Dialysis access–associated steal syndrome: The intraoperative use of duplex ultrasound scan

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Dialysis access–associated steal syndrome (DASS) is an uncommon but serious complication after the creation of an arteriovenous shunt for hemodialysis and is related to an excess perfusion of the fistula. Several surgical options have been described for DASS correction. To achieve an adequate distribution of the blood flow towards the fistula and the hand, intraoperative duplex ultrasound scan monitoring was used in this preliminary communication to control the surgical reduction of volume flow through the fistula. The shunt flow was not estimated with direct insonation of the shunt but calculated from the difference of the bilateral subclavian artery volume flow rates. This new technique has several advantages over a direct shunt evaluation that are discussed in this report. Three patients with DASS are described in whom the technique was successfully applied and led to a normalization of the hand perfusion and to the maintenance of a long-term patency of the fistula. (J Vasc Surg 2003;37:211-3.)

Hemodialysis is one of the basic measures for the treatment of chronic decompensated renal failure but requires, as a prerequisite, the creation of an arteriovenous fistula. If available, autologous vein material is preferred for the fistula, but synthetic materials, such as Dacron and polytetrafluoroethylene, present the alternative.[1] Minimal shunt volume flow rates in adult patients with autologous shunts range between 300 and 500 mL/min and are adequate for dialysis purposes but also to maintain the patency of the fistula.[1] With an inappropriately high shunt flow, cardiac complications from volume overload, but also a dialysis access–associated steal syndrome (DASS), may occur (ie, a shifting away of a high proportion of the volume flow from the perfusion of the hand towards the dialysis shunt). DASS presents an uncommon but serious complication, with an incidence rate of up to 4%, particularly with proximal fistulae.[2] Shunt flow reduction with surgical banding techniques is one of the options to cope with a DASS situation, although the results are overshadowed by a high incidence rate of postoperative shunt thrombosis.[3,4] This case report describes a new method for how this problem can be appropriately handled.

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MATERIALS AND METHODS

General patient information. This preliminary communication describes three male patients who were on hemodialysis because of chronic renal failure, who showed an inappropriately high shunt flow rate, and who had a DASS develop that required a shunt revision. DASS was characterized in all three patients by coldness of the hand, paraesthesia, numbness, and (particularly nocturnal) pain; the pain was aggravated by elevating the extremity and was more pronounced during hemodialysis. None of the patients had ischemic cutaneous lesions. Clinically, all had reduced or absent radial and ulnar pulses, and digital ischemia was documented with pulse volume recording.

In all patients, the shunt was revised surgically with duplex scan control. To calculate the shunt volume flow, the arterial flow rate was measured bilaterally over the distal subclavian artery (with an infraclavicular scanning approach) with the product of π, the squared radius, and the time average mean velocity (TAV).[5] The shunt flow then was equal to the difference of the ipsilateral and the contralateral subclavian volume flow rates. The procedure was performed before surgery and (dependent on the result of the surgical revision) several times during the shunt revision process, until a shunt flow rate in the desired order of magnitude together with a reoccurrence of a radial pulse was obtained. After surgery, the normalization of the hand perfusion was objectively documented with pulse volume recording and Doppler scan–assessed peripheral pressures.

Technical equipment and measurements. The duplex scan device used was an ATL HDI 5000 together with a 5-MHz to 12-MHz broadband linear array transducer (Philips Medical Systems, Best, The Netherlands). An appropriately large sample volume was placed covering the

Table I. Summary of clinical information on three DASS cases

	Case 1	*Case 2*	*Case 3*
Age (y)	67	66	78
Dialysis since (date)	1997	2000	1999
No. of shunt procedures	2	1	1
Present shunt	Brachiocephalic	Brachiocephalic	Brachiocephalic
Shunt revision procedure	Goretex interposition (L: 3 cm; ∅4 mm)	∅ reduction; running suture	∅ reduction; running suture
Time period shunt to DASS	4 months	7 months	Immediately
Shunt volume flow			
Preoperative (mL/min)	2800	1400	1580
Postoperative (mL/min)	940*	470	440
Follow-up (mo)	29	12	2.5

*Left at this high level to prevent thrombotic occlusion of massively dilated cephalic vein.

entire arterial lumen. The scanning angles varied (interindividually) between 54 degrees and 60 degrees, but the angle was kept constant for each individual patient.

Flow rates were automatically calculated with the machines' software on the basis of hand-defined radii and machine-calculated TAVs from five or more cardiac cycles. Each flow rate reported in this paper represents the arithmetic mean from four measurements.

The normality of the bilateral subclavian artery perfusion was tested before the creation of the first arteriovenous fistula with normal results of a clinical examination and bilaterally equal (Doppler scan–measured) systolic blood pressures (side difference $\leq$ 10 mm Hg). Also, before a shunt revision, the course of the proximal and the distal subclavian arteries was duplex scanned and the shunt revision only performed with duplex scan control, if B-mode results were not suggestive of any major obliteration and if color-mode and spectral analysis did not show any focal velocity acceleration.

Validation of experimental approach. To provide evidence on the correctness of the experimental approach, the shunt flow of five patients with a prosthetic bridge fistula (patients different from the study's patient sample) was assessed five times indirectly (bilateral subclavian arteries) and five times with direct insonation of the shunt (away from the proximal anastomosis). Data as assessed indirectly correlated well to directly measured flow data (standard parametric linear regression model, Pearson correlation coefficient, $r = 0.893$; $P < .0001$; nonparametric linear regression according to Passing-Bablok, Spearman rank correlation coefficient, $r = 0.809$; $P < .0001$).

Neither a two-tailed, paired, nonparametric comparison of indirectly and directly measured flow data (Wilcoxon signed rank test) nor a two-sided, paired t test did provide evidence that the null hypothesis must be rejected ($P = .43$; and $P = .58$, respectively). Detailed results of this preliminary validation are provided in the Statistical Appendix (online only) to this communication.

Patient-specific information and results. All relevant clinical data on the three patients with DASS are summarized in Table I. The original volume flow data from both subclavian arteries (see also Technical equipment and measurements) are given in the Statistical Appendix (online only) of this report.

DISCUSSION

The occurrence of a steal phenomenon or the development of cardiac overload–related cardiac failure are uncommon but serious complications after the creation of an arteriovenous fistula for hemodialysis access. To correct for a DASS, three options must be considered: the ligation of the shunt, an arterial ligation bypass procedure[6,7] (ie, the ligation of the main supplying artery in the direct distal vicinity of the fistula with a widely bridging bypass anastomosed at a sufficient distance from the shunt origin), or the reduction of the shunt volume flow rate (banding) down to an order of magnitude, which allows for a normal peripheral perfusion of the extremity, which avoids the occurrence of cardiac overload but is still sufficiently high to minimize the risk of a thrombotic shunt occlusion.

To guarantee an appropriate peripheral (hand and finger) perfusion, a method was described by Shemesh, Mabjeesh, and Abramowitz[8] and Shemesh et al[9] for synthetic material shunts that relies on the preoperative and intraoperative ultrasound duplex scan assessment of the area of interest. The shunt flow was reduced with shunt compression until the pressure in digital arteries rose to 60 mm Hg or more or until the digital-brachial pressure index reached values of 0.5 or more. The TAV in the compressed shunt was recorded, and the shunt was revised in a way so that a comparable TAV (and thus, volume flow rate) resulted. To confirm an appropriate outcome, the finger artery pressures were monitored during surgery.

This procedure was applied successfully by Shemesh but, in our opinion, has one potential disadvantage: the direct insonation of the shunt to access the TAV or the volume flow potentially leads to results that may be prone to error.[8,9] When insonating the shunt close to the arterial anastomosis, hemodynamic factors, such as the existence of flow separation and recirculation zones and the existence of a complex laminar flow (ie, helical flow pattern or a fully developed turbulent profile), will have their influences. The related problems can only be avoided by insonating at a sufficient distance from the anastomosis in an area where relaminarization of the flow profile can be expected.

Shemesh et al focused on the mere assessment of the TAV as being representative of the volume flow.[8,9] This assumption is correct for synthetic material shunts for which the diameter can be seen as a constant; however, problems may occur with autologous materials with a higher variability of the vascular anatomy and vascular diameters, particularly in a situation where repeated measurements demand that identical measurement sites are guaranteed.

The alternative methodology described in this report will overcome these problem areas. The shunt volume flow rate will be assessed before, during, and after surgery from the difference of the bilaterally measured subclavian artery flow rates. The vascular diameters at these sites can be measured with sufficient reliability, and the flow profiles can be assumed to be laminar. During surgery, with duplex scan monitoring, the shunt flow rate will be reduced with an appropriate surgical technique (eg, banding) until the peripheral perfusion normalizes. Duplex sonography will guarantee that the resulting shunt flow rate is still sufficiently high to allow for hemodialysis but to prevent thrombotic complications. Also, duplex scan control shall warrant that an inappropriately high shunt flow may lead to cardiac overload, particularly in patients with a preexisting cardiac problem.

With brachiocephalic shunts, the normalization of the peripheral perfusion can be easily followed by the reoccurrence of peripheral pulses. However, the mere focus on the recurrence of the pulses is not sufficient because this may occur at critically low or high shunt flow rates. With distal fistulas and because of the proximity to the operation site, the intraoperative interpretation of finger pulse tracings may be more appropriate.[10]

The described method can be equally used in patients with DASS and in patients with shunt flow-related cardiac failure. An additional practical advantage of the method is that no measurements close to the operation field are required.

Because the technique can be easily applied by a skilled vascular specialist, the authors believe that it may be of value in significantly reducing the incidence of thrombotic complications after banding surgery and that the necessity for arterial ligation bypass procedures may become the true exception. However, further data are required before finally judging the method.

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