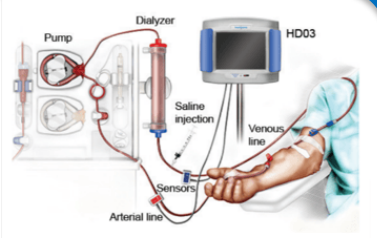
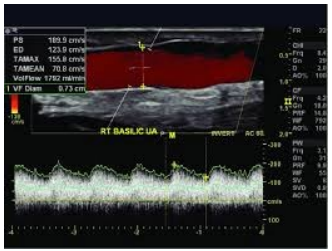
Flow measurement in dialysis access



Ultrasound dilution

Transit time flow measurement (TTFM)



Duplex Ultrasoud volume flow

Anton Razuvajev
Karolinska Universitetssjukhuset

Dialysis Access Surveillance — KDOQI & ESVS

KDOQI 2019

- Clinical monitoring first (history, exam, dialysis indicators).
- Surveillance (**Qa**/pressures/imaging) is supportive only.
- Avoid pre-emptive angioplasty based on surveillance alone.

ESVS 2018

- Include **scheduled Qa surveillance** in VA maintenance.
- Cadence: AVG monthly; AVF every 3 months.
- Use thresholds to trigger diagnostic confirmation (not automatic intervention).

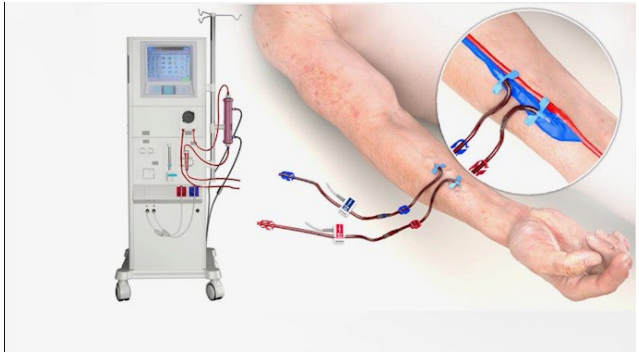
Flow thresholds to TRIGGER WORK-UP (ESVS)

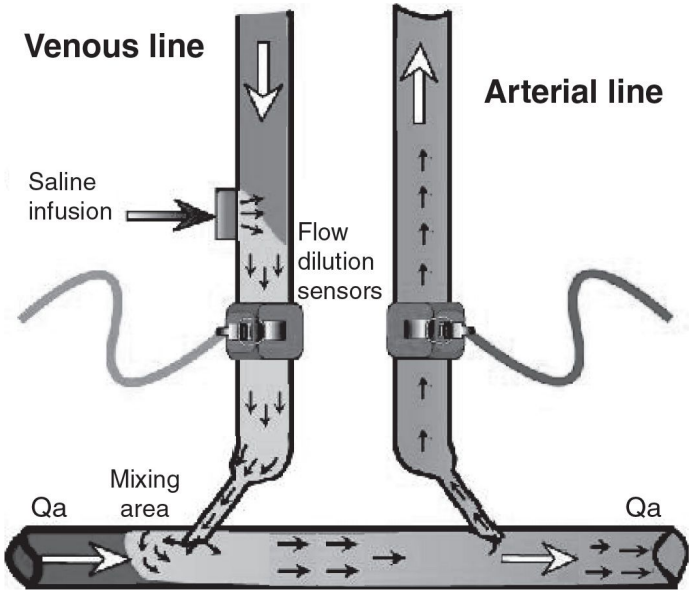
AVF	AVG	ΔQa
< 500 mL/min	**< 600 mL/min**	**> 33% drop**

Interpret vs patient baseline; CONFIRM with focused exam + duplex before treatment.

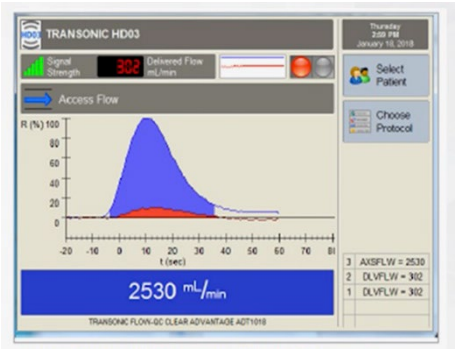
KDOQI Clinical Practice Guideline for Vascular Access (2019); ESVS Clinical Practice Guidelines on Vascular Access (2018).

Transonic dilution





From the **shape and timing** of the two curves—and knowing the **delivered pump flow (Qb)**—the monitor solves for the **access flow (Qa, mL/min)** and **recirculation (%)**.



Transonic dilution pitfalls

Variability ≈ 5-25 %

Tessitore N, et al. Am J Kid Dis 2003

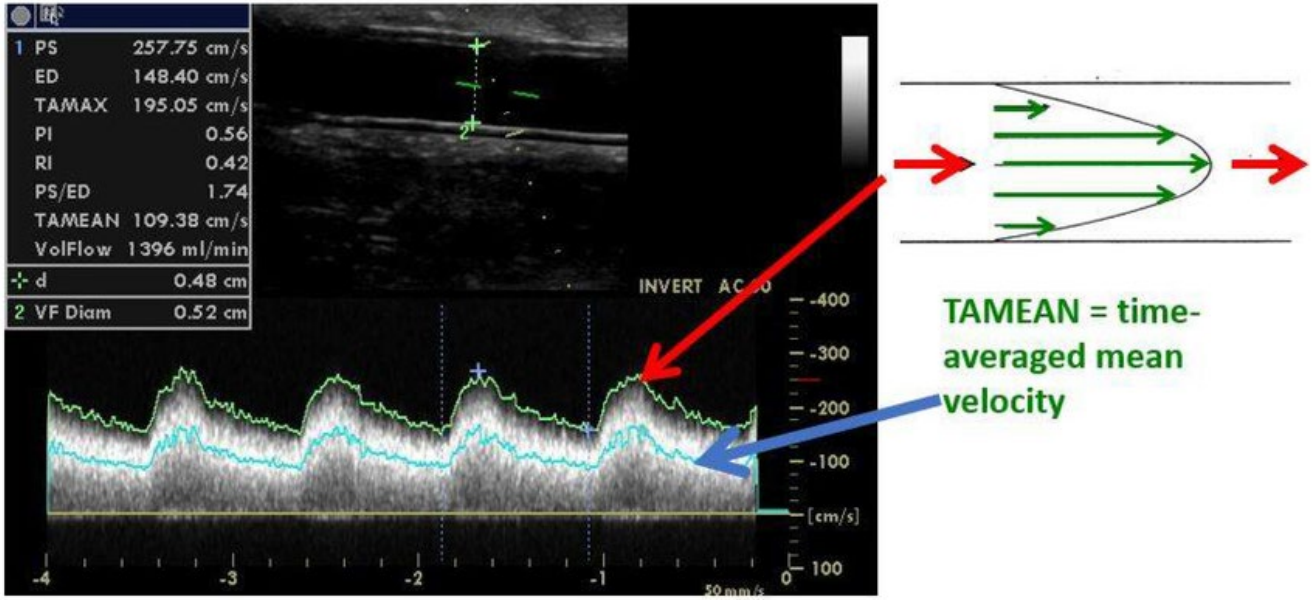
- Done at HD unit
- Does not require referrals, transport etc
- Regularly as surveillance
  or when symptoms

- Poor bolus (too small/slow or bubbly) → noisy curves → repeat.
- High baseline recirculation before Qa run → fix needle position, then re-measure.
- Patient not stable (MAP swings, shivering) → wait, then repeat.
- Tubing sensor size is correct and placed properly (no kinks/air).

Duplex Ultrasound Flow

Comes in a unique package Physiology + Morphology + Anatomy

Measure in the feeding artery (brachial)
Doppler: angle ≤60°
$CSA = \pi \cdot (Dcm/2)^2$
$Q\ (mL/min) = Vmean\ (cm/s) \times CSA\ (cm^2) \times 60.$



Duplex ultrasoud

Selective surveillance

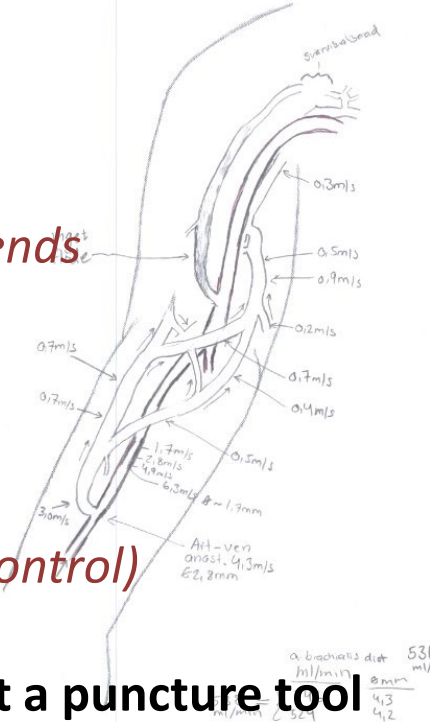
- *volume flow tresholds / trends*
- *anatomy (morphology)*

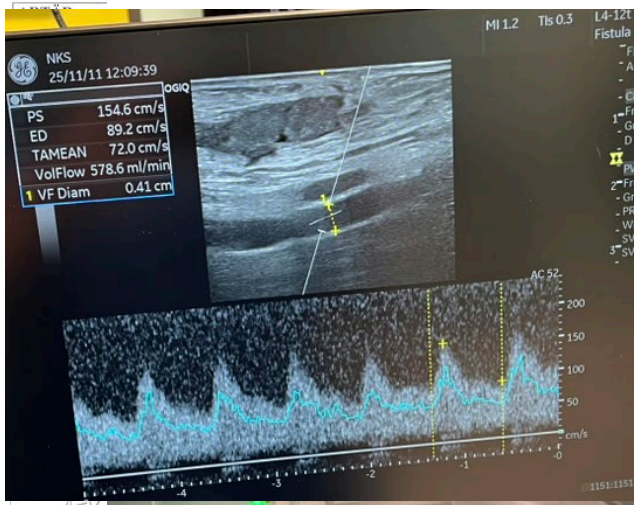
Surgical Revisions

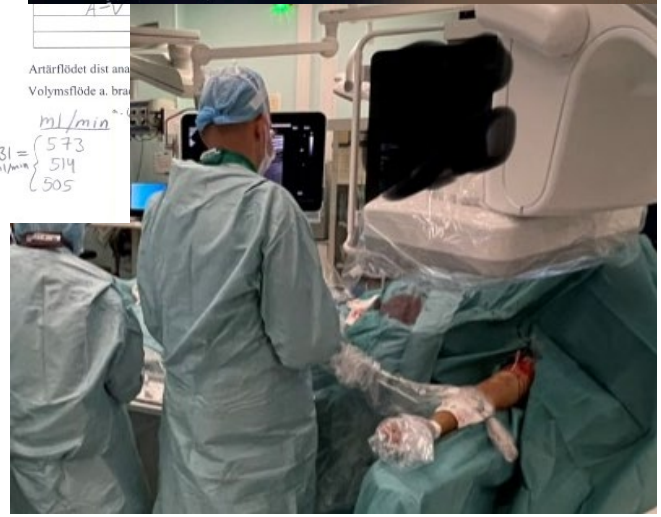
- *anatomy*
- *(volume flow completion control)*

Endovascular revisions – **not just a puncture tool**

- *stratification of the lesions*
- *avoid oculoangiografic reflex*
- *volume flow completion control*

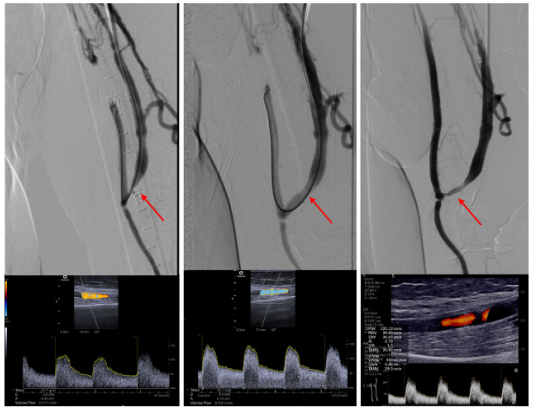






Ultrasound as completion control for endovascular treatment

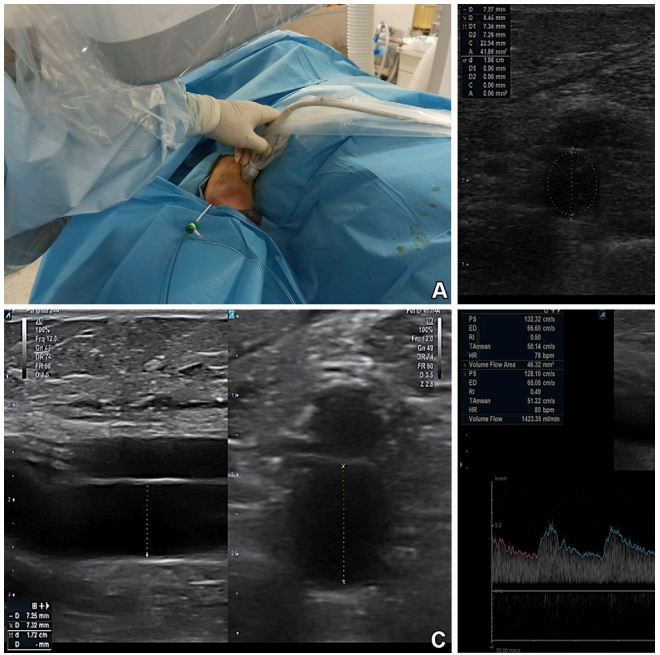
US Volume Flow Assessment to Optimize Angioplasty of Dysfunctional Dialysis Access: The VOLA-II Multicenter Study



- Prospective study of 100 participants with failing arteriovenous fistulas (AVFs).
- A higher postangioplasty volume flow (VF) (HR, 0.9) and forearm versus upper arm AVF (HR, 0.5) were predictors of fewer reinterventions.
- The target postprocedural VF value for balloon angioplasty should be >720 mL/min in distal and >1120 mL/min in proximal arm AVFs to optimize patency outcomes.

Spiliopoulos S and Filippou P et al. Published: November 26, 2024
https://doi.org/10.1148/radiol.233076

Radiology



Helps to understand what we treat
(and what we do not have to)

Duplex ultrasoud volume flow pitfalls

Variability ≈ 20–30 %
Hoyt K, et al *J Ultrasound Med.* 2009

- **Angle & alignment near 60° magnify velocity error.**
- **Sample volume size/centering: too small (core bias, Q↑) vs too large/wall (boundary layer, Q↓).**
- **Turbulence/skewed profiles near curves/anastomoses.**
- **Physiology drift: MAP/HR, rhythm (AF), respiration,**
- **The higher flow – the larger variation**

D = 6 mm → 0.6 cm ⇒ CSA = $\pi \times 0.3^2 \approx 0.283$ cm²

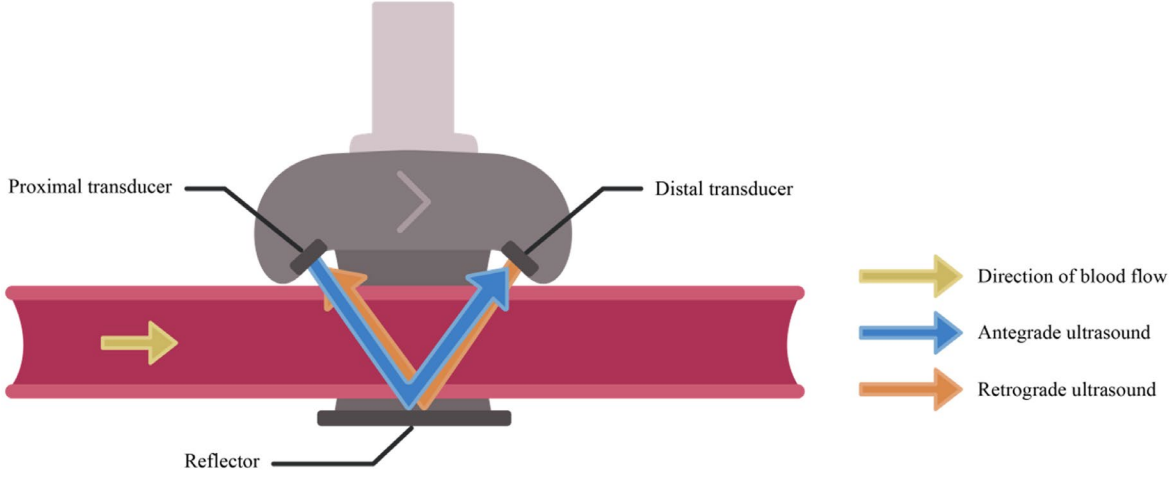
TAMEAN = 40 cm/s

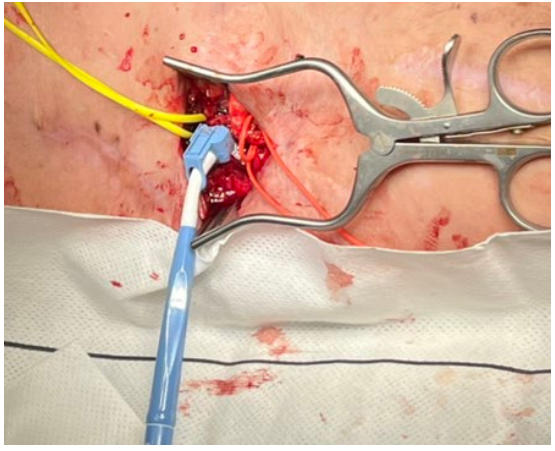
Q = 40 × 0.283 × 60 ≈ **680 mL/min**

D = 5.5 mm
Q = 570 ml/min

Transit time flow measurement - TTFM

reproducible **volume flow (mL/min)** intra-operatively.





Transit Time Flow Measurement: Experimental Validation and Comparison of Three Different Systems

Guido Beldi, MD, Andreas Bosshard, MD, Otto M. Hess, MD, Ulrich Althaus, MD, and Beat H. Walpoth, MD

Department of Cardiovascular Surgery and Division of Cardiology, University Hospital Insel, Bern, Switzerland

*Excellent correlation between TTFM and **true flow***

TTFM as completion control

Scand J Urol Nephrol 15: 323–326, 1981

THE PROGNOSTIC VALUE OF BLOOD-FLOW MEASUREMENTS DURING CONSTRUCTION OF ARTERIOVENOUS FISTULAE

J. Elfström and M. Thomsen

From the Department of Surgery, University of Linköping, Linköping, Sweden

Primary access creation

- *tresholds*

Revisions

- *situation based*

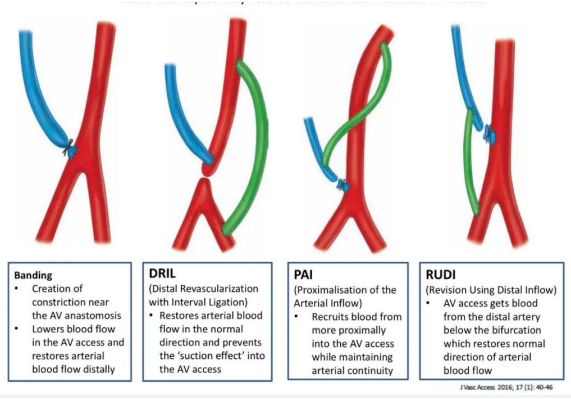
Guiding flow-reduction surgery

- *down to a level or "to half the flow"*

Intraoperative transit time flow measurement predicts maturation of radiocephalic arteriovenous fistulas JVS 2024

Eduard Pierre de Winter, MD,[a,b] Dorien Wilschut, MD,[a] Kim Plasmans, MD,[a] Daniel Eefting, MD, PhD,[a,b,c] Tim van der Steenhoven, MD, PhD,[a,c] Hein Putter, PhD,[b] Joris Rotmans, MD, PhD,[b] *and* Koen van der Bogt, MD, PhD,[a,b,c] *The Hague, Leiden, and Delft, the Netherlands*

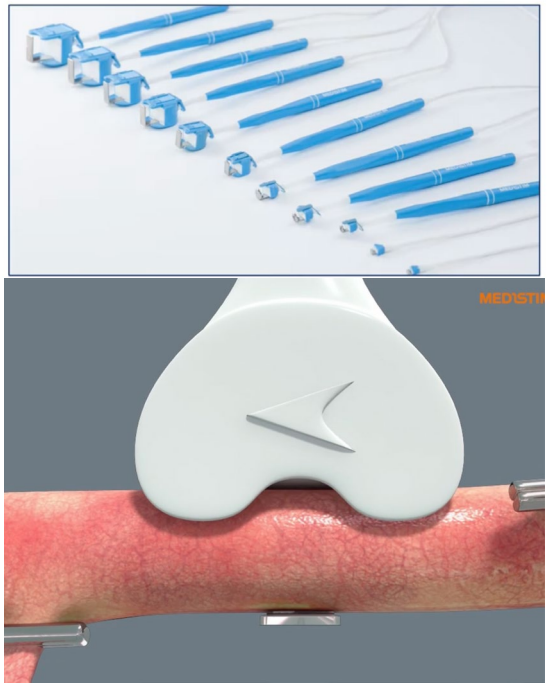
160 ml/min



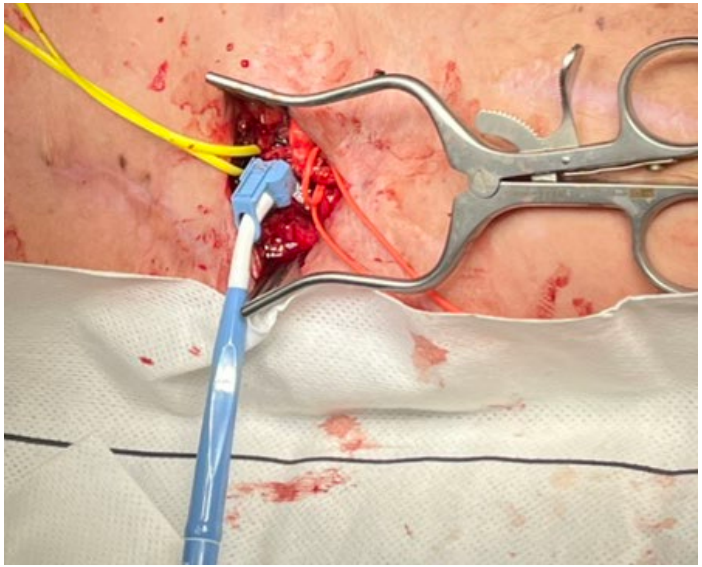
TTFM pitfalls

Variability ≈ 10–20 %

Bae et al., J Vasc Access 2015



- Right probe
- No angulation
- No branches
- No air
- ACI över 30%
- The higher flow – the larger variation



47 yo male, BB fistula

Dilution

– **2100** ml/min

US

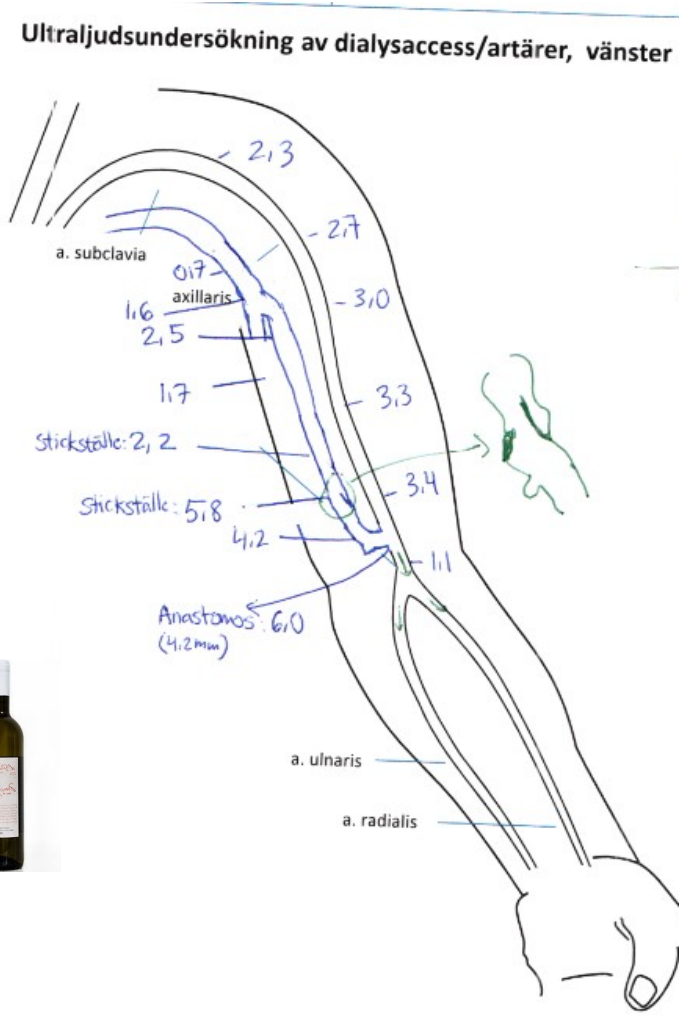
– **2800** ml/min

Surgery (TTFM)

- start **1800** ml/min
- after distalisation of inflow **850** ml/min

US control 3 month later

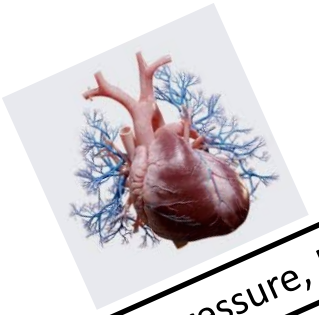
- **1600** ml/min



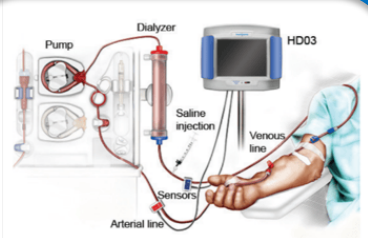
Volume state of the patient

anesthesia

Time between exams



Blood pressure, HR ETC

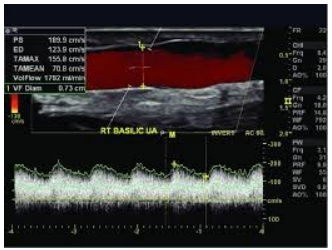


Transonic dilution

Variability ≈ 5–25 %

Transit time flow measurement (TTFM)

Variability ≈ 10–20 %



Duplex US flow

Variability ≈ 20–30 %

TTFM → intraoperative gold standard **Transonic → dialysis surveillance** **Duplex → anatomy + flow correlation**

	TTFM	Transonic	Duplex
Principle	Transit time difference of ultrasound beams → direct flow	Saline bolus dilution → calculates access flow (QA)	Doppler velocity × vessel area (πr^2) → volume flow
Setting	Intraoperative (open graft/vessel)	During dialysis (extracorporeal circuit)	Outpatient or bedside exam
Accuracy	±2–3% instrument, ±5–10% overall	±2–3% instrument, ±5–10% overall	±10–20% (angle, geometry)
Variability	5–15% (MAP, probe fit, spasm)	5–10% (bolus, CO stability)	10–25% (operator technique)
Clinical Threshold	↓Flow >20% or PI>5 → issue	QA<600 mL/min (AVG)/<400 (AVF) or ↓≥25%	Flow<500 mL/min or ↓≥25% + stenosis
Advantages	Real-time, intra-op quality control	Safe, repeatable, ideal for surveillance	Anatomy + function, non-invasive
Limitations	Needs open exposure; sensitive to MAP	Requires dialysis session; hemodynamic stability	Operator-dependent; turbulence & angle error

TTFM → gold standard for **intraoperative assessment**

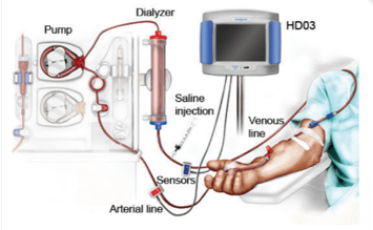
Transonic dilution → best for **routine quantitative surveillance**; reproducible, low risk.

Ultrasound duplex → best for **anatomic + functional** correlation; higher variability but provides morphology.

Ja, vi måste fortsätta tänka

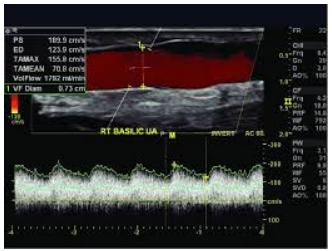
Accessflödet med “Transonic” eller **duplex**, hur ska vi tänka?

transonic



Ultrasound dilution

Transit time flow measurement (TTFM)



Duplex Ultrasoud volume flow

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Flow measurement in dialysis access