1995 Krivitski NM, Kidney Int.  
**Theory and validation of access flow measurement by dilution technique during hemodialysis.**  
New method introduced to measure access flow during dialysis. Measurements tracked a calibrated inline flow sensor within 3.25 +/- 0.34%; repeatable within 3%. Data showed that access flow can be accurately measured by ultrasound dilution.

1996 Bosman PJ et al, JASN  
**Access Flow Measurements in Hemodialysis Patients: In Vivo Validation of an Ultrasound Dilution Technique. (N=46)**  
“Measurements correlated well with flow rates determined by magnetic resonance angiography and by a technique based on intra-access flow-pressure curves. Access flow can be measured easily, noninvasively, and reliably by the ultrasound dilution device. The method requires little investment in time making it superior to other methods.”

1997 Gleed RD et al, NDT  
**Validation in the Sheep of An Ultrasound Dilution Technique for Haemodialysis Graft Flow.**  
Over a 10-fold range, 120-1260 ml/min, graft flow measured by ultrasound velocity dilution agreed well with graft flow measured directly with a scatter of 76 ml/min about the regression line. Ultrasound velocity dilution provides a method for measuring flow in the graft accurate enough for clinical evaluation of patients on dialysis.

1997 May et al, Kidney Int.  
**Predictive measures of vascular access thrombosis.**  
Three-center study of 170 patients over six months. “The blood flow by Dilution (for grafts) was the best predictor of thrombosis within the subsequent three months. Multivariate analysis showed a significantly increasing risk of thrombosis with decreasing access blood flow.”

**Prospective Study: Changes in access flow over time predicts vascular access thrombosis.**  
There is a 13.6-fold increase in the relative risk of thrombosis for accesses with more than 35% decrease in vascular access blood flow. Study prospectively determined that measurement of blood flow plays an important role in evaluation and detection of PTFE grafts at higher risk of thrombosis.

1998 Wang E et al, ASAIO J  
**Predictive Value of Access Blood Flow in Detecting Access Thrombosis.**  
Repeated measurements of access flow have the potential to predict future access failure in PTFE grafts.

1999 Sands JJ et al, ASAIO J  
**Intervention Based on Monthly Monitoring Decreases Hemodialysis Access Thrombosis. (N=103)**  
“We believe that monthly access flow measurement will ensure the lowest incidence of thrombosis and decrease the cost of access maintenance.”

**Hemodialysis arteriovenous access: detection of stenosis and response to treatment by vascular access blood flow.**  
“Sequential measurement of AV access flow is an acceptable means of both monitoring for the development of access stenoses and assessing response to therapy.”

**Vascular access blood flow monitoring reduces access morbidity and costs. (N=132)**  
“Vascular access blood flow monitoring along with preventative interventions should be the standard of care in chronic hemodialysis patients... the comprehensive cost is markedly reduced due to the decreased number of hospitalizations, catheters placed, missed treatments, and surgical interventions.”
Vascular Access Surveillance Bibliography cont.

2001 Smits JH et al, Kidney Int

Graft surveillance: venous pressure, access flow, or the combination?

Data demonstrate that standardized monitoring of venous pressure or access flow or the combination and subsequent corrective intervention can reduce thrombosis rate in grafts to below the 0.5 patient per year (NKF-DOQI) although it was noted that VP does not detect inflow stenosis.

2001 Goldstein SL et al, Kidney Int

Ultrasound Dilution Evaluation of Pediatric Hemodialysis Vascular Access.

The first study to evaluate the accuracy of ultrasound dilution predicting hemodialysis access stenosis in pediatric hemodialysis population. Study supports the use of monthly measurement to prevent access thrombosis in children receiving hemodialysis.

2001 Murray B et al, Am J Kidney Dis


(49 PTAs on 32 grafts) This study, on the effectiveness of intervention rather than the accuracy of surveillance, indicates that preemptive angioplasty of graft stenoses results in an initial doubling of ABF, but the effect is temporary, with the average ABF decreasing to baseline values by 3 months. Study underscores the need for more investigation on intervention techniques and controls.

2002 Begin V et al, AJKD

Prospective Evaluation of the Intra-Access Flow of Recently Created Native Arteriovenous Fistulae. Study established separate baseline flows for radiocephalic and brachiocephalic fistulae.

“Newly created native AVFs have an initial Q(ac) that does not vary significantly during the first 6 months and may already be maximal at 6 weeks or at the time of first needle puncture in our hands.”

2002 Goldstein S et al, Kidney Int.

Proactive monitoring of pediatric hemodialysis vascular access: effects of ultrasound dilution on thrombosis rates.

Prompt referral for angioplasty of VA with corrected vascular access flow rates <650 mL/min/1.73 m2 leads to decreased thrombosis rates in children.

2003 Tessitore N et al, JASN

A prospective controlled trial on effect of PTA on functioning AV fistulae survival. (N=141)

This study shows that prophylactic PTA of stenosis n functioning forearm AVF improves access survival and decreases access-related morbidity, supporting the usefulness of preventive correction of stenosis before the development of access dysfunction. It also strongly supports surveillance program for early detection of stenosis.

2003 Lok C et al, NDT

Reducing vascular access morbidity: a comparative trial of two vascular access monitoring strategies.

3 year study, 300-400 patients. Low flow rates detected using Transonic monitoring were associated with increased thrombosis, while stenosis detected using Duplex ultrasonography was not a strong predictor of incipient thrombosis.

2003 Hoeben H et al, AJN

Vascular access surveillance: evaluation of combining dynamic venous pressure and vascular access blood flow measurements.

The measurement sensitivity of access flow surveillance in AVF’s was 73.3% and specificity was 91%. In AVG’s the sensitivity was 68.8% and the specificity was 87.5%.

2004 Lopot et al, J. Vasc Access

Comparison of different techniques of hemodialysis vascular access flow evaluation.

Ultrasound Dilution measurements were used as the gold standard to compare other surveillance methodologies. “The very high reproducibility seen in UD, both for measurements at the same extracorporeal blood flow (QB) and for measurements at two different QB justifies its current status of a reference method in access flow.”

2006 Wijnen E et al, NDT

Impact of a quality improvement programme based on vascular access flow monitoring on costs, access occlusion and access failure.

“A quality improvement programme based on periodical access flow measurement reduced the number of acute vascular access failures due to thrombotic events and also significantly reduced health care costs in patients with AVG, but not in patients with AVF.”

2008 Tessitore Net al, NDT

Adding access blood flow surveillance to clinical monitoring reduces thrombosis rates and costs, and improves fistula patency in the short term: a controlled cohort study. (N=159)

Adding Qa surveillance to monitoring in mature AVFs is associated with a better detection and elective treatment of stenosis, and lower thrombosis rates and access-related costs.

2008 van Loon M et al, NDT

Implementation of a vascular access quality programme improves vascular access care.

(24 center, 2300 patient Quality Improvement Plan) Findings suggest that a vascular access care Quality Improvement Plan is worthwhile to improve dialysis patients’ care and access morbidity.
Vascular Access Surveillance Bibliography cont.

2009 Maoz D et al, Clin Nephrol
**Hemodialysis graft flow surveillance with prompt corrective interventions improves access long-term patency.** (N=92)

Stringent flow surveillance policy coupled with prompt intervention has proven effective in maintaining AVG long-term patency.

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2011 Chan KE et al, CJASN
**Access Survival amongst Hemodialysis Patients Referred for Preventive Angiography and PTA.**

Huge statistical study linked Medicare beneficiaries in Fresenius clinics to study 41,132 patients across 1342 facilities in 48 states and determined “The benefits of PTA interventions are most seen in newer accesses or accesses with insufficient flow.” This underscores the importance of flow measurement to guide PTA.

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2011 Tessitore N et al, CJASN
**In search of an optimal bedside screening program for arteriovenous fistula stenosis.** (N=119)

“Fistula stenosis can be detected and located during dialysis with a moderate-to-excellent accuracy using Physical Exam and vascular access flow measurement to screen for stenosis.”

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2013 Park HS et al, Kidney Res Clin Pract
**Effect of intradialytic change in blood pressure and ultrafiltration volume on the variation in access flow measured by ultrasound dilution.**

“The variation in access flow during HD is relatively small. They found that decreased blood pressure is a risk factor for variation in access flow measured by ultrasound dilution. In most patients whose blood pressures are stable during HD, the access flow can be measured at any time during the HD treatment.”

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2015 Ashoor IF et al, Blood Purif
**Arteriovenous Access Monitoring with Ultrasound Dilution in a Pediatric Hemodialysis Unit**

Thrombosis rate dropped from 13.5 per 100 patient-months on HD during the baseline period to 3.5 per 100 patient-months on HD during the surveillance period. Ultrasound Dilution surveillance is very sensitive in detecting hemodynamically significant stenosis and can decrease AV access thrombosis rates.”

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2016 Aragoncillo I et al J. Vasc Access
**The impact of access blood flow surveillance on reduction of thrombosis in native arteriovenous fistula: a randomized clinical trial.** (N =196)

3-year multicenter, prospective, open-label, controlled RCT found that the measurement of access flow combining Duplex Ultrasound and Ultrasound Dilution shows a reduction in thrombosis rate and an increased assisted primary patency rate in AVF after one-year follow-up.

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2017 Aragoncillo I et al, J. Vasc Access
**Adding access blood flow surveillance reduces thrombosis and improves arteriovenous fistula patency: a randomized controlled trial.** (N=207)

QA-based surveillance combining Doppler ultrasound and ultrasound dilution reduces the frequency of thrombosis, is cost effective, and improves thrombosis-free and secondary patency in autologous AV.

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**STUDIES THAT CHALLENGE SURVEILLANCE**

2009 Paulson WD et al, AJKD
**Accuracy of Decrease in Blood Flow in Predicting Hemodialysis Graft Thrombosis.**

(83 grafts, 80 patients over 12 months) “Study found a Qa less than 600 ml/min or net Qa of 20% or greater had a sensitivity of 77% with an FPR of 23%...Thrombosis was predicated to occur 1 month after a measurement period.” This study is largely referred to as a negative study, however the study findings were positive for ultrasound dilution’s sensitivity to detect flow limiting.

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**Clinical Performance Characteristics of Hemodialysis Graft Monitoring.**

“Over a period of one month, simultaneous flow and venous pressure monitoring [was performed]... in 71 dialysis patients with (PTFE) grafts. These patients were prospectively followed for one year... During the period of follow-up, there were 71 graft failures [in 38 patients]... Failed grafts had lower blood flow rate... when compared with those without failure... Conclusions. Although dialysis graft blood flow rates are statistically different in patients who have graft failure... versus those who do not, the performance characteristics [of a single month of patient measurements] preclude clinical decision-making [for the ensuing year].” Transonic notes that the methods studied in this article are in no way recommended for access surveillance by KDOQI or any other groups. Conclusions are not meant to be drawn from a single instance.

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2003 Moist LM et al, AJSN
**Regular monitoring of access blood flow rate compared with monitoring of venous pressure fails to improve graft survival.** (N=111)

“In the treatment group, the positive predictive value of Qa to detect stenosis larger than 50% was 87%... The observation that there is no significant different in thrombosis rate or graft patency between groups in spite of an improvement in detection of graft stenosis calls into question not the monitoring technique but the success of the PTA intervention”. This study is considered a challenge to UD but it explains its own shortfall.
of unsuccessful PTA or controlling for PTA in the body of the article itself. The data are positive and indicate that ultrasound dilution is effective at indicating flow limiting stenosis.

A randomized controlled trial of blood flow and stenosis surveillance of hemodialysis grafts. (N=101: Control Group 34; Flow Group 32; Stenosis Group 35)
“This study does not support the concept that Qa or stenosis surveillance are superior to aggressive clinical monitoring... Clearly, further studies are needed to evaluate the effectiveness of surveillance in reducing thrombosis and improving graft survival.”

2005 Shahin H et al, Kidney Int
Monthly access flow monitoring with increased prophylactic angioplasty did not improve fistula patency.
Ultrasound dilution surveillance increased the rate of angioplasty procedures shortening primary unassisted patency, but did not decrease the thrombosis rate or improve cumulative fistula patency when compared to historic controls. Rebuttal: The study was not randomized thereby risking an uncontrolled bias. For instance, changes in access management practices such as the trend toward increased upper arm fistulas or surgical expertise or better preoperative vascular mapping could explain why primary and cumulative fistula patency prior to initiation of UDT monitoring was better in Group 2 than Group 1.