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REVIEW

Surgical Techniques to Improve Cannulation of Hemodialysis Vascular Access

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Abstract *Objective:* Successful access cannulation is of utmost importance for adequate hemodialysis treatment. Upper arm fistulae, obesity and deep or tortuous veins may impair needling and can cause significant complications and inconvenience for the patient. In the ultimate case, cannulation problems lead to temporary central vein catheter use for dialysis or even to irreversible access loss. Surgical access revision may enhance successful cannulation.
Methods: A systematic literature review of all publications related to hemodialysis vascular access, cannulation complications and treatment was performed.
Results: A total of 384 publications were identified, of which only 17 were related to treatment of cannulation complications in large patient populations. The clinical success rate of surgical intervention with vein elevation or transposition ranges from 85% to 91%. The 1-year primary and secondary patencies are 60% and 71%, respectively. Lipectomy results in an initial success rate of 100% with a primary and secondary patency of 71% and 98%, respectively, after 1 year of follow-up.
Conclusion: Surgical revision to improve hemodialysis vascular access cannulation has a high clinical success rate with good long-term patency.

Introduction

Miscannulation of hemodialysis vascular access may cause infiltrations, haematoma formation, infection and aneurysms, and leads to morbidity, hospitalisation, access revision and even loss of the access. Difficult cannulation is painful and burdensome for the patient, which has a negative impact on the quality of life. Recent studies have shown cannulation-related complications in a great percentage (31%) of incident patients. In addition, alternative access methods, such as single-needle cannulation and central vein catheters were needed in these patients, with a potential higher morbidity and mortality rate. Miscannulation and cannulation-related complications are

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usually seen in autogenous arteriovenous fistulae (AVFs) but also occur in AV grafts. Obesity, female sex and the length of the cannulation route are important factors for the occurrence of cannulation-related complications. In a univariate analysis of patients with AVF, female sex ($P < 0.02$) and limited length of cannulation route ($P < 0.003$) were significant determinants for the use of catheter or single-needle dialysis. Multivariate analysis showed the limited length of cannulation route as the single predictive factor for cannulation problems ($P < 0.002$). Upper arm AVF exhibit more cannulation problems than forearm fistulae, but the difference is not statistically significant.[1] Ultrasound-guided needling may facilitate successful cannulation of difficult access, but this technique can be cumbersome to learn by dialysis nurses and extended experience is needed for good outcome.

Surgical access revision may enhance access cannulation and improve fistula outcome. For the description and outcome of the various surgical techniques, a literature review was performed.

Methods

A systematic literature review using a Medline search of English-language publications was performed. Keywords used were: vascular access; hemodialysis; cannulation; complications. For this review in particular, large population-based, randomised studies and meta-analysis were included. Small patient studies and case reports were excluded. A total of 384 studies were identified; 367 studies were excluded for review because of: not meeting the inclusion criteria ($n = 214$); case reports ($n = 106$) and non-English-language publications ($n = 47$). None of the identified studies was randomised or concerned a meta-analysis. Seventeen studies were eligible for review, including various techniques to enhance access cannulation. A test of heterogeneity showed no significant deviation of the different papers from the normal distribution.

Aetiology of miscannulation

Non-maturation

Fistula cannulation can be usually performed after successful maturation. A time period of 6 weeks to 3 months is sufficient to achieve adequate maturation in most patients. According to the National Kidney Foundation—Kidney Diseases Outcome Quality Initiative (NKF—KDOQI) guidelines autogenous fistulae have matured when they fulfil three criteria: a vein diameter of 6 mm; a blood flow of 600 ml min^{-1} and a vein depth of less than 6 mm.[2] These criteria are hardly met with in daily practice. As much as 30—40% of radiocephalic wrist fistulae and 10—20% of elbow and upper arm fistulae (brachiocephalic/basilic) fail or do not mature after creation. The reason for non-maturation is, in 90% of patients, a stenotic lesion at the arteriovenous anastomosis or arterial inflow. In addition, large-calibre accessory veins may be associated with non-maturation and cannulation difficulties. In 10 out of 15 patients with radiocephalic arteriovenous fistulae (RCAVFs), the presence of large-calibre accessory veins was the only significant predictor for non-maturation ($P = 0.01$).[3]

Obesity and deeply located veins

The number of obese end-stage renal disease patients, who frequently have type 2 diabetes, is continuously increasing. On the one hand, obese and diabetic patients belong to a group with an increased risk of autogenous arteriovenous fistula placement failure due to advanced arteriosclerosis and reduced accessibility of forearm vessels because of excessive fat tissue. Moreover, needling of the deeply located veins may be difficult. Up to 50% of AVFs may fail to mature, primarily because of problems with fistula cannulation. On the other hand, while physical examination usually does not show superficial veins in these patients, Doppler ultrasound vessel imaging may identify well-sized, good-quality radial arteries and cephalic veins for fistula creation and these are comparable between obese and non-obese patients.[4]

Still, AVF use for dialysis is less frequent among obese than non-obese patients. This discrepancy may be due to a lower rate of fistula placement in obese patients and a higher primary and secondary failure rate. A prospective study showed that fistula placement was equally likely between obese (body mass index (BMI) $\geq$30 kg m^{-2}) and non-obese (BMI $<$30 kg m^{-2}) patients (47.4 vs. 47.1%). The primary failure rate of fistulae was similar in both groups (46 vs. 41%, $P = 0.45$). Among those fistulae that were usable for dialysis, the secondary survival was worse in obese patients (hazard ratio 2.74; 95% confidence interval (CI), 1.48—7.90; $P = 0.004$). Secondary fistula survival in obese versus non-obese patients was 68% versus 92% at 1 year, 59% versus 78% at 2 years and 47% versus 70% at 3 years. On multivariate survival analysis with age, sex, race, diabetes, coronary artery disease, peripheral vascular disease, fistula location, surgeon and obesity in the model, obesity was the only significant factor predicting secondary fistula failure (hazards ratio 2.93; 95% CI, 1.44—5.93; $P = 0.004$). Long-term fistula survival is worse in obese than non-obese patients, owing to a higher secondary failure rate. Access failure in obese patients may be due to needling difficulties resulting in cannulation-related complications.[5]

In a large retrospective study, 1486 hemodialysis patients were included. Using BMI $<$30 kg m^{-2} as reference, obesity did not emerge as a factor in predicting vascular access revisions or failures. An increased risk of AVF failure to mature was found only in the highest BMI quartile ($>$35 kg m^{-2}) (Adjusted odds' ratio (AOR) 3.66 (95% confidence interval (CI): 1.27—10.55), $P = 0.017$). Peripheral vascular disease was independently associated with an increased risk of AVF failure (AOR 2.78 (95% CI 1.01—7.63), $P = 0.047$) and arteriovenous graft (AVG) failure (AOR 1.65 (95% CI 1.03—2.64), $P = 0.036$). Obesity was not associated with increased AVF or AVG revision rates or failure and only associated with poorer AVF maturity at the highest BMI quartile.[6]

Short vein segment and/or tortuosity

Vein anatomy may differ widely among patients, which implies a variety of accessible vein segments after access creation. In some patients, meandering veins may lead to