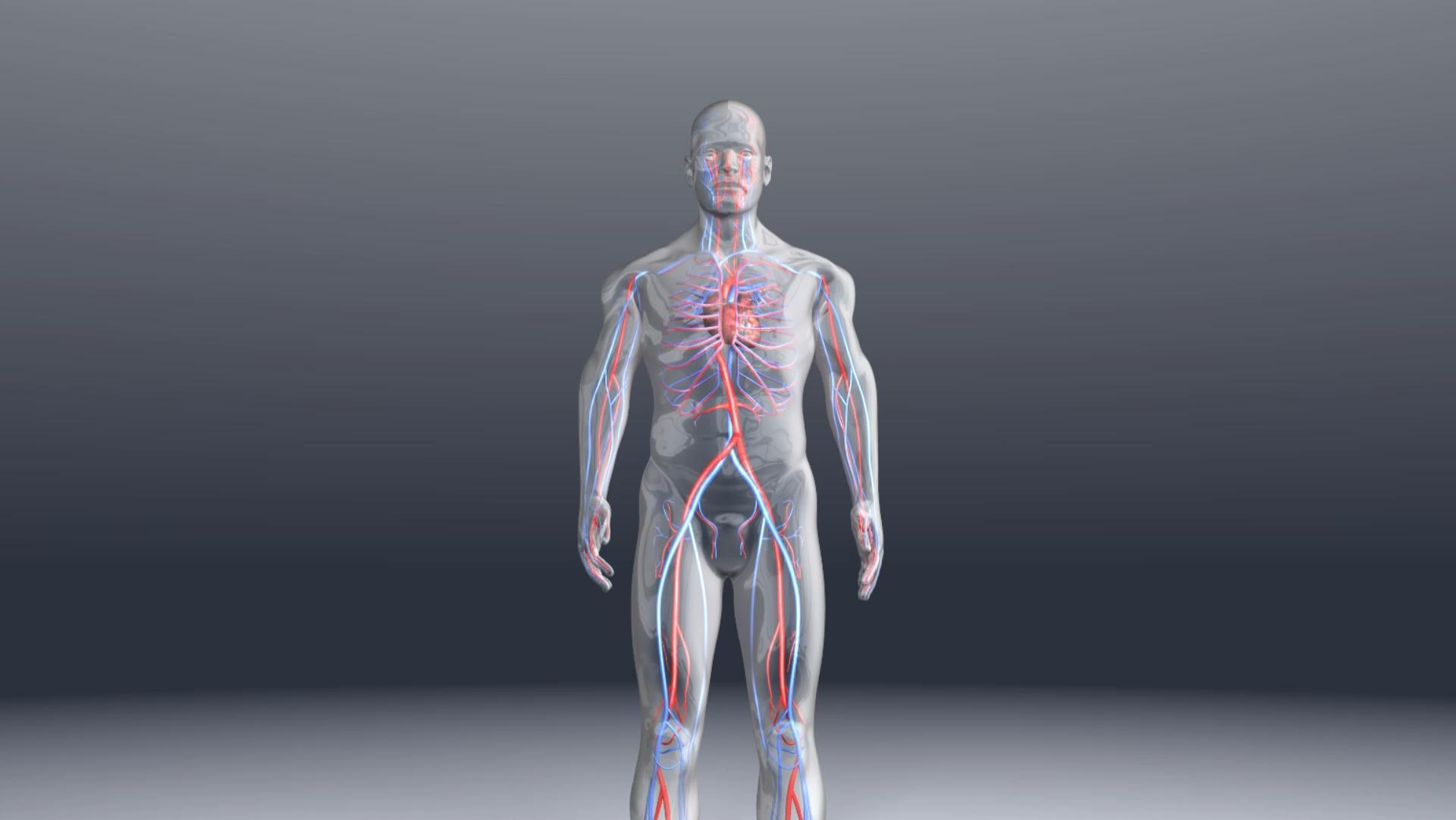
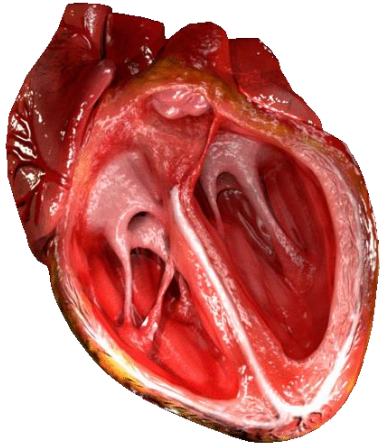


# THE HEMODYNAMIC SCIENCE OF HIGH-FLOW ARTERIOVENOUS ACCESS

Cardiac Remodeling, Flow Thresholds, and the Evidence Base

**John R. Ross, MD, FACS, FASDIN, MAMSE**

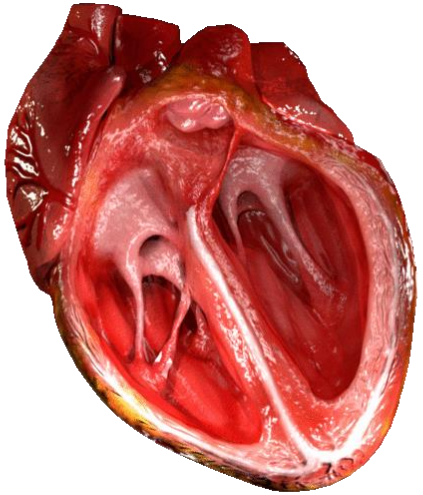
Dialysis Access Institute | VASA 2026





4 LITERS

2 LITERS



4LITERS



**2,500CC PER MIN**

# 42%

of ESRD patients on dialysis develop pulmonary hypertension

Schoenberg 2020 (systematic review & meta-analysis), cited in Warner 2023

# The Hemodynamic Cascade

**1**

**AV SHUNT**

Low-resistance path
arterial → venous

**2**

**↑ PRELOAD**

Frank-Starling
↑ stroke volume + CO

**3**

**LV REMODELING**

Eccentric hypertrophy
↑ LV mass + dilation

**4**

**RV FAILURE**

Pulmonary HTN
Volume + pressure
overload on RV

*Each step is measurable. Each step is potentially reversible.*

# The Physics

*Hagen-Poiseuille Law*

$$Q \propto r^4$$

**2×**

radius

**= 16× flow**

**20%**

radius reduction

**= 59% flow reduction**

**50%**

radius reduction

**= 94% flow reduction**

# 600

mL/min

The inflection point for cardiac remodeling

Stoumpos et al. Scientific Reports 2021 | n = 40 | Prospective | Cardiac MRI

# Cardiac MRI at 6 Weeks Post-AVF Creation

*Stoumpos et al. Scientific Reports 2021*

| ≥ 600 mL/min (n = 22) | | | < 600 mL/min (n = 18) | | |
|---|---|---|---|---|---|
| LV Mass | +15.6 g (10.2%) | p = 0.003 | LV Mass | -2.5 g (no change) | NS |
| LVEDV | +8.7% | significant | LVEDV | no significant change | NS |
| LA Volume | +14.7% | significant | LA Volume | no significant change | NS |
| Cardiac Output | +13.9% | significant | Cardiac Output | no significant change | NS |
| NT-proBNP | ↑ increased | p = 0.05 | NT-proBNP | stable | NS |

*First study linking early AVF flow to LV mass change using cardiac MRI (gold standard)*

# Banding Reverses the Damage

*Balamuthusamy et al. 2016 | n = 12 | 6-month follow-up*

**3.7 → 1.1**

L/min

Access Flow

**-68.9%**

**54 → 44**

mmHg

PA Pressure

**-18.5%**

**3.75 → 1.08**

per 6 mo

Hospitalizations

**-71.2%**

All $p < 0.01$ except CO ($p = 0.03$). LVMI: 130.4 → 125.5 g/m² ($p = 0.006$).

# Pre- vs. Post-Banding Echocardiographic Data

*Balamuthusamy et al. 2016 | n = 12 | Retrospective | Upper-arm AVF | Flow > 2 L/min*

| Variable | Pre-Banding | Post-Banding | P | Change |
|---|---|---|---|---|
| Access flow (L/min) | 3.7 +/- 0.7 | **1.1 +/- 0.4** | **0.001** | **-68.9%** |
| Cardiac output (L/min) | 7.06 | **6.47** | **0.03** | **-8.4%** |
| PA systolic (mmHg) | 54 +/- 11 | **44 +/- 7** | **0.02** | **-18.5%** |
| LVMI (g/m²) | 130.4 +/- 7.7 | **125.5 +/- 4.6** | **0.006** | **-3.8%** |
| EF (%) | 43.3 +/- 7.1 | **48 +/- 4.9** | NS | **+10.9%** |
| Hospitalizations (/6 mo) | 3.75 +/- 1.2 | **1.08 +/- 0.99** | **0.002** | **-71.2%** |
| NYHA stage | 2.67 +/- 0.65 | **1.83 +/- 0.38** | **0.001** | **-0.84** |
| Qa/CO ratio | 0.52 | **0.17** | -- | **-67.3%** |

**SD values as published. Qa/CO 0.52 = more than half of cardiac output through fistula.*

# Location Matters

*Fitzgibbon et al. JVS 2025 | VQI VISION Registry | n = 4,319*

## FOREARM ACCESS

Lower flow. Lower cardiac burden.

Mortality HR: **0.86**
(CI 0.75 - 0.98, p < 0.05)

**14% lower mortality vs. upper arm**

## UPPER ARM ACCESS

Higher flow. Higher cardiac burden.

Composite HR: **Reference**
(HR 0.90, CI 0.81-1.00 for forearm)

**67% exceed 600 mL/min (Stoumpos)**

*Observational. Compares ACCESS LOCATION, not intervention. Subject to confounding.*

# Inverse Proof: The ROX Coupler

*ROX CONTROL HTN Trial | Lancet 2015 | Randomized Controlled Trial*

If creating a small AV shunt ON PURPOSE lowers blood pressure...

then an uncontrolled AV shunt raises cardiac workload.

| | |
|---|---|
| Device | **4mm iliac AV coupler** |
| SBP Reduction | **-25.1 mmHg** |
| Evidence Level | **RCT (Lancet)** |
| Stenosis Rate | **33%** |

*The 33% stenosis rate confirms: even engineered AV devices experience narrowing over time.*

# The Cardiology Wake-Up Call

*Warner et al. Journal of Cardiac Failure 2023 | Commentary*

First cardiology journal to frame AVF-mediated cardiac disease as a cardiology problem

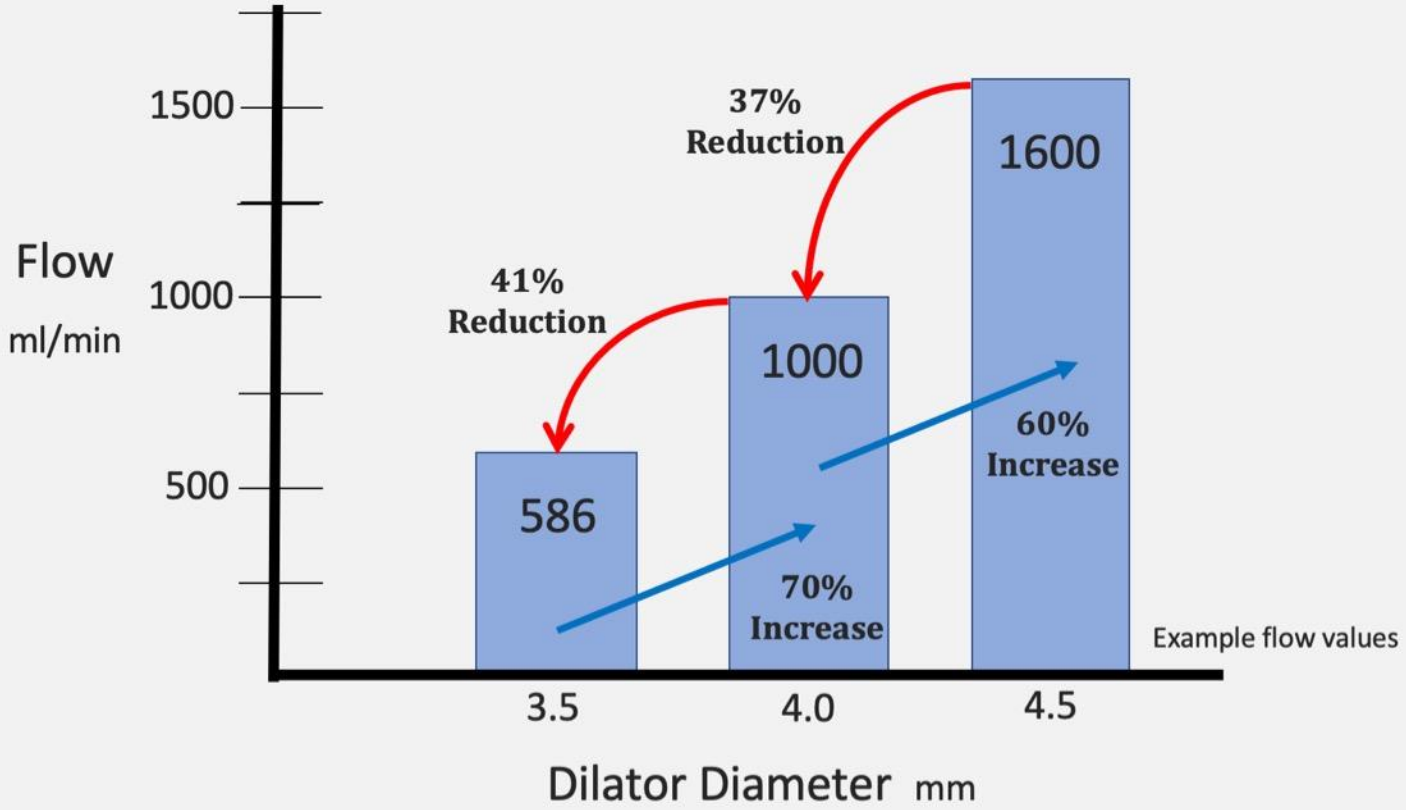
Recommends serial TTE surveillance for high-flow AVF patients

Manual compression test underestimates: 1.1 L/min reduction vs. 4.0 L/min with ligation (Raza) — 3.6x gap

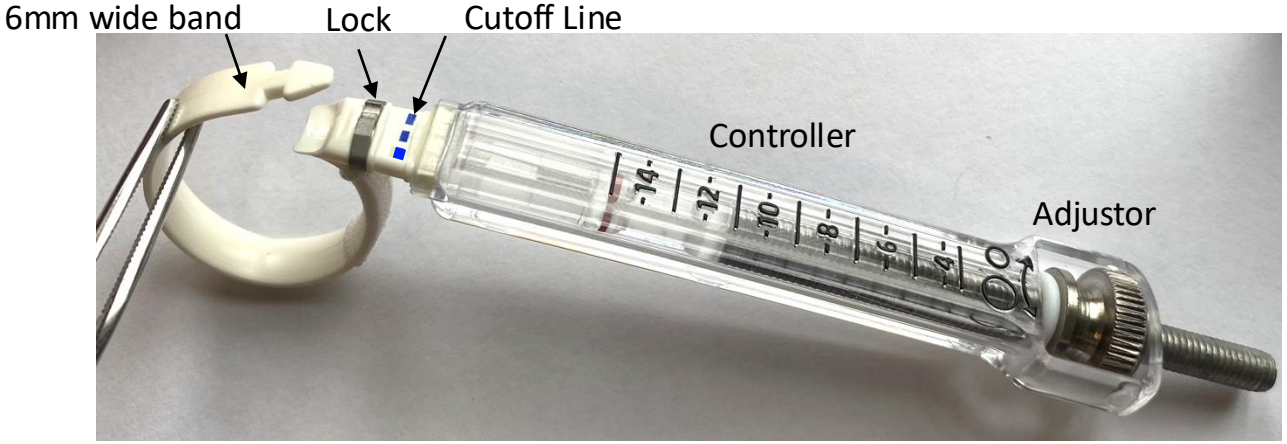
Endorses PD for PH/HOHF patients: first published cardiology recommendation for modality switch

*Warner bridges cardiology and nephrology: two fields that previously operated in silos on this issue.*

# Miller Banding 'Flow Control'

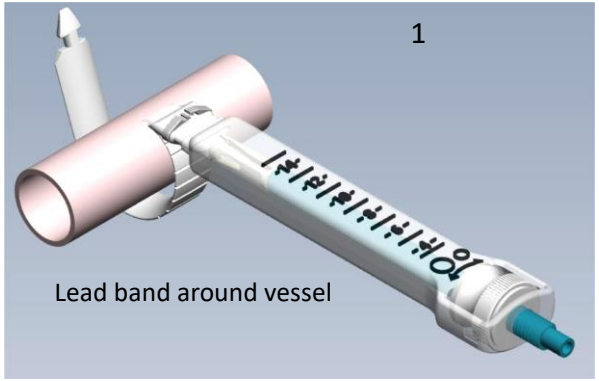


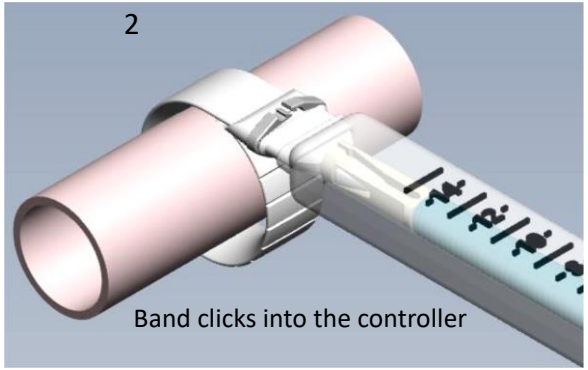
# Flowband Device

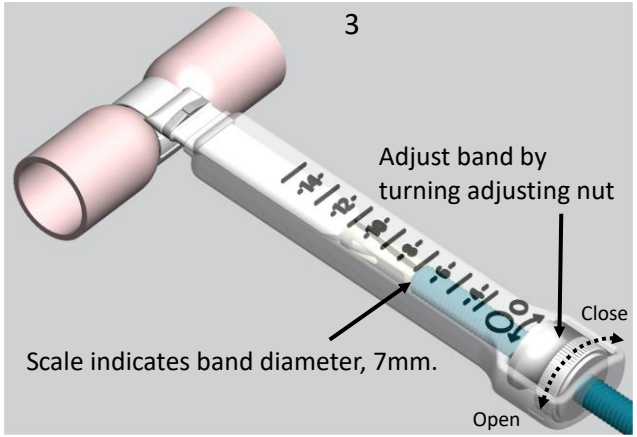


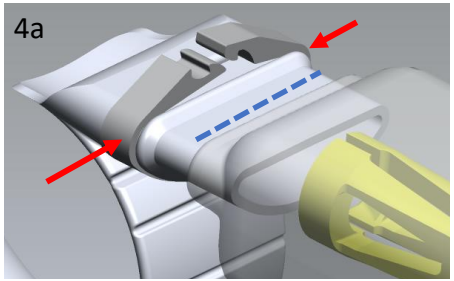

Provides continuous adjustment

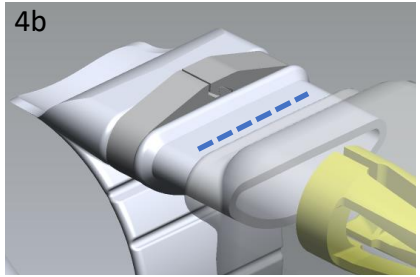
# Installation Sequence



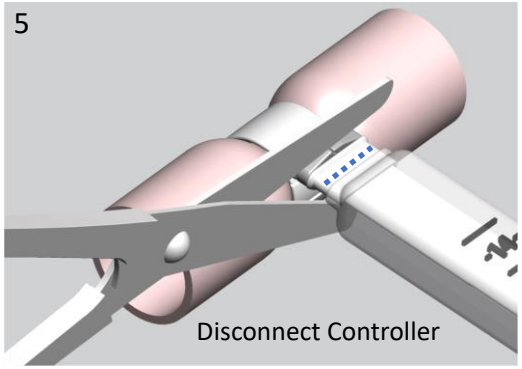



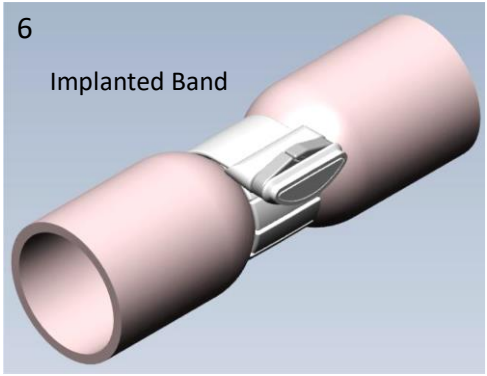



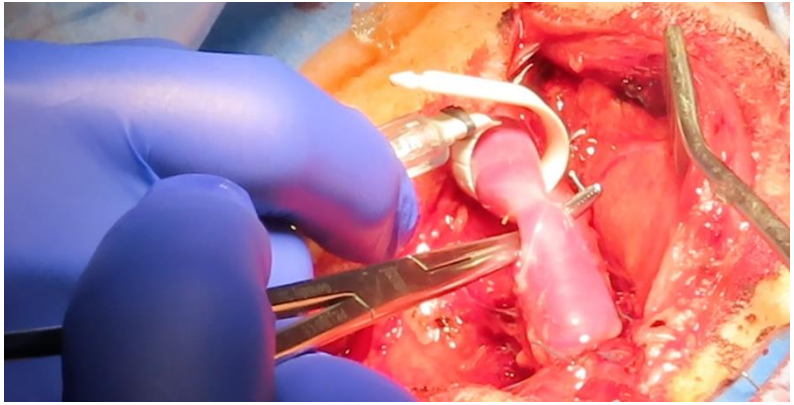

Pinch sides to close the lock



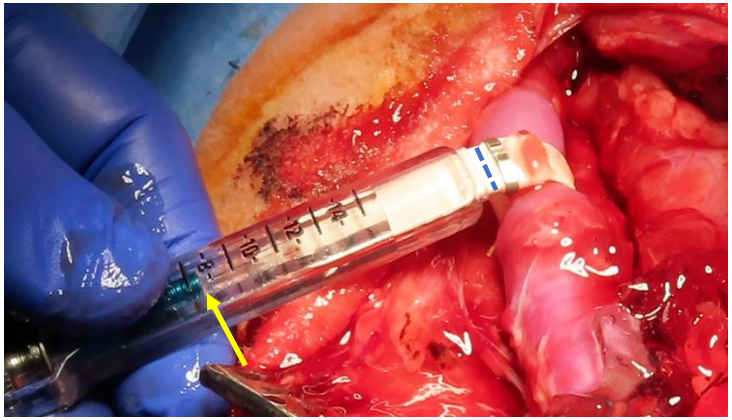




Lock

OPEN xxxx ml/min



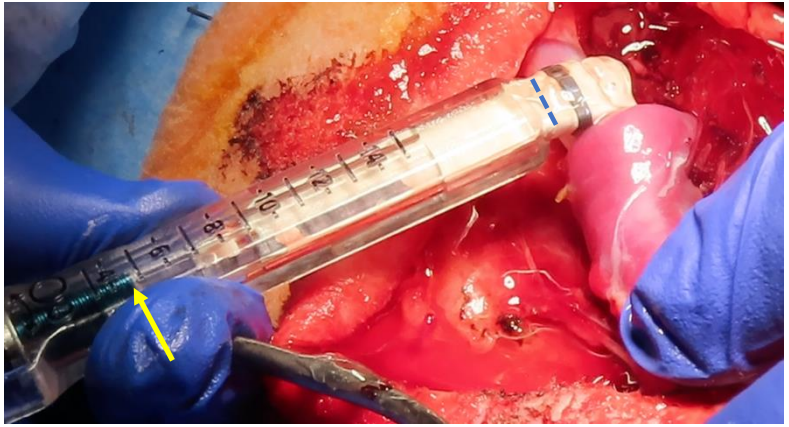
7.5mm

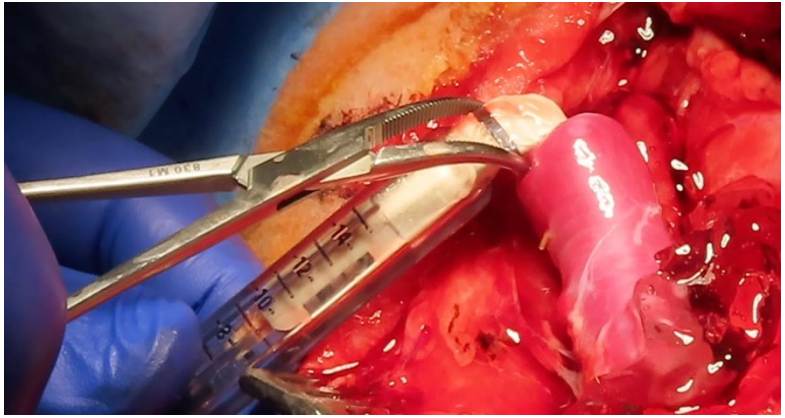


13mm



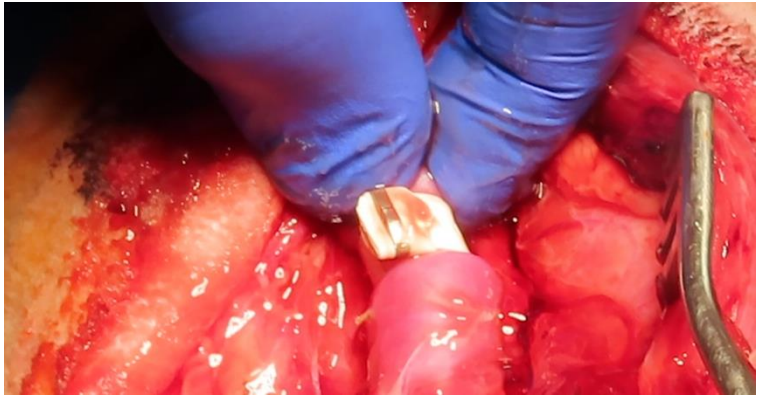
4.75mm





Pinch Lock Closed

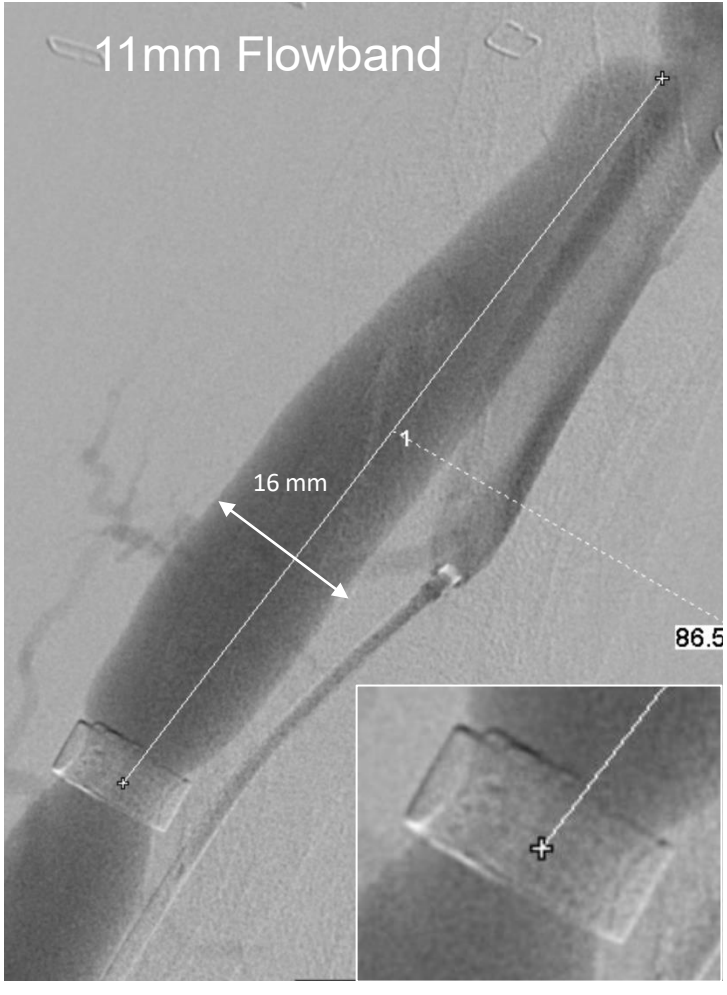
NEED DISCONNECT PIC

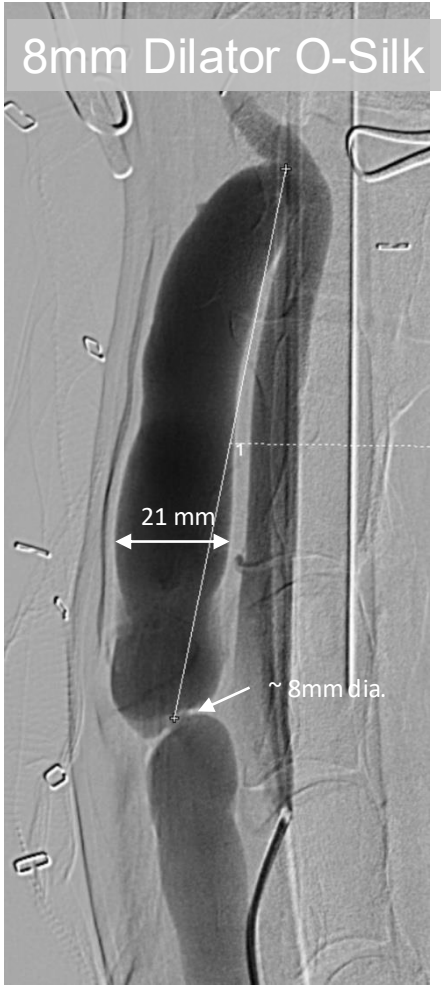


Final Implanted Band

# Ovine Carotid-Jugular Fistula



# The impact of high-flow access

- Heart must pump significantly more blood to compensate
- Can lead to high-output heart failure
- Chronic volume overload causes cardiac remodeling



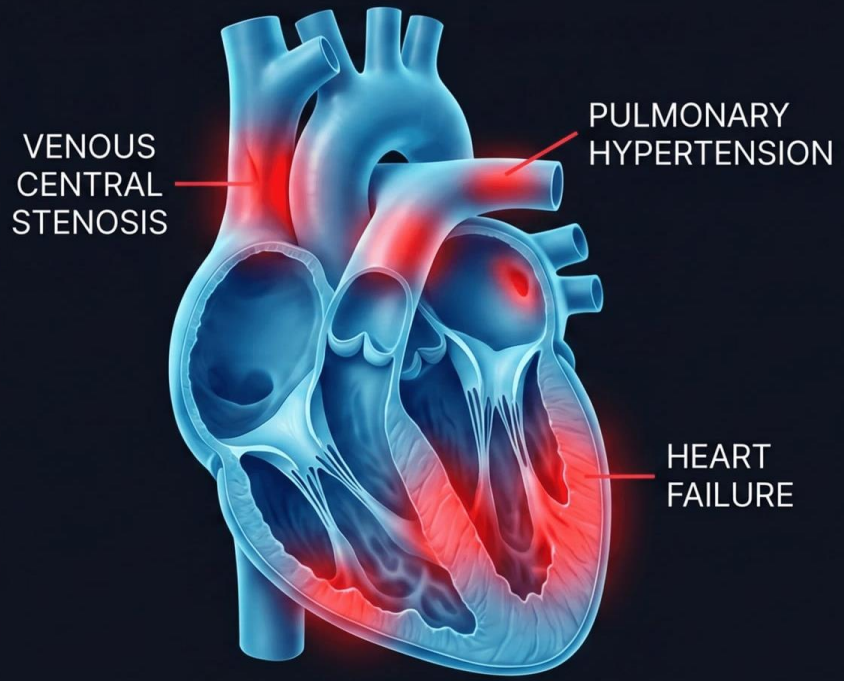
# 10 BATHTUBS

## EVERY DAY!



# Proven injury pattern

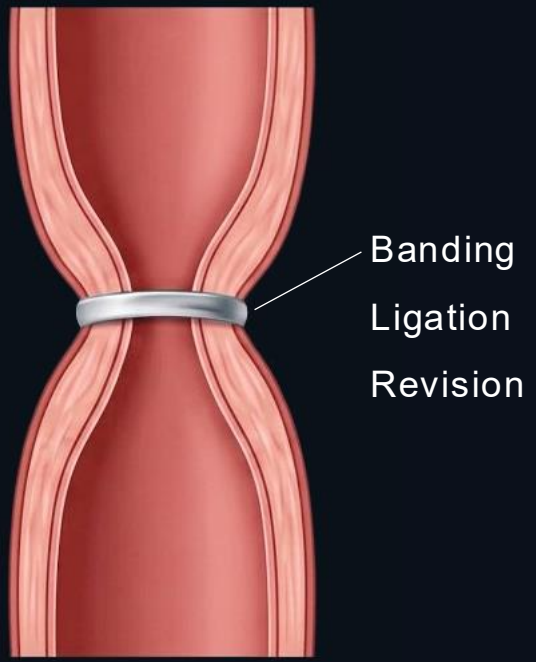
- ✗ High-output heart failure
- ✗ Diastolic dysfunction
- ✗ LVH
- ✗ Dilation
- ✗ Pulmonary hypertension




(Valerianova 2021; Zamboli 2018; Zoccali 2004)

# But proven reversible!

- Less high-output heart failure
- Improved diastolic dysfunction
- Improved LVH
- Less dilation
- Less pulmonary hypertension

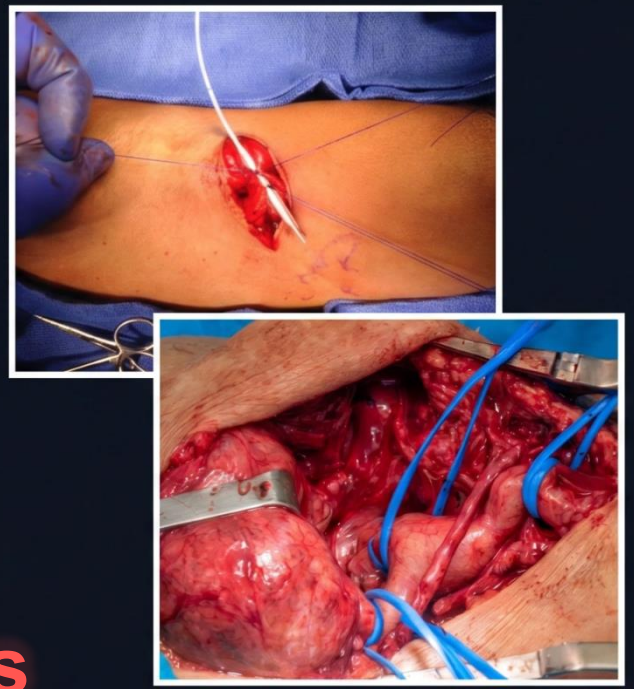



(Valerianova et al., Int'l Journal of Cardiology, 2021)

# Reversible, but…

- Additional invasive surgery
- Unpredictable flow control
- Thrombosis risk
- Difficult adjustments
- Irregular, pleated inner lumen

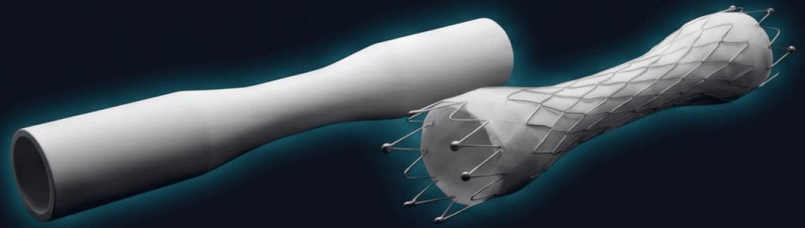
**Used only in severe cases**



# Solutions finally coming!

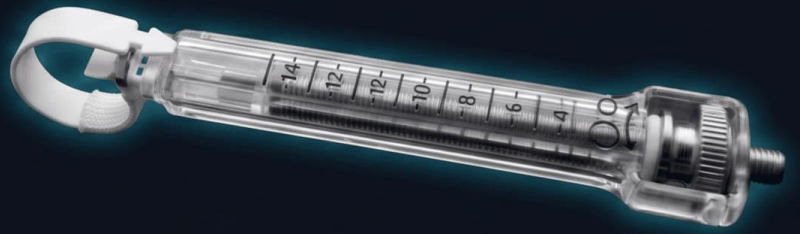
## VascX patented platform

- Elastic flow-control grafts (avail. 2027)
- Elastic flow-control stents (avail. 2028)

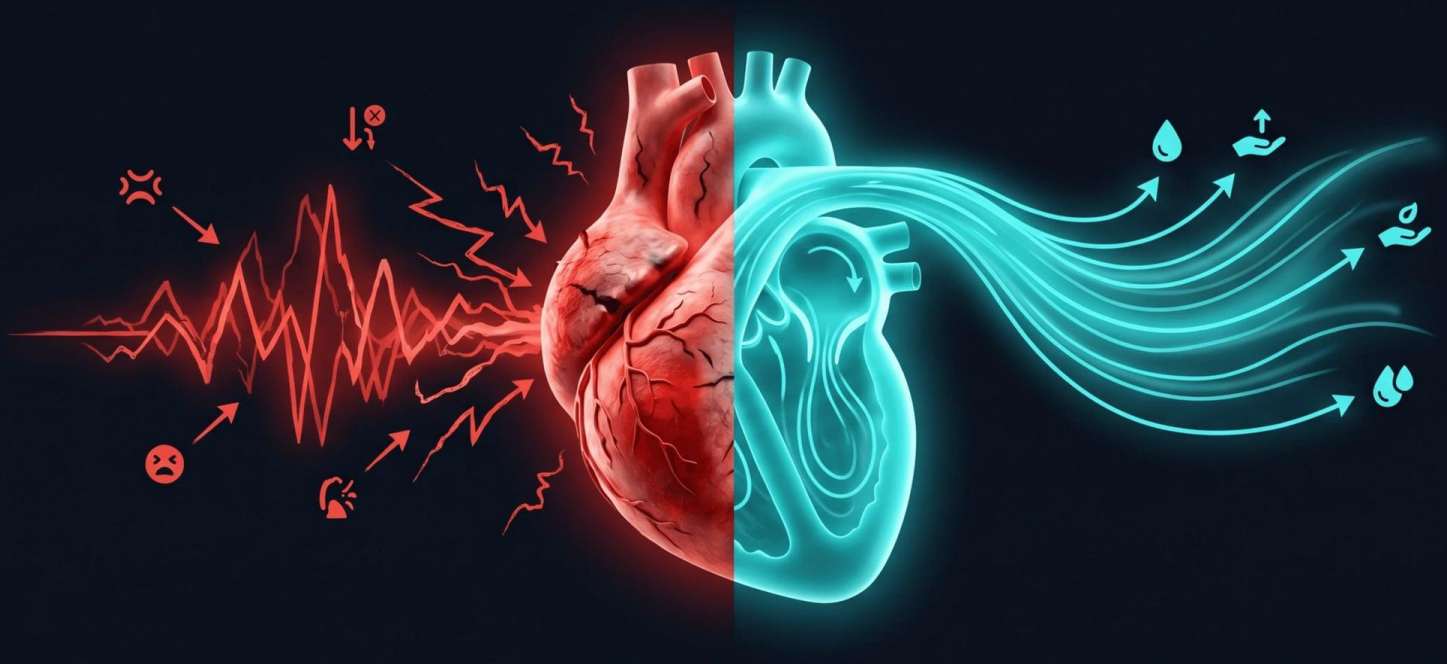


## BandCo

- Adjustable banding device



# Would patients live longer?



Access flow damages the heart

Flow-reduction reverses the damage

Flow-control at implant should extend life

# Would life improve?



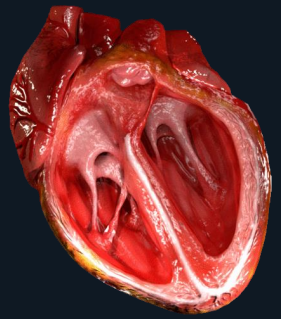
Breathlessness ✓ Reduced

Fatigue ✓ Reduced

Surgeries & interventions ✓ Reduced

# What the Evidence Tells Us

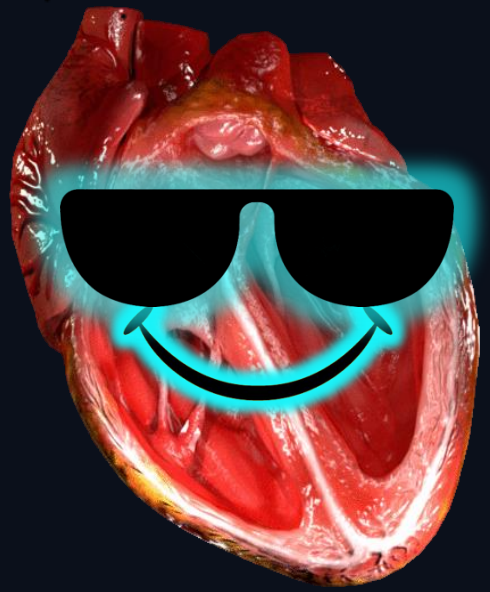
| | |
|---|---|
| A | AVF creates measurable cardiac remodeling proportional to flow |
| A | 600 mL/min is the CMR-validated inflection point for LV mass change |
| B | 42% of ESRD dialysis patients develop pulmonary hypertension |
| B | Forearm access associated with 14% lower mortality (n=4,319) |
| C | Surgical banding reduces flow, reverses echo parameters, cuts hospitalizations 71% |
| -- | No flow-reduction device has published clinical outcome data |



# Screen.
# Manage.
# Don't ignore.

John R. Ross, MD, FACS, FASDIN, MAMSE | Dialysis Access Institute

VASA 2026 | Salt Lake City



Future hearts **thank you!**