cannulators), was allowed to cannulate the patient. Only one pair (arterial and venous) of BH sites was created for all patients (daily or 3 times weekly). All patients had a blood flow of 400 mL/

min, except for one daily patient, whose blood flow was limited to 300 mL/min because of patient preference.

Long-term cannulation of the buttonhole
Six months from the initial sharp needle cannulation, the BHC team started dull needle cannulation in the now mature buttonhole access. If no certified BHC was available, the access was cannulated using sharp needles at a nonbuttonhole site by the regular HD nurses. The BH access was never cannulated using dull needles by a noncertified BHC.

Skin preparation
Preparation involved application of an antiseptic solution (10% povidone-iodine solution or chlorhexidine gluconate 2%) to the skin, before removal of the scabs formed from previous cannulation. The solution was then reapplied to the cannulation sites, before the insertion of the needles.

Outcomes

Initial evaluations of the fistula were performed before the implementation of the SMH-modified cannulation technique (baseline measurement), and in the course of the follow-up, as described below.

Access performance evaluation
Dynamic pressure monitoring (venous and arterial), at a blood pump speed of 200 mL/min, was performed during every dialysis treatment for 1 month, then once weekly for 6 months, and thereafter, monthly until the completion of the study. Access flow and percent recirculation were measured with the transonic dilution technique (Transonic HDO2 Hemodialysis Flow QC monitor, Transonic Systems Inc., Ithaca, NY, U.S.A.), and were performed at baseline and every 3 to 4 months thereafter.

Status of skin and bleeding
The status of the skin was recorded in a descriptive manner before cannulation during every treatment. Quantification of the severity of blood loss during the treatment could not be determined with confidence. Nevertheless, a gauze was placed over the needle insertion sites, and the appearance of blood on the gauze during the treatment was recorded. Hemostasis post-HD was determined as follows: 5 min after removing each needle (venous first), pressure on the site was released. If blood appeared through the folded gauze, pressure was reapplied immediately in the same manner. This process was repeated every 5 min until there was no sign of fresh blood in the needle entrance site.

Patient and staff comfort
Pain on each cannulation was documented by the patient using a 10-point visual analogue pain scale (1—no pain, 10—extreme pain) throughout the study. Both arterial and venous cannulation pain scores were recorded for each patient.

The degree of difficulty experienced by the nurses cannulating the tunnel tracks was evaluated, using a 3-point scale (1—easy, independent, 2—cannulated with guidance, 3—unable to cannulate) by the team leader. This evaluation was carried out only on the first occasion that each nurse cannulated each patient during 3 distinct time periods. The TTC were evaluated in 3 periods during the first 6 months. The BHC were evaluated over 2 periods during the last 6 months of the study and at 1-year post-evaluation.

Statistics

Continuous variables are reported as medians with the interquartile range (25th and 75th percentiles) and were compared using the Mann-Whitney test, the Wilcoxon signed rank test, and the Friedman test where appropriate. Categorical variables are reported by proportion and compared using chi-square testing. A linear mixed model was created to evaluate the factors determining pain on cannulation. Modality (daily vs. 3 times weekly) and treatment period were selected as fixed effects in a first-order autoregressive covariance structure. Six treatment periods were selected to reflect the different stages in the evolution of the tunnel track: baseline, remaining sharp needle cannulation, 2 weeks of dull needle cannulation, 1 to 6, 6 to 12 months, and 1 year. The number of treatments was selected as the repeating variable and pain score as the dependent variable. The intercept was evaluated in the model. A p value <0.05 was considered significant. Statistical analysis was performed with SPSS v11.0 (SPSS Inc., Chicago, IL, U.S.A.).

RESULTS

Seven nurses were recruited for the first team of cannulators (primary and secondary cannulators) to create the BH tracks. With the passage of time, 3 did not progress in their ability to cannulate with dull needles and withdrew from this category. From the second group of nurses recruited, (BHC) of the 7, only 1 nurse withdrew.

Fourteen patients had BH accesses established in problematic fistulae, 9 were dialyzed 3 days weekly, 5 were dialyzed "daily," (4 were 5 days per week and 1 was 4 days per week). None of the daily dialysis patients had more than a 1-day interdialytic interval. The demographics are presented in Table 1. Of note, all fistulae had been in use for at least 12 months before BH creation. The results of the clinical monitoring are depicted in Table 2. The creation of the buttonhole access had no adverse effect on access flow or pressures during dialysis. There was significant improvement in the hemostasis time postdialysis. No patient had detectable recirculation at any time during the study.

The patients' evaluation of pain on cannulation of the arterial tunnel track is presented in Figure 1. Both modality (daily vs. 3 times weekly; $p < 0.02$) and the number of treatments ($p < 0.001$) had a significant impact on the pain experienced on cannulation of both arterial and venous tunnel tracks. Table 3 presents the pain evaluation during the 6 stated periods for both the arterial and venous cannulations of all patients. The arterial and venous cannulations were analyzed as paired data, and cannulation of the arterial buttonhole was significantly less painful than the venous for each patient (Wilcoxon signed ranks test, $p = 0.001$), despite the fact that the median values appear similar (Table 3). For both arterial and venous cannulations, the most significant improvement in pain experienced occurred between the baseline and the completion of the tunnel tracks (2 weeks of dull needles) and significant additional improvement occurred after 6 months of dull needle cannulation (Friedman test, $p < 0.001$). Daily dialysis patients experienced less pain than those cannulating 3 days weekly, throughout the study (Mann-Whitney test, $p < 0.01$) (see Figure 1).

Table 1 Demographics of the study population

Number	14
Male gender (%)	43
Age (years)	48.5 (41.5, 53.3)
Duration of dialysis (months)	408 (216, 582)
Fistulae	
Radio-cephalic fistulae (%)	79
Mean fistula age (months)	41 (27, 66)
Cause of renal failure (%)	
Diabetes type II	21
Glomerulonephritis	36
Vascular disease	21
Pyelonephritis	14
Polycystic disease	7

Table 2 Clinical parameters assessed at the onset of the creation of the buttonhole access, and at the end of the study

Parameters (n = 14)	Initial	Final	p
Access flows (mL/min)	800 (540, 1380)	860 (465, 1420)	0.505
DAP monitoring (mmHg)	−65 (−80, −40)	−55 (−80, −37.5)	0.132
DVP monitoring (mmHg)	95 (80, 120)	100 (85, 130)	0.097
Hemostasis postdialysis (min)	20 (15, 40)	13 (9, 20)	<0.001

DAP = dynamic arterial pressure; DVP = dynamic venous pressure.

The results of the independent assessment of the degree of difficulty experienced by the nurses achieving cannulation are presented in Table 4. It is evident that in both the TTC (months 1–6) and the BHC (months 6–12), there was an initial difficulty that disappeared with time. In both groups, this change in ease of cannulation with time was significant ($p < 0.01$). When the scores of the nurses who withdrew from the cannulation program were removed, there was absolutely no impact on the results in both categories, and therefore, the data are not presented. There was no difference in the degree of difficulty experienced by the TTC and BHC cannulators ($p = 0.13$).

The status of the associated problems with the fistula is depicted in Figure 2. By the time the tunnel track had been created, before the cannulation with dull needles, the blood oozing during dialysis had ceased. By 6 months, most of the skin abnormalities had disappeared. At 1 year, 2 aneurysms were less visible and palpable, but were still present (Figure 3). In no case was an increase in the size of the aneurysm observed, nor was an intervention required to address thrombosis or a reduction in access flow during the study.

Of the 14 patients, 9 have progressed to self-cannulation and 4 have gone on to home HD. This latter advancement had been planned in only 2 cases.

The major complication observed was a *Staphylococcus aureus* septic arthritis, which occurred in one patient. She received Cloxacillin IV for 24 days followed by oral cloxacillin for 1 week. There has been no recurrence. A second patient developed a *S. aureus* endocarditis after the study period had ended, 1 year and 9 months following the creation of the buttonhole access. This patient required replacement of the mitral valve and drainage of a myocardial abscess. She has completely recovered. A third patient developed a contact dermatitis secondary to prolonged skin contact with chlorhexidine.

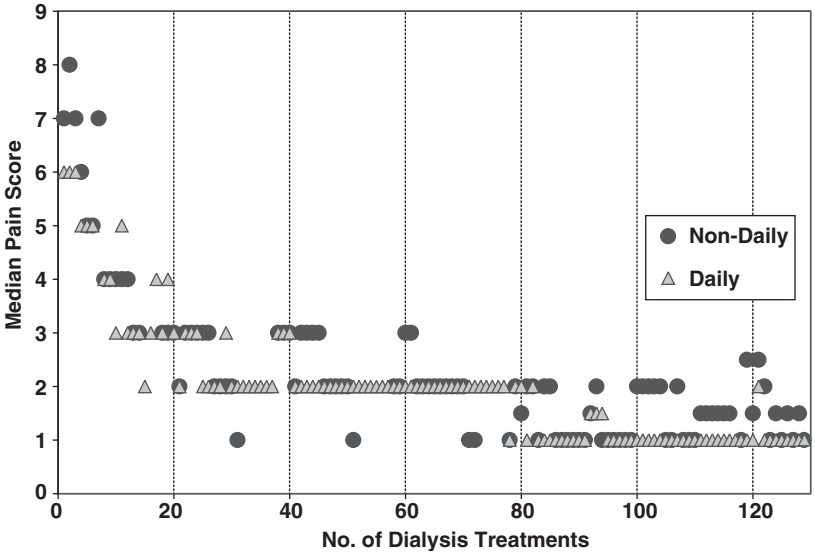

Figure 1 Patients' evaluation of pain on cannulation of the arterial buttonhole, using a 10-point scale. Data are plotted separately for patients on daily and 3 dialyses per week. Each point represents the median of either 9 (3 days/week) or 5 (daily) values (Mann-Whitney, $p < 0.001$). The plot of the venous buttonhole is very similar and therefore the data are not presented.

DISCUSSION

With the increasing age of incident HD patients and the high prevalence of diabetes mellitus, many patients come to dialysis with a shortage of ideal veins for fistula creation. The DOQI stimulated "fistula first" program[11,12] will predictably increase the number of fistulae that are less than ideal and that may have a limited area for cannulation.

Repeated punctures in a small circumscribed area may cause damage to the skin and destruction of the vessel wall, producing aneurysmal dilatation of the fistula.[3] The size of this aneurysmal dilatation is directly related to the number of punctures per unit area of cannulation, i.e., the smaller the area, the larger the aneurysmal dilatation.[3,13] In this study, BH cannulation sites were successfully created in all fistulae with aneurysmal dilation. That BH cannulation facilitates the healing of damaged skin and stabilization of the aneurysmal dilatation is a major step in maximizing fistula longevity in problematic fistulae. Although we had no control group, all patients had been recruited on the basis of having developed aneurysms, and all showed improvement in their symptoms (bleeding during and postdialysis and healing of their skin), indicating that the BH cannulation technique had a beneficial impact on their problem. Interestingly, despite the thesis that these dilatations progress, even without further cannulation[3,13] we did not see progression of any aneurysms in our study. In fact, in 2 cases, there was remodeling of the fistula and shrinkage of the aneurysm.

Table 3 Pain evaluation over time

n=14	Arterial	Venous
First sharp needle	7.0 (5.8, 8.0)	6.5 (5.8, 8.5)
Remaining sharp	6.0 (5.0, 8.0)	6.0 (5.0, 7.0)
Start of dull needle	4.0 (2.0, 4.0)	3.0 (2.0, 4.3)
1 to 6 months post dull needle	2.0 (2.0, 3.0)	2.0 (2.0, 3.0)
6 to 12 months post dull needle	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)
12 months post dull needle	1.0 (1.0, 2.0)	1.0 (1.0, 2.0)

Wilcoxon signed rank, $p=0.001$ (matched arterial and venous in each patient).

The differences between the classical buttonhole and the SMH modified buttonhole technique are as follows: the classical technique involves a single cannulator, cannulating an ideal fistula with sharp needles, whereas the SMH technique involves multiple cannulators, cannulating a problematic fistula using dull needles. The use of multiple cannulators is novel and necessary for the use of this cannulation technique in full-care dialysis units. It is essential that the unit administration be committed to the successful implementation of the BH cannulation technique as the appropriate scheduling of cannulators is critical. To facilitate the logistics, the primary cannulators in the SMH modified buttonhole program were restricted to a team of 2 (occasionally 3) for any given patient. When 3 nurses were required, the third

Table 4 Ease of first cannulation by nurse

	With ease		With assistance		Incapable		
	Arterial (%)	Venous (%)	Arterial (%)	Venous (%)	Arterial (%)	Venous (%)	p value
First cannulation group[a]							
1 to 2 months	66	67	31	31	3	2	
2 to 3 months	88	91	12	9	0	0	<0.001
3 to 6 months	98	91	2	9	0	0	
Second cannulation group[a]							
6 to 9 months	65	66	35	34	0	0	
9 to 12 months	92	95	8	5	0	0	<0.001
12 months	98	100	2	0	0	0	

[a]Chi square, p=0.13 (first vs. second cannulation group).

was the team leader, who provided the backup for this additional flexibility. If no member of the primary team was available, a different site using sharp needles was used for traditional cannulation. The use of dull needles was part of an early modification of the BH technique.[9] After the tunnel had been established, the use of dull needles facilitated the cannulation of the buttonholes by the larger group of BHC.

It is important to recognize that BH cannulation is a technique that requires a different skill set than conventional cannulation, and it should not be assumed that if one is an expert in conventional cannulation, that one will similarly be an expert in cannulation of a BH access. Successful BHC had to learn to "feel" the needle sliding down the tunnel track into the vessel; this "soft touch" skill may be variable among cannulators. In fact, of the original 14 cannulators, chosen because of their expertise with conventional cannulation, 4 withdrew because of difficulty mastering the technique. Even those especially skilled cannulators initially required direction from one of the nurses who created the original tunnel track, guiding their hand as the needle was advanced down the tunnel. With time, the more mature tunnel track could be cannulated by most BH certified nurses, but often required a "to and fro" motion while the needle descended into the tunnel. If resistance was encountered, with this technique, some nurses preferred to rotate the needle, in a drilling motion, during insertion.

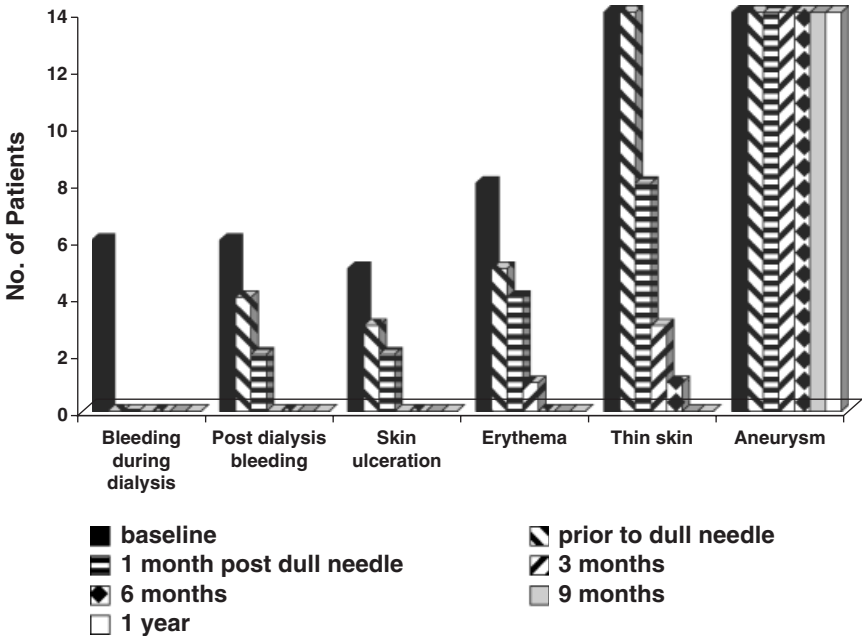

Figure 2 Incidence of fistula-related problems. Incidence of fistula-related problems at the 7 indicated phases of the study.

After 4 weeks, the cannulation was significantly less painful, but it took more than 6 months for the pain to disappear in the majority of patients. The disappearance of pain had 2 major benefits: it led many patients to agree to self-cannulation, which was a giant step in progression to self-care or home HD, and it facilitated the conversion of other patients with internal jugular lines to a permanent fistula. It is clear that a major deterrent to patients, who start dialysis with a central line, agreeing to have a fistula created is the observation of patients experiencing severe pain, and nurses experiencing difficulty during the cannulation of the permanent access, while they (via their central lines) were quickly and painlessly placed on dialysis.

The creation of BH tunnel tracks proactively in fistulae where rope ladder cannulation is not possible may prevent the development of aneurysmal dilatations. Secondly, the achievement of painless cannulation may be a sufficient justification for the routine creation of buttonhole accesses in all patients with fistulae, providing the risk of infectious complications can be minimized. The time necessary to cannulate the fistula using the BH technique, including skin preparation and scab removal, is approximately 20 min; this longer time may be more than compensated for by the possibility of fewer interventions and increased primary survival of the access.

Finally, the need for meticulous preparation of the skin before cannulation is of critical importance in this cannulation technique. However, once the process is well established, personnel and patients may become casual and prepare the skin with inadequate attention. This can be associated with bacteremia and severe clinical sequelae. It is possible that the tunnel tracks may harbor organisms, and may require more fastidious antibacterial cleaning, before cannulation than the routine fistula. In the whole SMH modified BH program, there have been 2 cases of septic arthritis (both with *S. aureus*) and one case of *S. aureus* endocarditis with a myocardial abscess. While it is possible that these serious complications resulted from breaches in the cleansing protocol, they have never been seen previously in this dialysis unit with the conventional cannulation

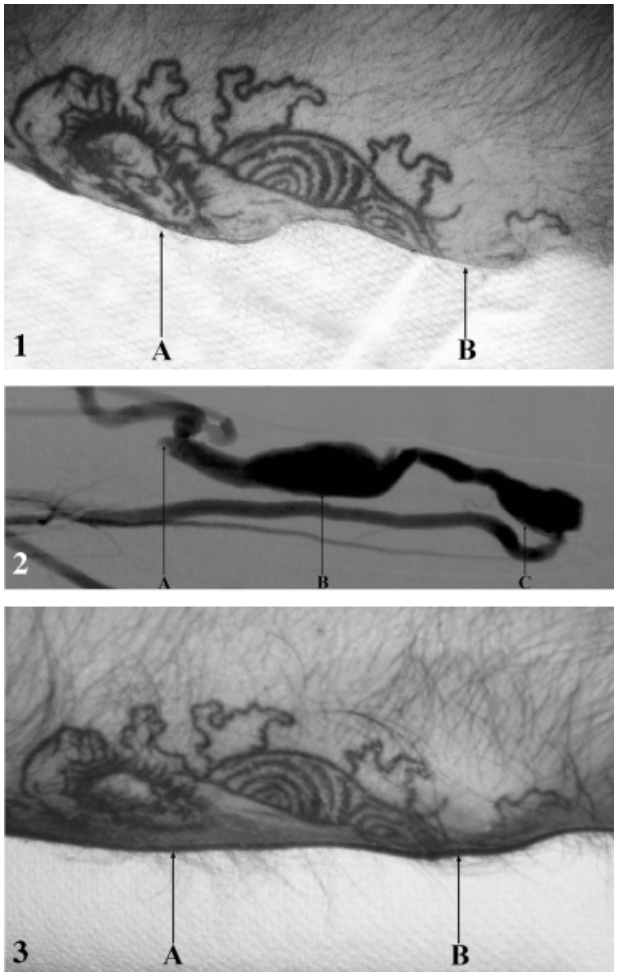

Figure 3 Evolution of aneurysmal dilatation postcreation of buttonhole access. This patient had his original buttonhole access created on November 12, 2002. Trauma to fistula resulted in thrombosis of fistula at the level of the venous buttonhole (A) November 30, 2003. A large collateral enabled survival of the fistula. A new arterial buttonhole was created at site (C), and the original arterial buttonhole became the new venous buttonhole (B). In all panels: (A) indicates original venous buttonhole, created on November 12, 2002. (B) indicates original arterial buttonhole, created on November 12, 2002 and (C) indicates the site of subsequent arterial buttonhole (not included in panels 1 and 2). Panel 1: access appearance before buttonhole creation, November 12, 2002. Panel 2: fistulogram after trauma to fistula and thrombosis of original venous buttonhole (site A). Patent large collateral evident. December 1, 2003. Panel 3: access appearance 26 months after buttonhole access creation. The patient has not had a fistulogram to document the change in the aneurysmal dilatation subsequent to the buttonhole creation; however, the presence of the tattoo, ensuring a similar view, allows an objective comparison of the 2 photos. While the thrombosis could explain the shrinkage of the original venous aneurysmal area (site A), it would not be expected to cause shrinkage at site B. The patient attests to a significant shrinkage in the size of the dilatation at site B, but has not had a clinical indication for a repeat fistulogram.

technique. Therefore, the BH technique must have a more stringent protocol of skin preparation before cannulation and after removal of the needles. As a result of these infections, our skin preparation procedure now includes the application of antibacterial ointment (betadine or polysporin) on the gauze used during the withdrawal of the needles, with the ointment remaining in place for 6 hr after the needle removal. We have experienced no further infectious complications over the subsequent 15 months since this change has been instituted. In their initial paper, Twardowski and Kubara[2] drew attention to the problem of inflammation at the insertion site resulting from contamination between dialyses, and suggested a dressing to prevent contamination for at least 12 hr postdialysis. Unfortunately, we have had to "rediscover" this important advice. Clearly, this problem merits frequent emphasis and further investigation. In view of these serious infectious complications, it is premature to recommend the routine use of BH cannulation in all fistulae. This will require demonstration, in a randomized study, of the safety and benefits of the BH cannulation technique, as compared with rope ladder cannulation in adequate fistulae. However, in fistulae with inadequate area for rope ladder cannulation, the SMH modified BH cannulation technique provides a possible method to avoid aneurysmal dilatation.

In summary, the successful establishment of the SMH modified buttonhole technique in a busy HD unit using multiple cannulators and dull needles has been demonstrated. Using this technique, problematic fistulae that have developed aneurysmal dilatations because of a small area available for cannulation have been salvaged. The prophylactic creation of BH cannulation sites in fistulae with restricted cannulation sites may prevent the development of such problematic fistulae.

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