

## Spanish Clinical Guidelines on Vascular Access for Haemodialysis

### ANNEXES TO CHAPTER 4

**Clinical Question X. How reliable is Doppler ultrasound in determining blood flow in the arteriovenous fistula in comparison to dilution screening methods?**

No studies were found which, comparing these two diagnostic techniques, provided information on the following clinical outcomes relevant to the above question: access survival, access patency, thrombosis, arteriovenous fistula, adverse effects and mortality.

The available studies mainly provide information on the performance of different techniques (ROC curve), or the consistency between the results of the different studies.

**Doppler ultrasound compared to ultrasound dilution**

The studies comparing Doppler ultrasonography and ultrasound dilution were published over a decade ago (Weitzel 2001; Schwarz 2003; Lopot 2003; Lin 2004).

The Weitzel study (2001) evaluated the comparability of the flow measurements by Doppler ultrasound with those made by ultrasound dilution in 24 patients with prosthetic grafts. They also assessed the reproducibility of the Doppler technique in 54 pairs of measurements.

The variations in the Doppler measurements were 4% for accesses with flow of less than 800 ml/min (n=17), 6% for accesses with flow of 801 to 1600 ml/min (n=22), and 11% for accesses with flow greater than 1600 ml/min (n=15).

The mean coefficient of variation of the measurement was 7% for Doppler compared to 5% for ultrasound dilution.

The coefficients of correlation (r) between the access flow measurements by Doppler and by ultrasound dilution were 0.79 (n=24, p<0.0001), 0.84 for accesses with flow of less than 2,000 ml/min (n=20, p<0.0001), and 0.91 for accesses with flow of less than 1,600 ml/min (n=18, p<0.0001).

They conclude that Doppler ultrasound provides reproducible measurements of access flow volume which correlate with the measurements made by ultrasound dilution. The Doppler method is dependent on the pump-induced change in access Doppler signal and is therefore inherently more accurate and reproducible at lower access blood flow rates. This method seems capable of determining access flow rates in the clinically useful range.

**Low quality**

The Schwarz study (2003) compared these two techniques, using fistulography as gold standard. They evaluated 59 haemodialysis patients with forearm fistulae who underwent all three measurements in the following order: ultrasound dilution technique, colour Doppler ultrasonography, and fistulography. Access stenosis was diagnosed in 41 patients who subsequently underwent percutaneous angioplasty

The performance of the two techniques, evaluated by ROC curve, was similar: average areas under the curve were 0.79 (95% CI: 0.66 to 0.91) for ultrasound dilution and 0.80 (95% CI:

**Low quality**

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<p>0.65 to 0.94) for Doppler ultrasound. The correlation between blood flow rates measured by ultrasound dilution and measured by colour Doppler ultrasound was 0.37 (Spearman's rho = 0.004).</p> <p>The optimal cut-off calculated for the prediction of stenosis was 465 ml/min for ultrasound dilution and 390 ml/min for Doppler ultrasound.</p> <p>Both ultrasound techniques were valid for predicting access stenosis (p&lt;0.01).</p> <p>Restenosis occurred in 13 patients within the first 6 months after percutaneous angioplasty. Blood flow after the percutaneous angioplasty, measured by ultrasound dilution, was significantly lower in these 13 patients compared with the other 21 patients.</p> <p>They concluded that blood flow monitoring of haemodialysis access by ultrasound techniques provides a reasonable prediction of access stenosis and restenosis.</p>	
<p>The Lopot study (2003) provides data on comparison of measurements by duplex Doppler and ultrasound dilution, used as the gold standard, in 27 patients. They found good correlation between the two techniques (r=0.8691).</p>	<b>Low quality</b>
<p>The Lin study (2004) compared the reproducibility and correlation between Qa measurements using a variable-pump flow-based Doppler ultrasound method combined with spectral analysis of duplex Doppler imaging (VPFDUM), with the ultrasound dilution method, and the conventional Doppler ultrasound method, in 73 patients on haemodialysis, 70 with fistula and 3 with graft.</p> <p>The mean value of Qa by VPFDUM (870.8 ± 412.0 ml/min) was very similar to that of the ultrasound dilution measurements (868.6 ± 417.9 ml/min) but higher than that of the conventional Doppler measurements (685.1 ± 303.6 ml/min; p&lt;0.005).</p> <p>The mean coefficients of variation were similar by VPFDUM (1.6%) and ultrasound dilution (1.4%) but lower than by conventional Doppler (6.8%, p&lt;0.01).</p> <p>The correlation coefficient and the intra-class correlation coefficient of repeated Qa measurements by VPFDUM (0.985 and 0.993, p&lt;0.001) were also similar to those by ultrasound dilution (0.992 and 0.995, p&lt;0.001), but slightly higher than those by conventional Doppler (0.917 and 0.948, p&lt;0.005).</p> <p>The reproducibility of the VPFDUM technique (r=0.98, p&lt;0.0001) and the correlation between VPFDUM and ultrasound dilution (r=0.99, p&lt;0.0001) in Qa measurements was good.</p> <p>Unassisted vascular access patency at 6 months was significantly poorer in patients with Qa &lt;500 ml/min than those with Qa &gt;500 ml/min (13.6% vs 92.2%, p&lt;0.0001).</p> <p>They concluded that the VPFDUM technique is a non-invasive, accurate, and reliable procedure for Qa measurement and prediction of the prognosis of vascular access in haemodialysis patients.</p>	<b>Low quality</b>

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<b>Doppler ultrasound compared to thermodilution</b>	
<p>Fontseré (2013) compares application of the thermodilution (TD) method for measuring Qa to Doppler ultrasound (DU), used as <i>gold standard</i>, in a cross-sectional study conducted in 64 patients (41 male) in haemodialysis programmes; mean age was 59.9 years, 54 had AVF and 10 had polytetrafluoroethylene (PTFE) grafts.</p> <p>The reference Qa was determined by Doppler ultrasound in the humeral artery for arteriovenous fistulae and in the area of arterial puncture for grafts. Bland-Altman and intraclass correlation coefficients (ICC) were used to study consistency.</p> <p>The Qa obtained by Doppler ultrasound was <math>1426 \pm 753</math> ml/min for AVF and <math>1186 \pm 789</math> ml/min for PTFE grafts. The values obtained by thermodilution were AVF <math>1372 \pm 770</math> (bias 54.6; ICC 0.923) and PTFE <math>1176 \pm 758</math> (bias 10.2; ICC 0.992).</p> <p>In the subgroup of 28 patients with side-to-end radiocephalic AVF, the Qa obtained by Doppler ultrasound was <math>1232 \pm 767</math> ml/min. Qa values in the radial artery: 942 (ICC 0.805); radial- ulnar artery: 1103 (ICC 0.973); cephalic vein: 788 (ICC 0.772), and with thermodilution: 1026 (ICC 0.971).</p> <p>They detected 5 cases of significant stenosis; Kt post-revascularisation with angioplasty balloon catheter: 79 litres (61; p=0.043) and thermodilution-Qa post-angioplasty was 895 ml/min (663; p=0.043).</p> <p>They concluded that thermodilution is a useful automated indirect method for measuring Qa. In the subgroup of patients with radiocephalic AVF, flow measurements obtained in the radial and ulnar arteries were more accurate. However, thermodilution also had an excellent correlation with the brachial artery.</p>	<b>Low quality</b>
<p>Sacqu��p��e (2012) compared the correlation of measurements made with both methods in 15 patients, 14 with fistula and one with prosthetic graft. Eight were female and seven male, mean age was 61, and they had been on haemodialysis a median of six years.</p> <p>The average vascular access flow was <math>1088 \pm 576</math> l/min measured by Doppler and <math>1094 \pm 570</math> measured by thermodilution.</p> <p>Comparison of the access flows obtained with the two techniques showed a strong linear relationship. The average time taken for a measurement was six minutes for Doppler and five minutes for thermodilution. No adverse effects were detected in the study.</p> <p>They concluded that thermodilution is fast, economical and can be performed during the haemodialysis session by the nurse.</p>	<b>Low quality</b>
<p>Heerwagen (2011) compared the clinical performance of catheter-based thermodilution and Doppler ultrasound of the brachial artery for the measurements of blood flow during vascular access procedures.</p> <p>Thirty patients with arteriovenous fistulae who underwent 46 interventions had access blood flow measured before and after every procedure using thermodilution and Doppler ultrasound, which were compared to the reference method of ultrasound dilution. Thermodilution and Doppler were performed during the endovascular procedures while flow by ultrasound</p>	<b>Low quality</b>

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<p>dilution was determined within three days of the procedure. The methods were compared by regression analysis.</p> <p>Failure to position the thermodilution catheter correctly was observed in 8 out of 46 (17%) pre-intervention measurements. Post-intervention measurements and Doppler ultrasound measurements were feasible in all patients.</p> <p>The average level of agreement was good when comparing the catheter-based thermodilution measurement to the ultrasound dilution measurement. However, blood flow by ultrasound dilution may differ from blood flow by thermodilution by <math>\pm 130</math> ml/min (<math>\pm 22\%</math>) at a flow level of 600 ml/min.</p> <p>Results from Doppler ultrasound showed a moderate level of agreement on average when compared to ultrasound dilution. Blood flow measured by ultrasound dilution may differ from blood flow measured by Doppler ultrasound by <math>\pm 160</math> ml/min (<math>\pm 27\%</math>) at a flow level of 600 ml/min.</p> <p>No systematic bias was detected by either method.</p> <p>They conclude that on average, results from catheter-based thermodilution were more in agreement with results from the ultrasound dilution technique than results from Doppler ultrasound.</p> <p>However, considering the cost and the high technical failure rate of the thermodilution system, they recommend the use of Doppler ultrasound.</p>	
<p>The Lopot study (2003) provides data on comparison of measurements by thermodilution and ultrasound dilution, used as the gold standard, in 54 patients. They found good correlation between the two techniques (<math>r=0.9543</math>).</p>	<b>Low quality</b>
<b>Summary of evidence</b>	
<p>No studies were found comparing the clinical outcomes of using different access flow measuring techniques (access survival, access patency, thrombosis, arteriovenous fistula, adverse effects and mortality).</p>	<b>Low quality</b>
<p>Comparator studies of access flow measurements show a high degree of concordance between ultrasound dilution and Doppler ultrasonography, and between ultrasound dilution and thermodilution.</p>	<b>Low quality</b>
<p><b>Patients' values and preferences</b>  <i>No relevant studies related to this aspect have been identified.</i></p>	
<p><b>Use of resources and costs</b>  <i>No relevant studies related to this aspect have been identified.</i></p>	

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<b>Recommendations [Proposal]</b>	
<b>Weak</b>	We suggest using ultrasound dilution, or Doppler ultrasound or thermodilution for determining vascular access flow (Qa).
<b>References</b>	
<p>Fontseré N, Mestres G, Barrufet M, Burrel M, Vera M, Arias M, Masso E, Cases A, Maduell F, Campistol JM. Practical utility of thermodilution versus doppler ultrasound to measure hemodialysis blood access flow. <i>Nefrologia</i>. 2013; 33(3):325-32.</p> <p>Heerwagen ST, Hansen MA, Schroeder TV, Ladefoged SD, Lönn L. Blood flow measurements during hemodialysis vascular access interventions--catheter-based thermodilution or Doppler ultrasound? <i>J Vasc Access</i>. 2012 Apr-Jun; 13(2):145-51.</p> <p>Lin CC, Chang CF, Chiou HJ, Sun YC, Chiang SS, Lin MW, Lee PC, Yang WC. Variable pump flow-based Doppler ultrasound method: a novel approach to the measurement of access flow in hemodialysis patients. <i>J Am Soc Nephrol</i>. 2005 Jan; 16(1):229-36.</p> <p>Lopot F, Nejedlý B, Sulková S, Bláha J. Comparison of different techniques of hemodialysis vascular access flow evaluation. <i>J Vasc Access</i>. 2004 Jan-Mar; 5(1):25-32.</p> <p>Lopot F, Nejedlý B, Sulková S, Bláha J. Comparison of different techniques of hemodialysis vascular access flow evaluation. <i>Int J Artif Organs</i>. 2003 Dec; 26(12):1056-63.</p> <p>Sacquépée M, Tivollier JM, Doussy Y, Quirin N, Valéry JC, Cantin JF. [Comparison of different techniques of hemodialysis vascular access flow evaluation: blood temperature monitoring thermodilution and doppler debimetry]. <i>Nephrol Ther</i>. 2012 Apr; 8(2):96-100.</p> <p>Schwarz C, Mitterbauer C, Boczula M, Maca T, Funovics M, Heinze G, Lorenz M, Kovarik J, Oberbauer R. Flow monitoring: performance characteristics of ultrasound dilution versus color Doppler ultrasound compared with fistulography. <i>Am J Kidney Dis</i>. 2003 Sep; 42(3):539-45.</p> <p>van Hooland S, Malik J. Hemodialysis vascular access ultrasonography: tips, tricks, pitfalls and a quiz. <i>J Vasc Access</i>. 2010 Oct-Dec;11(4):255-62.</p> <p>Weitzel WF, Rubin JM, Leavey SF, Swartz RD, Dhingra RK, Messana JM. Analysis of variable flow Doppler hemodialysis access flow measurements and comparison with ultrasound dilution. <i>Am J Kidney Dis</i>. 2001 Nov; 38(5):935-40.</p>	

**Table 1. STUDIES EXCLUDED**

<b>Study</b>	<b>Cause for exclusion</b>
Hooland 2010	Does not compare different techniques. Article on recommendations for use of Doppler ultrasound.
Lopot 2004	Identical to Lopot 2003, but published in a different journal.