



ELSEVIER



# Preoperative Mapping for Haemodialysis Access Surgery with CO<sub>2</sub> Venography of the Upper Limb

S. Heye<sup>a,\*</sup>, I. Fourneau<sup>b</sup>, G. Maleux<sup>a</sup>, K. Claes<sup>c</sup>, D. Kuypers<sup>c</sup>, R. Oyen<sup>a</sup>

<sup>a</sup> Department of Radiology, University Hospitals Leuven, Herestraat 49, B-3000 Leuven, Belgium

<sup>b</sup> Department of Vascular Surgery, University Hospitals Leuven, Herestraat 49, B-3000 Leuven, Belgium

<sup>c</sup> Department of Nephrology, University Hospitals Leuven, Herestraat 49, B-3000 Leuven, Belgium

Submitted 5 August 2009; accepted 22 November 2009

Available online 18 January 2010

## KEYWORDS

Arteriovenous fistula;  
Carbon dioxide;  
Venography

**Abstract Objective:** This study aims to evaluate the impact of CO<sub>2</sub> venography on the planning and outcome of native arteriovenous fistula (AVF) creation.

**Methods:** Records of patients who underwent CO<sub>2</sub> venography prior to access surgery between January 2000 and December 2008 were reviewed. CO<sub>2</sub> venography was performed selectively in chronic kidney disease (CKD) in stage IV–V patients without suitable veins on clinical examination. Findings at surgery were compared to CO<sub>2</sub> venography images. Patency of AVFs was analysed by the Kaplan–Meier method. Differences in outcome of maturation were compared using a  $\chi^2$  test.

**Results:** A total of 209 CO<sub>2</sub> venograms were obtained in 116 patients. In 89 patients (77%), 101 AVFs (21 forearm AVF (21%) and 80 elbow AVF (79%)) were created. Surgical findings corresponded with CO<sub>2</sub> venography findings in 90% of patients. In 10 cases (10%), access was created at the elbow despite a patent forearm cephalic vein on CO<sub>2</sub> venography ( $n = 2$ ) or access was attempted with a vein which was thought to be unsuitable on CO<sub>2</sub> venography ( $n = 8$ ). Maturation rate of the latter was 50% (4/8) vs. 88% (80/91) for AVFs created with veins considered usable ( $P = 0.004$ ). The overall maturation rate was 84% with 1-year primary, assisted primary and secondary patency rates of 63%, 70% and 71%, respectively.

**Conclusion:** CO<sub>2</sub> venography is a useful tool for venous mapping prior to vascular access surgery, resulting in an overall maturation rate of 84% and good patency rates.

© 2009 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

Preoperative venous mapping is useful to improve the success of creating haemodialysis native arteriovenous fistulas (AVF). This technique enables the identification of

suitable veins which are impalpable or invisible on physical examination.<sup>1,2</sup> Preoperative ultrasound (US) and/or venography are the two most commonly used imaging modalities before haemodialysis vascular access surgery.<sup>3,4</sup> US is non-invasive and allows evaluation of both arteries and veins in the upper limb, but central veins are only indirectly assessable. Conventional venography with iodine

\* Corresponding author. Tel.: +32 16 343782; fax: +32 16 343765.  
E-mail address: sam.hey@uzleuven.be (S. Heye).

as contrast medium offers direct imaging of both peripheral and central veins in the upper limb.<sup>1</sup>

The major disadvantage of conventional venography is the use of iodinated contrast medium and the potential risk of contrast-induced nephropathy (CIN), especially in patients with end-stage renal disease who do not yet require haemodialysis.<sup>1,5</sup> It is also reported that in patients with advanced chronic kidney disease (CKD stage 4) and candidates for haemodialysis, an AVF should be created as soon as possible, preferably at least 6 months before the anticipated start of haemodialysis treatment to allow enough time for maturation, or for potential further interventions that may be required to ensure appropriate venous access when dialysis is initiated.<sup>6,7</sup>

A safe alternative for conventional contrast-enhanced venography is carbon dioxide (CO<sub>2</sub>) venography, which demonstrated a specificity of 97% and a sensitivity of 85% in assessing upper limb vein patency and stenosis in one series.<sup>5</sup>

The purpose of this retrospective study was to evaluate the impact of CO<sub>2</sub> venography on the planning and outcome of haemodialysis AVF creation.

## Methods

The local Ethics Committee waived informed consent and approved this retrospective study.

The medical and radiological records of all patients who underwent CO<sub>2</sub> venography prior to haemodialysis access surgery between January 2000 and December 2008 were reviewed. Patients with CKD stage 4 or 5 were referred to an experienced vascular surgeon (I.F.) when haemodialysis was considered the preferred renal replacement therapy. The decision to undertake venography was made by the vascular surgeon when clinical examination with and without tourniquet failed to show a vein suitable for vascular access creation or when central venous stenosis had to be excluded because of a history of central venous catheters or because venous collaterals on the chest wall were found on physical examination. In all patients, the upper limb arterial system was considered suitable for vascular access on physical examination (good arterial pulse, negative Allen's test and no significant difference in blood pressure measured in both arms). The decision to undertake bilateral or unilateral venography was made based on surgeon and patient preferences, clinical findings and medical history.

CO<sub>2</sub> was chosen as the contrast medium if the patient had residual renal function and/or recovery of renal function was expected. Patients already receiving haemodialysis, but with residual kidney function, were also included in the study. No preoperative duplex US was used at the time.

## Venography technique

After placement of a 21- or 20-gauge intravenous access needle in a superficial vein at the dorsum of the hand, 0.1 mg of nitroglycerine was injected prior to the injection of CO<sub>2</sub> to obtain venous dilatation and to prevent vasospasm. Digital subtraction angiography (DSA) images from

the wrist up to the chest were obtained with the patient's arm in the anatomical position, when possible. Between January 2000 and January 2008, DSA was performed in an interventional suite with a movable C-arm equipped with an under-table X-ray tube unit and an image intensifier above the patient (Polystar, Siemens Medical Solutions and Angiostar, Siemens Medical Solutions, Erlangen, Germany). From February 2008 on, DSA procedures were performed in an angiosuite with a flat-panel detector system (Axiom Artis dTA, Siemens Medical Solutions, Erlangen, Germany). When possible (i.e., no motion artefacts during DSA), image stacking post-processing software was used. A tourniquet was not applied routinely.

CO<sub>2</sub> venograms were obtained using either a CO<sub>2</sub> injector (CO<sub>2</sub>nnect Autoflush set, Angiodynamics, Queensbury, NY, USA) or a hand-held commercially available 100 ml syringe connected with a three way stopcock to a CO<sub>2</sub>-containing cylinder on one side and to the patient's venous access cannula on the other side (CO<sub>2</sub> Angioset, Optimed, Ettlingen, Germany). The syringe has adjustable settings in 20 ml steps.

In case of the CO<sub>2</sub> injector, the injection rate was set to 10 ml s<sup>-1</sup>. The injected volume was always 10 ml for the first injection to accustom the patient to the resulting sensation. The following injection volumes varied between 10 ml and 30 ml for opacification of the forearm and upper arm veins and between 30 ml and 50 ml for the central veins. DSA images with the CO<sub>2</sub> syringe were made with an injected volume of 20 ml for the arm veins and 20 ml or 40 ml for central vein opacification.

## Imaging and data analysis

The CO<sub>2</sub> venograms were reviewed by one radiologist (S.H.). Both cephalic and basilic vein in forearm and upper arm as well as the central veins were evaluated on whether they could be used in a haemodialysis AVF. A patent cephalic or basilic vein without stenosis and with a diameter of at least 2 mm in the forearm or upper arm was considered usable, although the basilic vein in the forearm was not routinely used as primary vascular access. The choice of access was made based on the results of the CO<sub>2</sub> venography, but in case of several possible choices, attempts were made to use the non-dominant arm over the dominant arm and a radiocephalic forearm AVF over an elbow AVF. When several choices were possible for an elbow AVF, a brachial artery-median vein AVF was preferably used over a brachiocephalic AVF and a brachiocephalic over a brachio basilic AVF when the choices were equivalent. Central vein stenosis or occlusion precluded an upper limb usable for haemodialysis access creation.

## Definitions

Primary failure was defined as an AVF that was abandoned without cannulation ever being successful (AVF considered impossible to cannulate by the haemodialysis nurse, vascular surgeon and/or nephrologist) or being requiring further surgical intervention. The standards for reporting by Sidawy et al.<sup>8</sup> were used for the definition of primary, primary assisted and secondary patency. Primary patency

was defined as the interval from the time of AVF creation until any intervention to maintain or re-establish patency, AVF thrombosis or the time of measurement of patency. Primary-assisted patency was defined as the time interval between AVF creation and abandonment or the time of measurement of patency including intervening (surgical or endovascular) manipulations to maintain patency. The definition of secondary patency was the time interval between access creation until abandonment or the time of measurement of patency including interventions to restore patency of thrombosed access. Patency was evaluated by clinical examination and duplex US.

### Statistical analysis

Patency of the AVF created was evaluated using the Kaplan–Meier method. Data analysis was censored for patients who died with a patent access or underwent renal transplantation before reaching the follow-up end points of 3 months, 6 months, 1 year, 2 years, 3 years and 4 years after haemodialysis access creation. Differences in outcome of maturation were calculated with the use of  $\chi^2$  test. A *p*-value of 0.05 or less was considered significant. Analyses have been performed using SAS software, version 9.2 of the SAS System for Windows (SAS Institute Inc., Cary, NC, USA).

### Results

During the study period, CO<sub>2</sub> venography prior to vascular access surgery was performed in 141 patients. Twenty-five patients were excluded because additional images with

iodinated contrast were made according to another study protocol (*n* = 22) or because the images were lost (*n* = 3), resulting in 116 patients (46 men, 70 women) available for analysis (Table 1). Twenty-five patients (22%) were already undergoing haemodialysis with either a non-tunneled (*n* = 13) or a tunneled haemodialysis catheter (*n* = 12).

In 23 patients (20%), CO<sub>2</sub> venography of one upper limb (right/left: 12/11) was performed; the remaining 93 patients (80%) underwent bilateral CO<sub>2</sub> venography, resulting in a total of 209 upper limb CO<sub>2</sub> venograms. Indications for unilateral venography were a failing prior AVF in either the same (*n* = 3) or contralateral (*n* = 5) arm, preference for the non-dominant arm (*n* = 5), known contralateral central vein thrombosis (*n* = 2), port catheter in the contralateral arm (*n* = 2), contralateral spasm after cerebrovascular accident (*n* = 1), lymphoedema after mastectomy and lymphadenectomy (*n* = 3) and coronary artery bypass graft using the left internal mammary artery (*n* = 2). Technical success was 100%. No procedural complications were seen and injection of CO<sub>2</sub> was well tolerated by all patients.

A central venous stenosis greater than 50% or a central vein occlusion was present in 15 venograms (7%). More than 50% of the stenoses were located in the subclavian vein (*n* = 8). Central vein occlusion was found either in the subclavian vein (*n* = 2), the innominate vein (*n* = 3) or both subclavian and innominate veins (*n* = 2).

Of the 209 CO<sub>2</sub> venograms, 57 cephalic veins in the forearm (27%) in 40 patients (35%) were considered suitable for access creation, as well as 48 basilic veins in the forearm (23%) in 38 patients (33%). Upper arm veins were more often seen and considered suitable based on CO<sub>2</sub> venography: 79 cephalic veins (38%) in 56 patients (48%) and 175 basilic veins (84%) in 106 patients (91%). A mean of 1.7 suitable veins per CO<sub>2</sub> venogram (359/209) were found.

Twenty-seven of the 116 patients (23%) did not receive a native AVF as haemodialysis access. Nine patients (8%) were considered unsuitable for AVF creation based on the CO<sub>2</sub> venograms. Six of these nine patients (67%) underwent a haemodialysis AV-graft (AVG) creation (five straight AVGs in the upper arm and one axillo-femoral AVG), and the remaining three patients were lost to follow-up. Another three patients (3%) continued haemodialysis through a tunneled cuffed catheter. Eight patients (7%) did not require vascular access in the end, because of partial renal function recovery or a stabilisation of renal function. Two patients had renal transplantation during the interval between CO<sub>2</sub> venography and planned vascular access surgery. Four patients (4%) eventually went on to peritoneal dialysis instead of haemodialysis and one patient refused access surgery.

In the remaining 89 patients (77%), a native AVF was created. Twelve of them (14%) received a second AVF based on the existing CO<sub>2</sub> venography, resulting in a total of 101 AVFs of which 21 forearm AVFs (21%) and 80 elbow AVFs (79%) are summarised in Table 2. In nine of the latter 12 patients, a new access was created because of non-maturation. The remaining three patients had a matured AVF that thrombosed after a mean of 180 days (range: 50–335 days). One of them had already undergone haemodialysis through this AVF before thrombosis; the other two were not yet haemodialysis dependent.

**Table 1** Demographics.

Total patient number	<i>N</i> = 116 (%)
Gender	
M/F	46/70 (39.7/60.3)
Age (y)	
Mean	58
Range	2–87
Aetiology CKD stage V	
Diabetes mellitus	23 (19.8)
Renal vascular disease	17 (14.7)
Glomerular disease	19 (16.4)
Tubulo-interstitial disease	21 (18.1)
/obstructive	
Autosomal dominant polycystic kidney disease	3 (2.59)
Calcineurin-inhibitor associated nephrotoxicity	10 (8.6)
Other/unknown	23 (19.8)
Comorbidities	
Arterial hypertension	67 (57.8)
Diabetes mellitus	40 (34.5)
Prior AVF	26 (22.4)
Already receiving haemodialysis	
Tunneled catheter	12 (10.3)
Non-tunneled catheter	13 (11.2)

**Table 2** Native AVF creation.

Total AVF number	<i>N</i> = 101 (%)
Forearm	
Radiocephalic	20 (19.8)
Ulnobasilic	1 (0.99)
Upper arm	
Brachial artery – median cubital vein	22 (21.8)
Brachiocephalic	33 (32.7)
Non-transposed brachiobasilic	14 (13.9)
Transposed brachiobasilic	11 (10.9)

Vascular access surgery corresponded with the findings of CO<sub>2</sub> venography in 90% of cases (91/101). In the remaining 10 cases, vascular access was created at the elbow although a patent cephalic vein in the forearm was seen on CO<sub>2</sub> venography (*n* = 2) or access creation was attempted with a vein that was considered not suitable on CO<sub>2</sub> venography (*n* = 8). The maturation rate of the latter eight AVFs was 50% (4/8) vs. 88% (80/91) for the AVF created with veins considered suitable for access surgery on CO<sub>2</sub> venography (*P* = 0.004).

Ten patients were lost to follow-up after access creation because of further therapy in other dialysis units. In total, primary failure or non-maturation of the AVF was seen in 15 of the 91 AVFs created (17%). This occurred in seven radiocephalic AVFs (35% of all radiocephalic AVFs), one ulno-basilic AVF (100%), four brachiocephalic AVFs (12.1%), two brachiobasilic AVFs (8%) and one brachial artery-median vein fistula.

One-year primary, assisted primary and secondary patency rates for the 91 AVFs were calculated and was 63% (95% confidence interval (CI): 52%; 72%), 70% (95% CI: 59%; 78%) and 71% (95% CI: 60%; 79%), respectively (Table 3, Figs. 1–3).

Eighteen of the 26 patients with previous native haemodialysis fistulas (69%) received an AVF after CO<sub>2</sub> venography. Ten of them (39%) had had one AVF in the past and eight (31%) had had two previous AVFs. One patient was lost to follow-up; of the remaining 17 patients, non-maturation occurred in three patients (18%). Maturation rates between patients with a prior AVF and patients with a first-access AVF were not significantly different (82% vs. 84% respectively, *N.S.*).

## Discussion

Venography and venous US are commonly used imaging modalities for preoperative venous mapping to increase the prevalence of a native AVF as haemodialysis access.<sup>2,4</sup> Although the risk for CIN after conventional venography in patients with end-stage renal disease appears to be lower than initially thought if low doses of iodinated contrast material are used,<sup>4,9,10</sup> CO<sub>2</sub> venography was shown to be a safe alternative in one series.<sup>5</sup> This was confirmed in our series, where technical success was 100%, without complication, although potential bias could not be excluded given the retrospective nature of the study.

**Table 3** (A) Primary, assisted primary (B) and secondary (C) patency of the created AVF.

Patency (mo)	Survival	Lower limit of 95%CI	Upper limit of 95%CI
<b>A. Primary patency</b>			
1	86	77	91
3	78	68	85
6	71	60	79
10	64	53	73
12	63	52	72
24	50	39	60
36	44	32	55
48	40	28	52
<b>B. Assisted primary patency</b>			
1	86	77	92
3	79	69	86
6	74	64	82
10	71	60	79
12	70	59	78
24	61	49	70
36	59	47	69
48	55	42	67
<b>C. Secondary patency</b>			
1	86	77	92
3	79	69	86
6	76	65	83
10	72	61	80
12	71	60	79
24	62	50	72
36	60	48	70
48	56	43	68

In our series, preoperative venous mapping by CO<sub>2</sub> venography in patients without suitable veins on physical examination resulted in AVF access creation in 77% of patients. This is comparable to the study of Patel et al. where venography or a combination of venography and US was used.<sup>11</sup> However, this figure is lower than results reported in the study of Huber et al. where a native AVF was created in 90% of patients who underwent both US and invasive preoperative imaging following an algorithm.<sup>12</sup> Hyland et al. reported 75% of their patients received permanent access following preoperative venography (with iodine, CO<sub>2</sub> or a combination of both or gadolinium), but only half of them were AVFs.<sup>4</sup>

Although the number of suitable veins found on venography was comparable to the study of Hyland et al.<sup>4</sup> (1.7 veins per venogram vs. 1.9 veins per venogram), there were some differences in the vein type. The percentage of suitable basilic veins was higher both in the forearm and the upper arm (23% and 84%, respectively). However, this did not interfere substantially with the type of AVF that was created, since the incidence of brachiobasilic AVFs created (25%) was in the range of other studies (13–39%).<sup>11,12</sup> Twenty percent of the AVFs in our series were radiocephalic AVFs, which correlated well with the results of Patel et al. and Huber et al. both of whom reported that 22% of their procedures performed were radiocephalic AVF.<sup>11,12</sup>

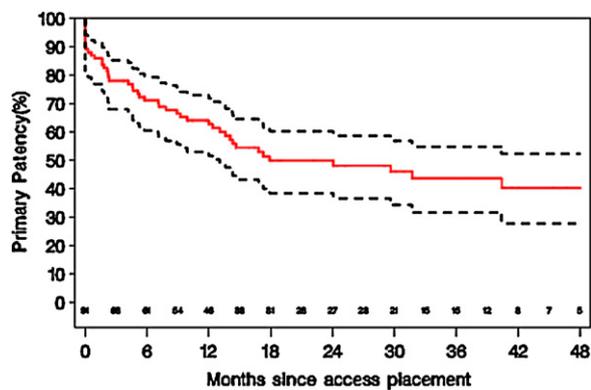


Figure 1 Primary patency of the matured AVF.

Biuckians et al. demonstrated a higher percentage of radiocephalic AVFs created (33%), but these were performed in patients without prior permanent access of whom 25% were already considered suitable for native AVF based on physical examination alone.<sup>13</sup> The fact that in our study as well as that of Hyland et al.,<sup>4</sup> usable veins were not identified by physical examination alone and that we encountered 26% of patients with prior AVF in our study might explain this difference. In all but two patients with prior arteriovenous access, at least one prior access was a radiocephalic AVF, reducing the possibility forming a radiocephalic AVF. The incidence of brachiocephalic AVF performed after preoperative imaging (33%) was also comparable to other studies, in which brachiocephalic AVF were created in approximately 35% of the patients.<sup>11,12</sup>

The prevalence of central venous stenosis/occlusion precluding access creation in this study (7%) was in the range of other studies of Hyland et al. (10%) and Huber et al. (8%).<sup>4,12</sup>

The site of access surgery was at the surgeon's discretion, based on clinical examination and CO<sub>2</sub> venography. Correlation between CO<sub>2</sub> venography findings and subsequent access surgery was high (90%), while Patel et al. reported a correlation of 98% between the preoperatively planned access and the actual procedure, using both US and venography.<sup>11</sup> In two patients, an AVF was created at the elbow (one brachiocephalic and one brachial–median vein AVF) while CO<sub>2</sub> venography demonstrated a patent cephalic vein in the forearm in elderly patients where early dialysis

was required. The higher maturation rate of brachiocephalic AVF over radiocephalic AVF in the series of Ngyen et al. and Miller et al. would favour this approach in this subset of patients in whom preservation of the veins as much as possible may not be the main issue given their age.<sup>14,15</sup> However, this remains controversial as a study of Weale et al. showed that age did not affect usability or patency of either radiocephalic or brachiocephalic AVFs.<sup>16</sup>

In general, non-maturation or primary failure of the AVF was seen in 17%, comparable to the study of Huber et al. and Snyder et al. where an AVF maturation rate of 84% was found,<sup>12,17</sup> and slightly higher to the results of Elsharawy et al. who reported early failure in 8% of patients who have had access creation following preoperative venography.<sup>2</sup> Allon et al. showed an overall primary access failure of 46% for AVF in his series of access placement after sonographic mapping.<sup>3</sup> Patel et al. compared native fistulas created after preoperative duplex US and venography with access fistulas that were created before the liberal use of preoperative venous mapping and found that despite the increase in native fistula creation, functional maturation rate decreased from 73% to 57%.<sup>11</sup> They reported that an AVF created on the basis of vein identification at duplex US was inferior to one created based on a vein that was identified at physical examination only,<sup>11</sup> suggesting that the quality of the vein identified solely by vascular mapping might be inferior to the quality of a vein that could be adequately evaluated at physical examination (in a non-obese patient).

Maturation rates between patients with a prior AVF and patients with a first-access AVF were not significantly different and were higher than the 64% primary success rate in the study of Wang et al. who reviewed the outcome of AVF as first vascular access without preoperative vascular mapping.<sup>18</sup>

The primary patency rates were comparable to other studies on vascular mapping, where 1-year primary patency ranged between 44% and 84% for AVF created after preoperative US.<sup>17,19</sup> The percentage of forearm AVF was higher in these studies (between 25% and 85% vs. 20%), but in the majority of these studies preoperative mapping was done routinely in all patients and not selectively in those patients who were considered to have no suitable veins on physical examination. Even though Kidney Disease Outcome Quality Initiative (KDOQI) guidelines suggests vascular mapping in every patient,<sup>6</sup> this may not be necessary in patients with favourable physical examination findings.<sup>20,21</sup>

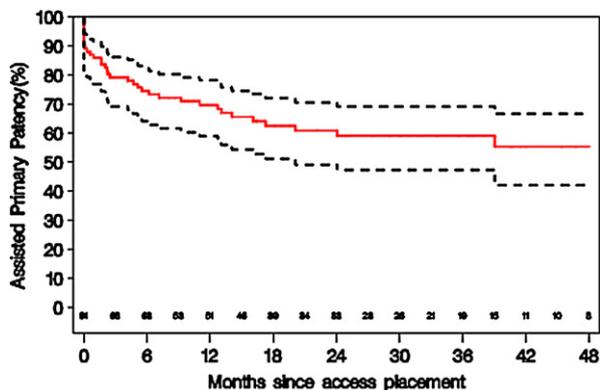


Figure 2 Assisted primary patency of the matured AVF.

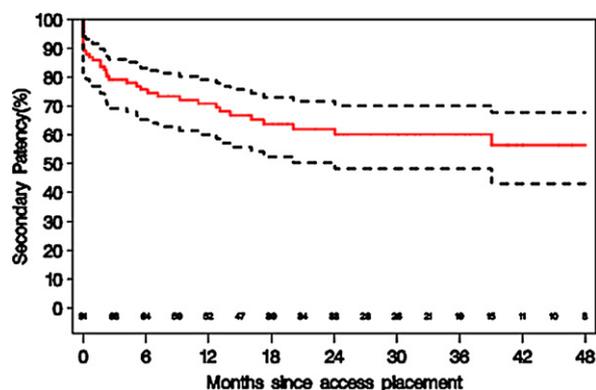


Figure 3 Secondary patency of the matured AVF.

Patel et al. noted that including patients with excellent veins on physical examination in a routine preoperative vein mapping protocol with duplex US would artificially increase the results.<sup>11</sup>

The main limitation of this study is the fact that it was a single centre, retrospective study with a relatively small number of patients included.

In conclusion, CO<sub>2</sub> venography is a useful tool for venous mapping prior to vascular access surgery, resulting in an overall maturation rate of 84% and patency rates comparable to other studies on AVF creation after preoperative vascular US.

## Conflict of Interest

None.

## Financial disclosure

None.

## References

- Asif A, Ravani P, Roy-Chaudhury P, Spergel LM, Besarab A. Vascular mapping techniques: advantages and disadvantages. *J Nephrol* 2007;**20**:299–303.
- Elsharawy MA, Moghazy KM. Impact of pre-operative venography on the planning and outcome of vascular access for haemodialysis patients. *J Vasc Access* 2006;**7**:123–8.
- Allon M, Lockhart ME, Lilly RZ, Gallichio MH, Young CJ, Barker J, et al. Effect of preoperative sonographic mapping on vascular access in haemodialysis patients. *Kidney Int* 2001;**60**:2013–20.
- Hyland K, Cohen RM, Kwak A, Schlansky-Goldberg RD, Soulen MC, Patel AA, et al. Preoperative mapping venography in patients who require haemodialysis access: imaging findings and contribution to management. *Radiology* 2008;**19**:1027–33.
- Heye S, Maleux G, Marchal GJ. Upper extremity venography: CO<sub>2</sub> versus iodinated contrast material. *Radiology* 2006;**241**:291–7.
- National Kidney Foundation. NKF-K/DOQI clinical practice guidelines and clinical practice recommendations for 2006 updates: haemodialysis adequacy, peritoneal dialysis adequacy and vascular access. *Am J Kidney Dis* 2006;**48**(Suppl. 1):S188–S191.
- Sidawy AN, Spergel LM, Besarab A, Allon M, Jennings WC, Padberg Jr FT, et al. The society for vascular surgery. Clinical practice guidelines for the surgical placement and maintenance of arteriovenous haemodialysis access. *J Vasc Surg* 2008;**48**:25–25S.
- Sidawy AN, Gray R, Besarab A, Henry M, Ascher E, Silva Jr M, et al. Recommended standards for reports dealing with arteriovenous haemodialysis accesses. *J Vasc Surg* 2002;**35**:603–10.
- Asif A, Cherla G, Merrill D, Cipleu CD, Tawakol JB, Epstein DL, et al. Venous mapping using venography and the risk of radiocontrast-induced nephropathy. *Semin Dial* 2005;**18**:239–42.
- Kian K, Wyatt C, Schon D, Packer J, Vassalotti J, Mishler R. Safety of low-dose radiocontrast for interventional AV fistula salvage in stage 4 chronic kidney disease patients. *Kidney Int* 2006;**69**:1444–9.
- Patel ST, Hughes J, Mills Sr JL. Failure of arteriovenous fistula maturation: an unintended consequence of exceeding dialysis outcome initiative guidelines for haemodialysis access. *J Vasc Surg* 2003;**38**:439–45.
- Huber TS, Ozaki CK, Flynn TC, Lee WA, Berceli SA, Hirneise CM, et al. Prospective validation of an algorithm to maximize native arteriovenous fistulae for chronic haemodialysis access. *J Vasc Surg* 2002;**36**:452–9.
- Biuckians A, Scott EC, Meier GH, Panneton JM, Glickman MH. The natural history of autologous fistulas as first-time access in the KDOQI era. *J Vasc Surg* 2008;**47**:415–21.
- Ngyen TH, Bui TD, Gordon IL, Wilson SE. Functional patency of autogenous AV fistulas for haemodialysis. *J Vasc Access* 2007;**8**:275–80.
- Miller PE, Tolwani A, Luscly CP, Deierhoi MH, Bailey R, Redden DT, et al. Predictors of adequacy of arteriovenous fistulas in haemodialysis patients. *Kidney Int* 1999;**56**:275–80.
- Weale AR, Bevis P, Neary WD, Boyes S, Morgan JD, Lear PA, et al. Radiocephalic and brachiocephalic arteriovenous fistula outcomes in the elderly. *J Vasc Surg* 2008;**47**:144–50.
- Snyder DC, Clericuzio CP, Stringer A, May W. Comparison of outcomes of arteriovenous grafts and fistulas at a single veteran's affairs medical center. *Am J Surg* 2008;**196**:641–6.
- Wang W, Murphy B, Yilmaz S, Tonelli M, MacRae J, Manns BJ. Comorbidities do not influence primary fistula success in incident haemodialysis patients: a prospective study. *Clin J Am Soc Nephrol* 2008;**3**:78–84.
- Ferring M, Henderson J, Wilmsink A, Smith S. Vascular ultrasound for the pre-operative evaluation prior to arteriovenous fistula formation for haemodialysis: review of the evidence. *Nephrol Dial Transplant* 2008;**23**:1809–15.
- Wells AC, Fernando B, Butler A, Huguet E, Bradley JA, Pettigrew GJ. Selective use of ultrasonographic vascular mapping in the assessment of patients before haemodialysis access surgery. *Br J Surg* 2005;**92**:1439–43.
- Nursal TZ, Oguzkurt L, Tercan F, Torer N, Noyan T, Karakayali H, et al. Is routine preoperative ultrasonographic mapping for arteriovenous fistula creation necessary in patients with favorable physical examination findings? Results of a randomized controlled trial. *World J Surg* 2006;**30**:1100–7.