Workshop Nefrologie Papendal
15 December 2022

Cardiotoxiciteit van dialyseshunts

Joris Rotmans, internist-nefroloog
Afdeling Interne Geneeskunde
Leids Universitair Medisch Centrum

Arie van Dijk, cardioloog
Afdeling Cardiologie
Radboudumc, Nijmegen

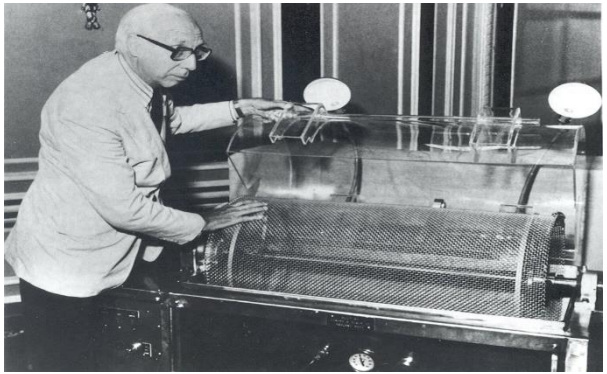
Disclosure belangen Joris Rotmans

(potentiële) belangenverstrengeling	
Voor bijeenkomst mogelijk relevante relaties met bedrijven	Bedrijfsnamen
• Onderzoeksgeld • Honorarium of andere (financiële) vergoeding • Aandeelhouder • Andere relatie, namelijk …	• Consultant Xeltis • Bestuurslid Vascular Access Society

Disclosure belangen Arie van Dijk

(potentiële) belangenverstrengeling	
Voor bijeenkomst mogelijk relevante relaties met bedrijven	Bedrijfsnamen
• Onderzoeksgeld • Honorarium of andere (financiële) vergoeding • Aandeelhouder • Andere relatie, namelijk …	• Janssen • Consultant Janssen, MSD

History of hemodialysis and vascular access



Kolff

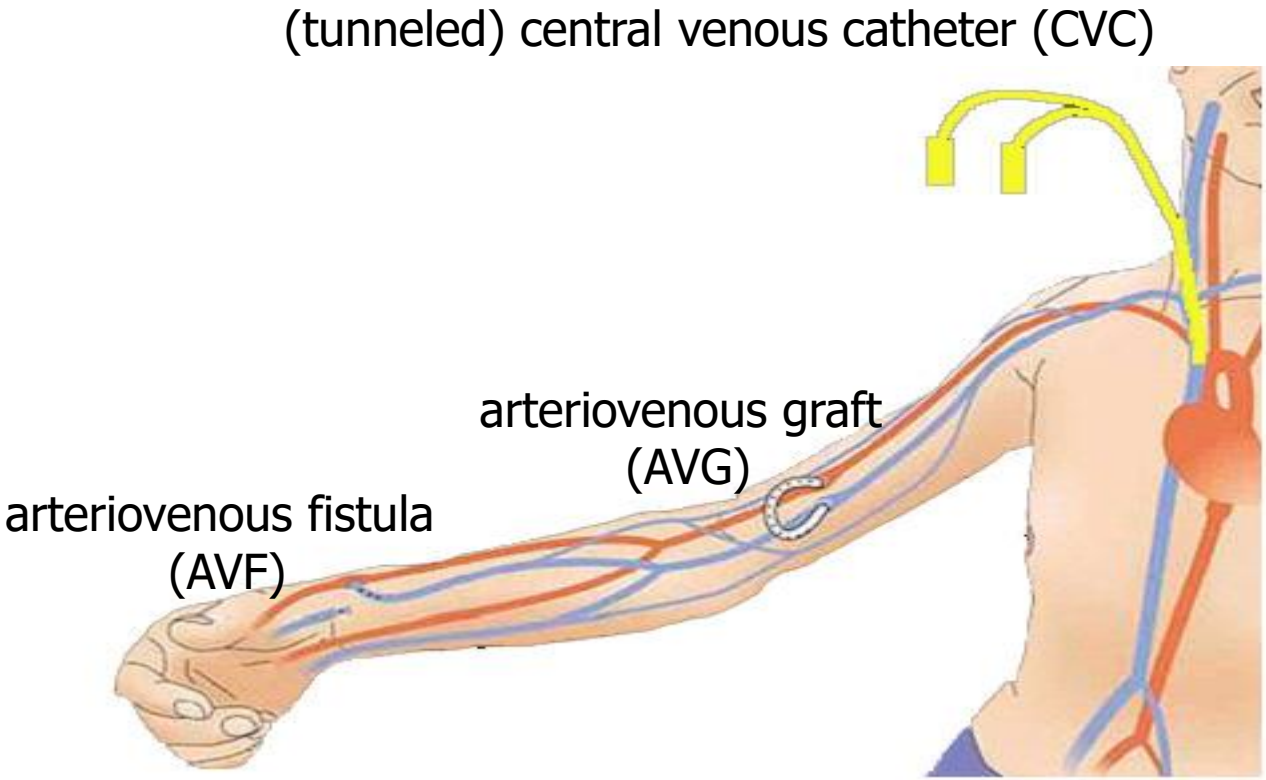
1943 1966 1985 2020

Brescia, Cimino, Appel

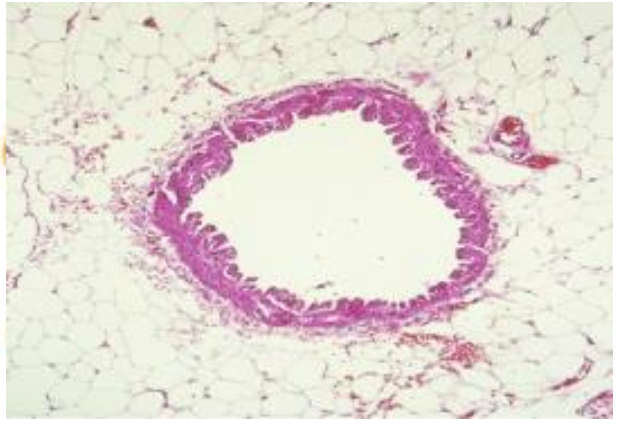
RCAVF: still the best option for most patients

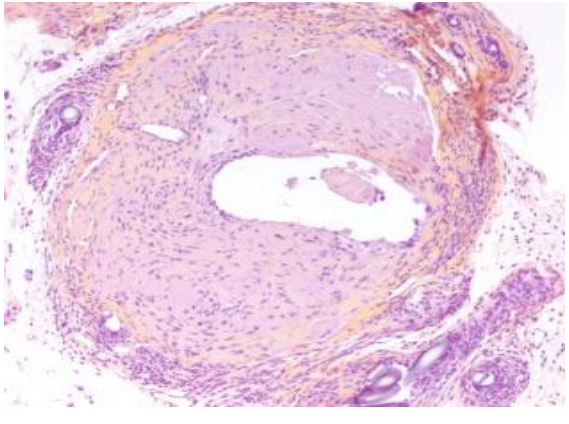
…..but with a high burden for patients !

Current options for vascular access

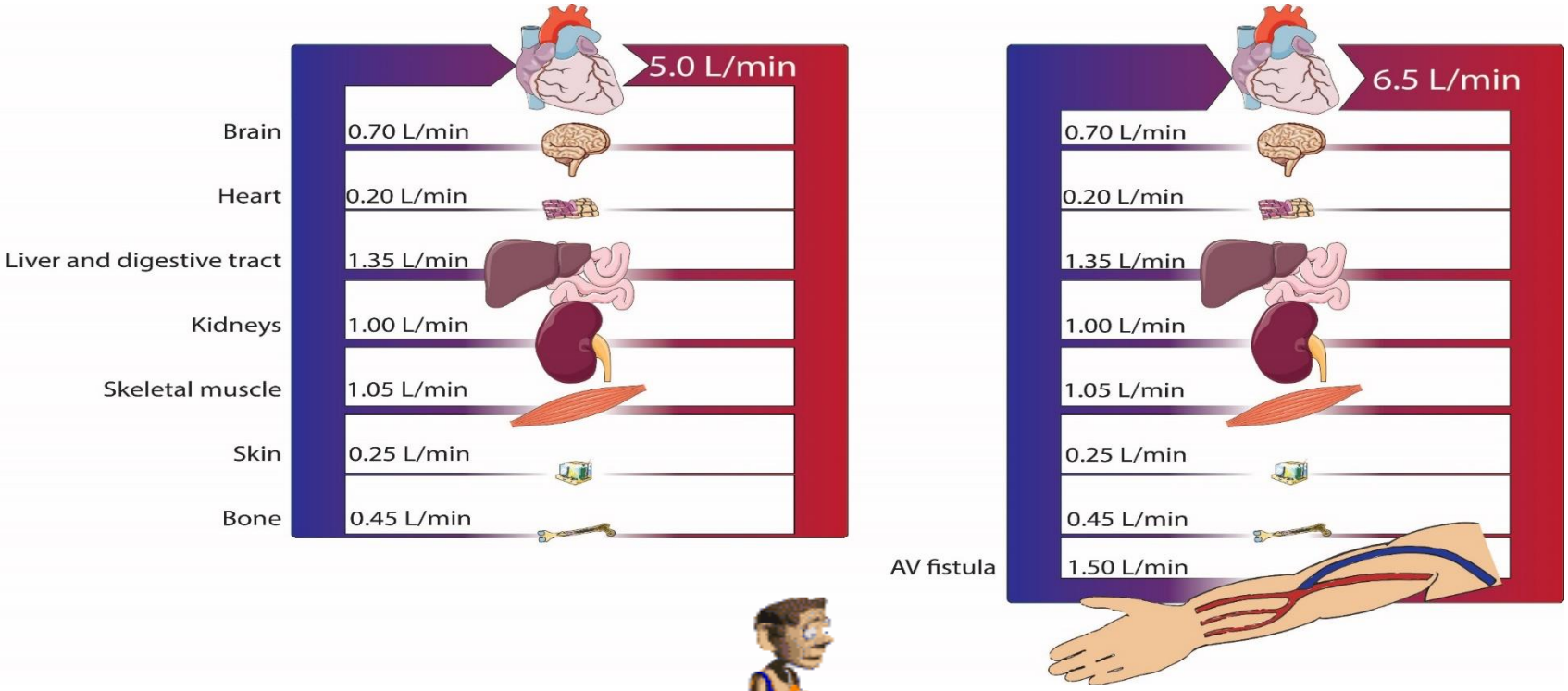


Arteriovenous fistulas are a non-physiological condition





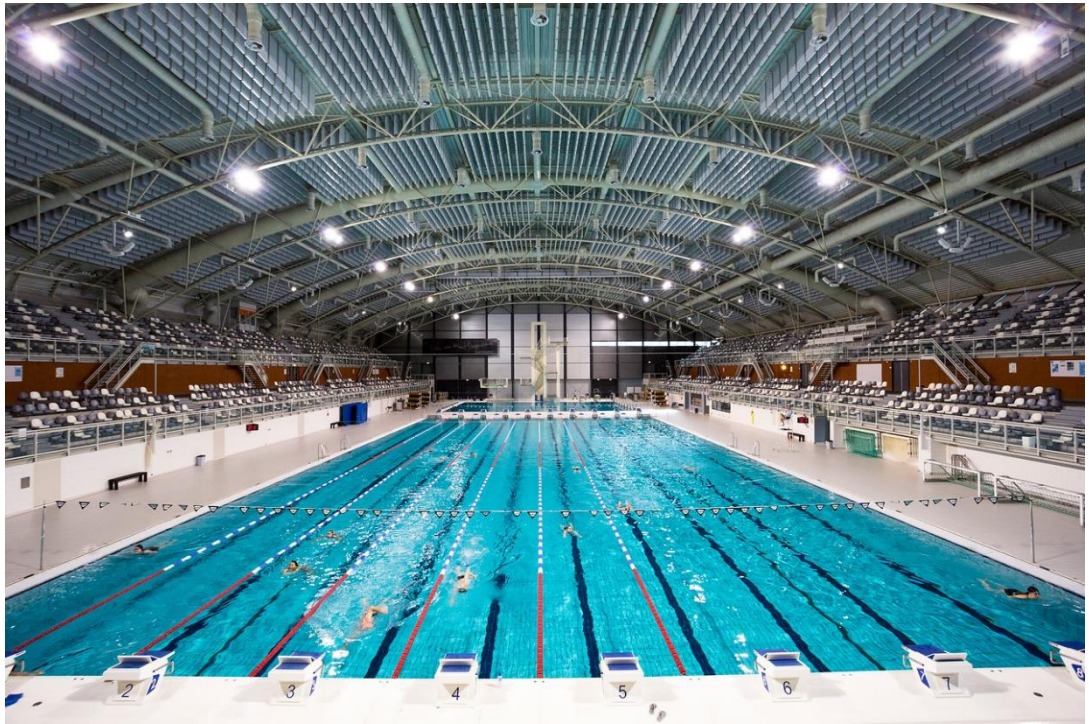
Effect of AVF on cardiac output



Voorzaat, Rotmans et al. J Vasc Access 2016

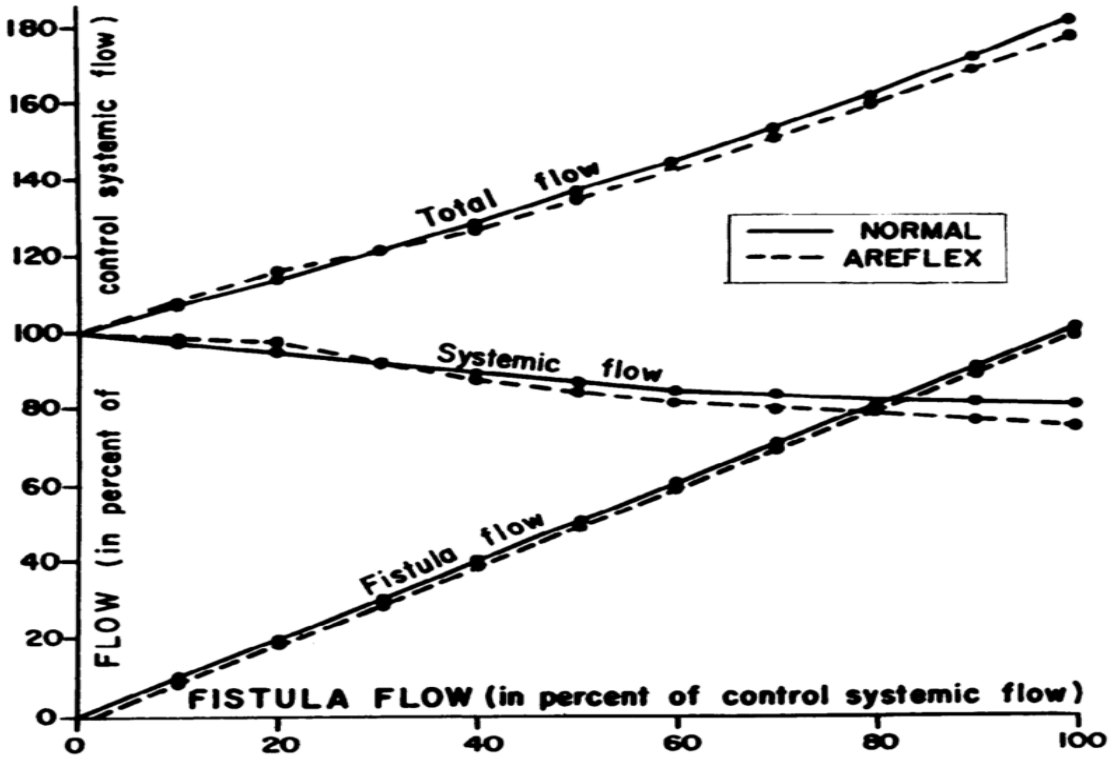
Excess cardiac output of BCAVF in HD patient

Blood flow during HD 350 ml/min:	**250 liters/week**
Required blood flow of AVF is 500 ml/min	**360 liters/week**
BCAVF flow	**2 liter/min**
	20.000 liters/week
	1 million liters/year
	2.5 million liters/2.5 year



Acute cardiac adaptation

20 dogs with AVF



Guyton et al. Am J Physiol 1961

AVFs in animal models of heart failure

Original Paper

Format: Abstract

Send to

Am J Physiol. 1979 May;236(5):H698-704.

Chronic arteriovenous shunt: evaluation of a model for heart failure in rat.

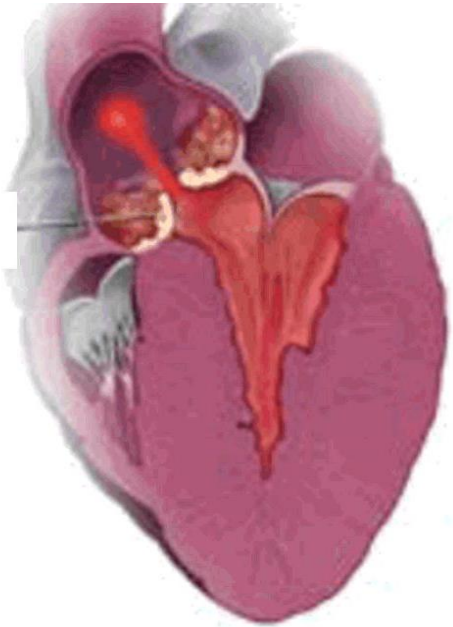
Flaim SF, Minteer WJ, Nellis SH, Clark DP.

Abstract

A model for high output heart failure (HCO) was developed in male, Sprague-Dawley rats using an abdominal aortocaval shunt equal to 50% of total cardiac output (CO) with 2 mo of postsurgical recovery. The model was evaluated by analysis of hemodynamics, peripheral blood flows (BF) (radioactive microspheres), and plasma catecholamine levels as well as mass and fluid content of organs. In HCO, CO and left ventricular end-diastolic pressure were increased with significant left and right ventricular hypertrophy. Mean blood pressure (BP) was unchanged, but pulse BP was increased in HCO. BF to skeletal muscle, cutaneous, and some splanchnic regions was reduced to HCO, whereas BF to the cerebral, coronary, and renal beds was protected. Plasma epinephrine and norepinephrine levels were significantly elevated in HCO suggesting enhanced sympathetic as well as adrenal catecholamine release. Tissue analysis indicated altered circulatory status secondary to HCO in liver, kidney, spleen, and lung. The results indicate that this model will be a relevant tool for studies of the circulatory effects of heart failure.

[a]Department of Cardiology and [b]Center for Cardiovascular Research, Institute for Clinical and Experimental Medicine – IKEM, Prague, and [c]Department of Physiology, 2nd Faculty of Medicine, Charles University, Prague, Czech Republic

Cardiac effects of AVF in patients with ESKD



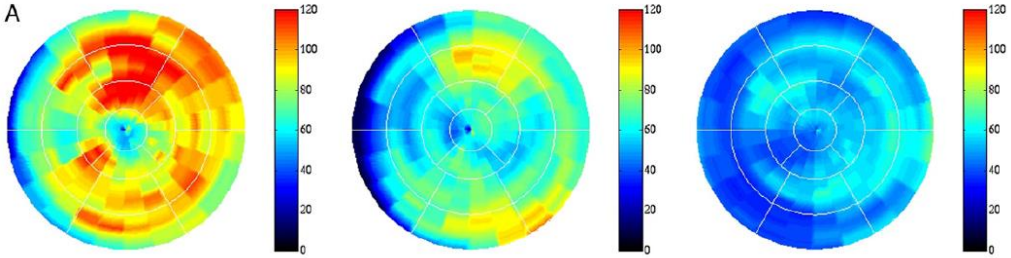
50 % has LVH

75 % has hypertension

50 % has coronary artery disease

Adverse cardiac effects of the hemodialysis procedure itself

Decrease in cardiac perfusion



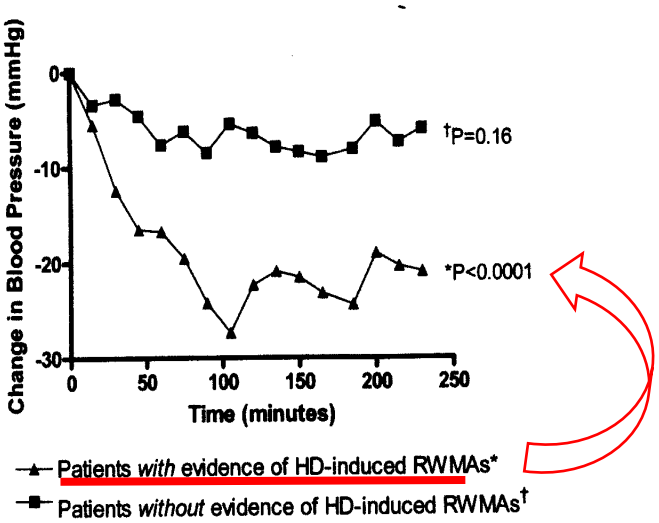
Before HD

30 min after start HD

220 min after start HD

Ultrafiltration of 3 liter from intravascular compartiment !

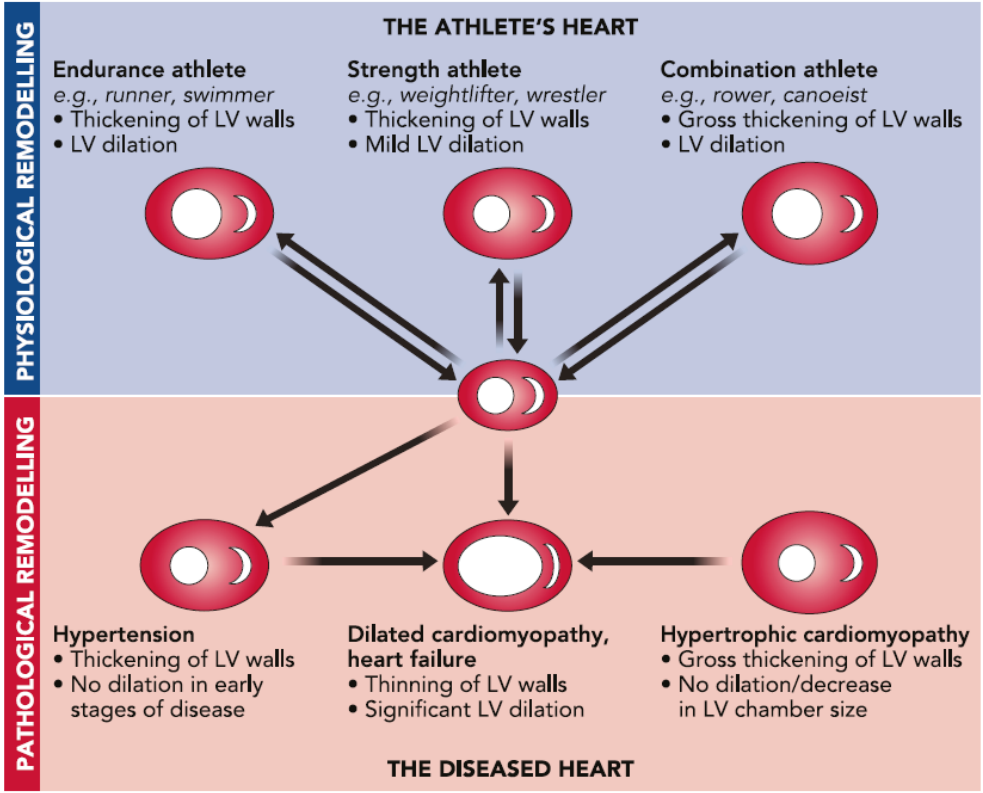
Intradialytic hypotension



Assa et al. AJKD 2012

Burton et al; cJASN 2009

Cardiac responses to a (chronic) hyperdynamic circulation



THE ATHLETE'S HEART

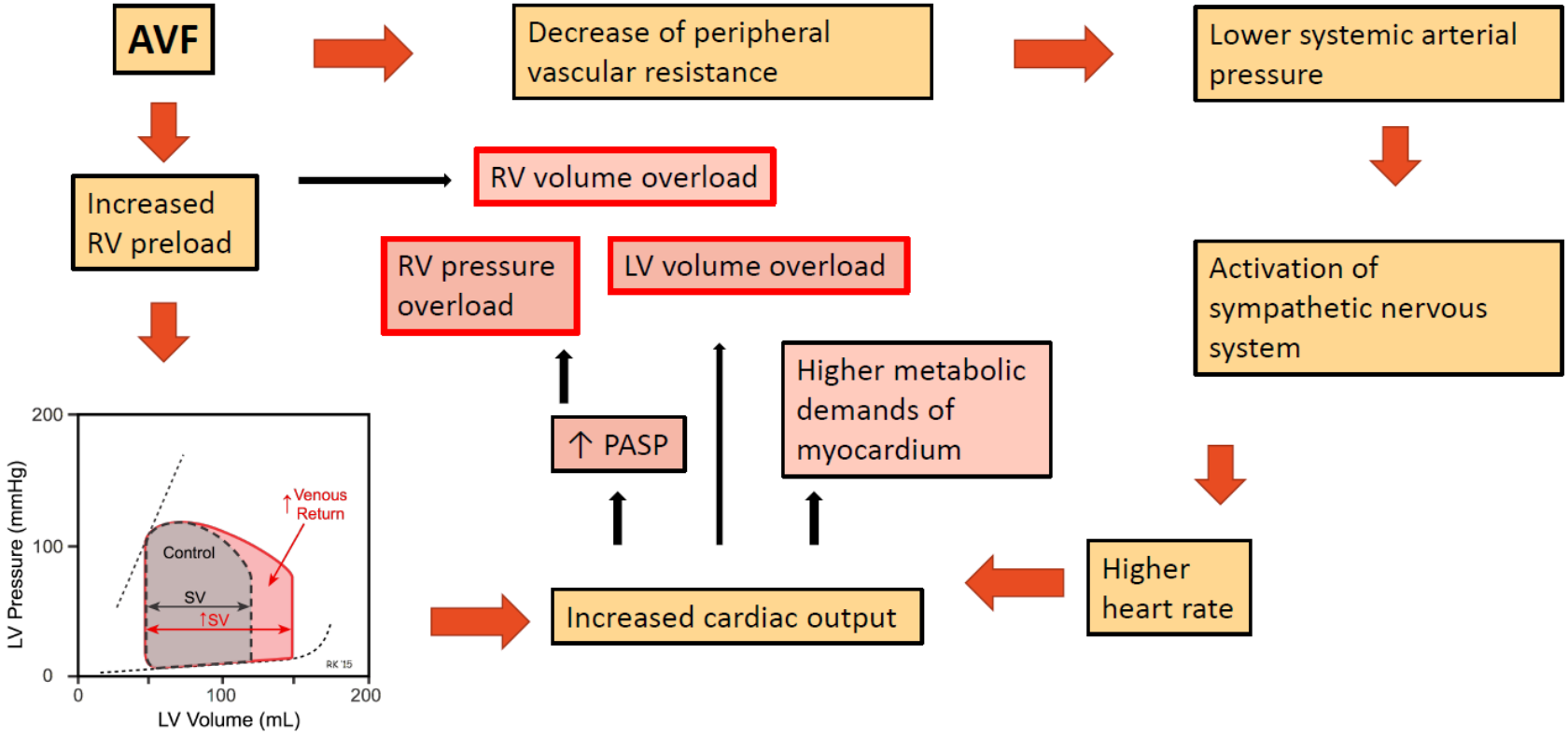
- Increased heart mass
- Normal cardiac function
- Reversible

THE FAILING HEART

- Increased heart mass
- Reduced cardiac function
- Irreversible
- Cell death and fibrosis
- Increased mortality

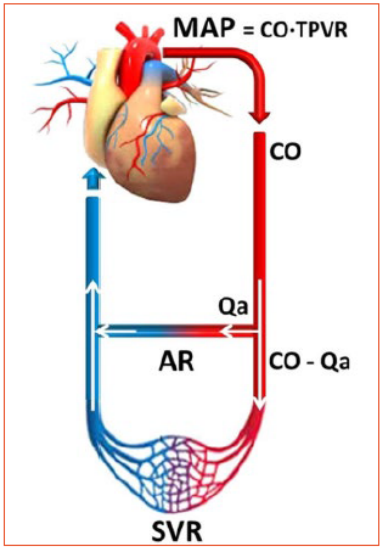
Weeks at el. Physiology 2011

Cardiac response upon AVF creation



Courtesy of Jan Malik

Cardiac output and access flow volume (Qa)



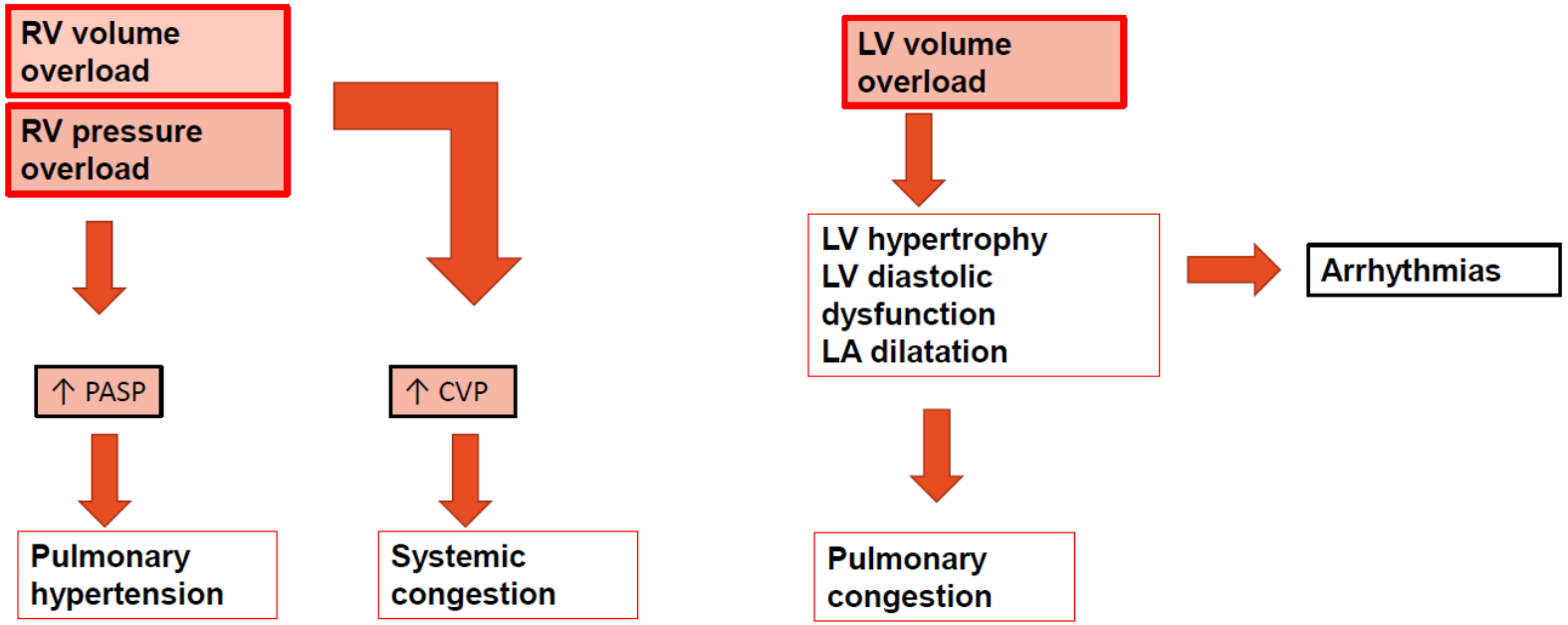
- Effective CO: $CO_{ef.} = CO - Qa$
- Effective cardiac index ($CI_{ef.}$)

$AR = \Delta P / Qa$

- High-flow AVF:
  - >1500-2000 ml/min
  - Qa > 1/3 of CO

Basile et al. Sem Dial 2018

Creation of AVF: potential consequences



Courtesy of Jan Malik

Casus

74-year-old patient

Medical history: T2DM, CABG, femoropopliteal bypass

eGFR 12 ml/min, anticipated start HD in 4 months

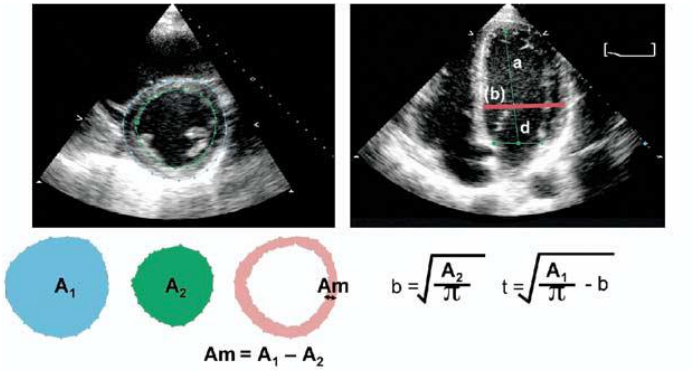
Which cardiac information do we need to determine the preferred type of access?

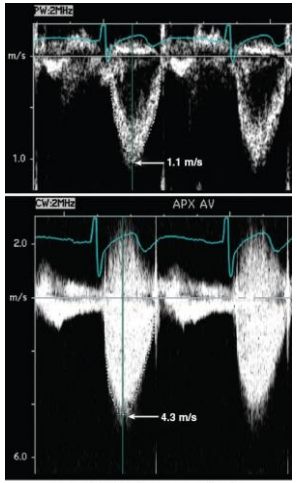
Pre-operatieve cardiale evaluatie

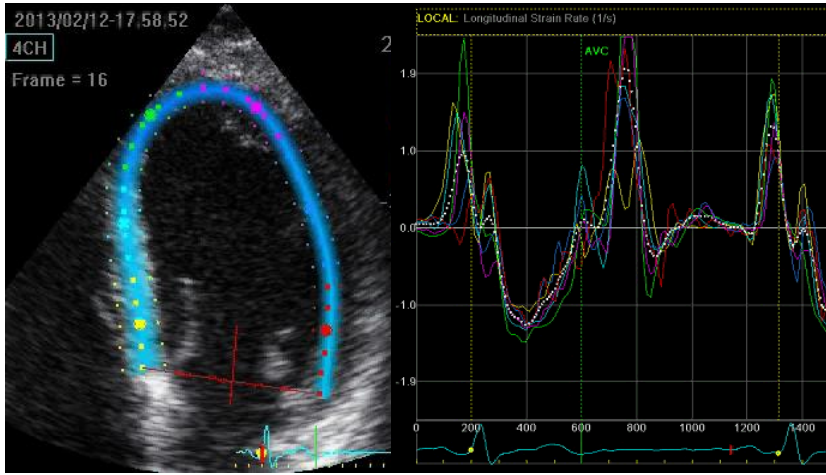
- Welke patiënten screenen?
- Hoe te screenen ?
- Wanneer een shunt vermijden vanwege cardiale disfunctie ?

How to evaluate cardiac function in HD patients?

- echocardiography
  - structure (dimensions)
  - myocardial function (visually, endsystolic volume, ejection fraction, strain, diastology)
  - flow: cardiac output, pressure estimation







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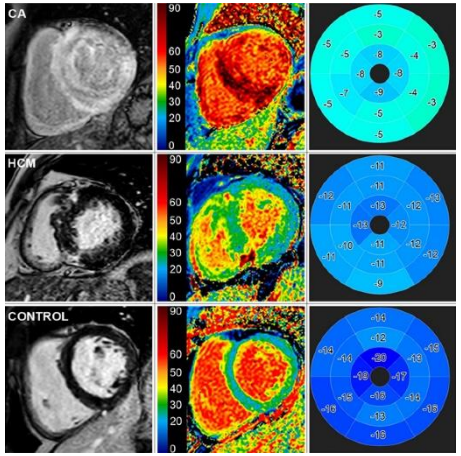
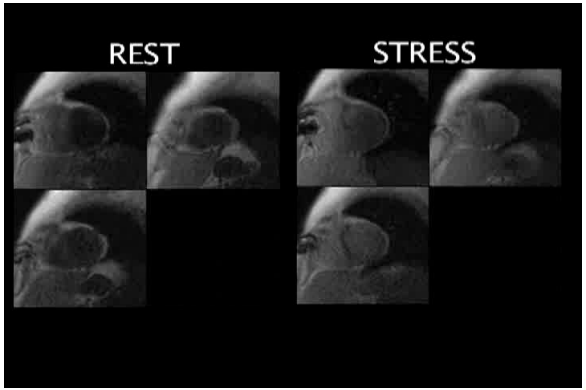
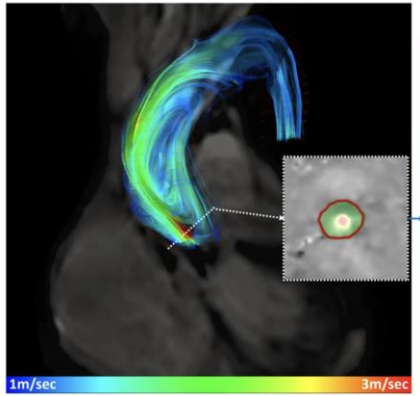
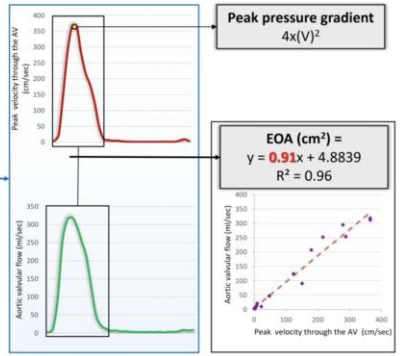
How to evaluate cardiac function in HD patients?

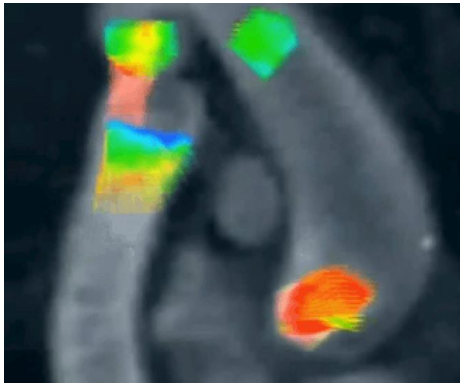
- cardiale MRI
  - tissue characterization (T1, T2-mapping, DGE)
  - flow (perfusion, bloodflow, flow-dynamics)





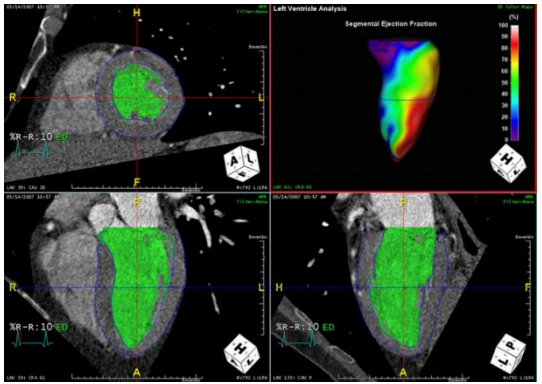


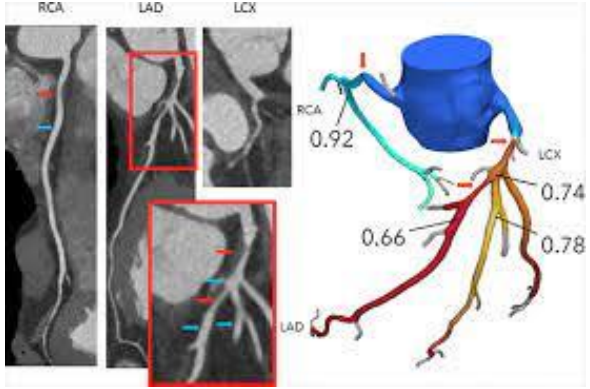




How to evaluate cardiac function in HD patients?

- Cardiac CT
  - calciumscore
  - coronary angiography, including functional flow reserve (perfusion)
  - dimensions (volume, mass)





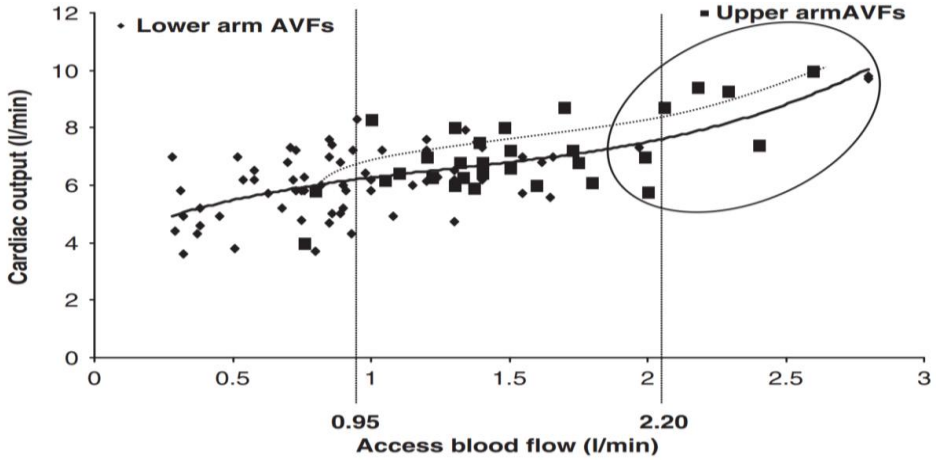
- Invasive hemodynamics and angiography by cardiac catheterization

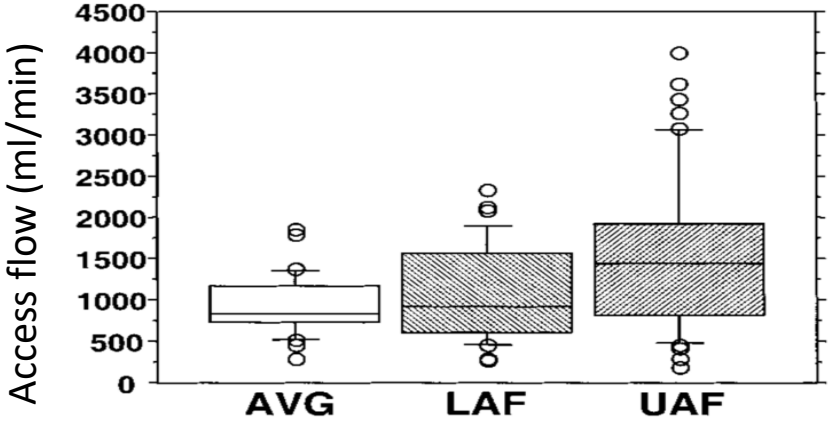
Suggestions for management

Cardiac work up prior to access creation

- Cardiac history
- ECG
- NT-proBNP
- Echocardiography
  - LV mass, LV systolic and diastolic function
  - Estimation of SV and cardiac output
  - Estimation of pulmonary pressures
- (cardiac CT)
- (cardiac MR)
- (diagnostic HC)

Access flow and cardiac output



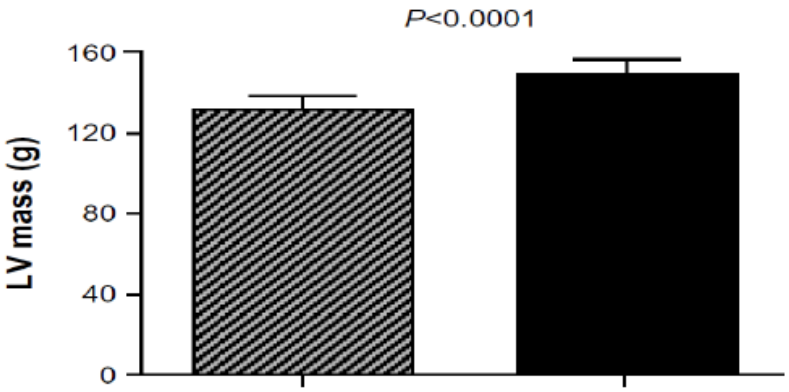


Basile, et al. Nephrol Dial Transplant 2008

Dixon, et al. Am J Kidney Dis 2002.

Increased LV mass following AVF creation

Mean brachial artery flow: 1.158 ± 0.44 L/min



Pre-AVF 6 months post AVF

132 ± 32 g 149 ± 35 g

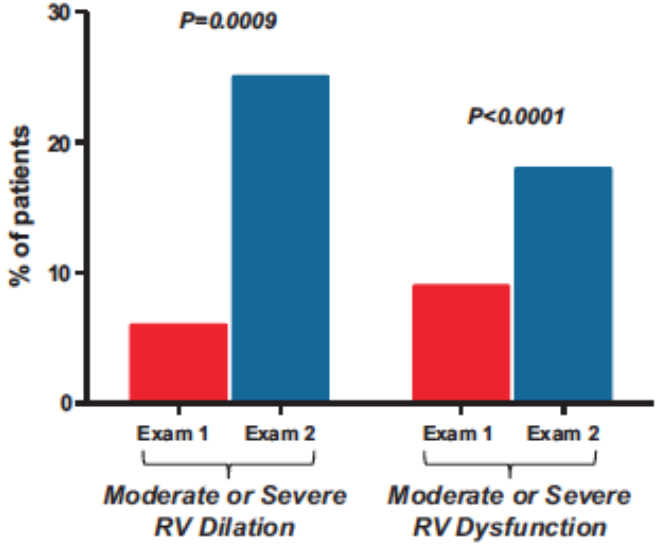
+13%

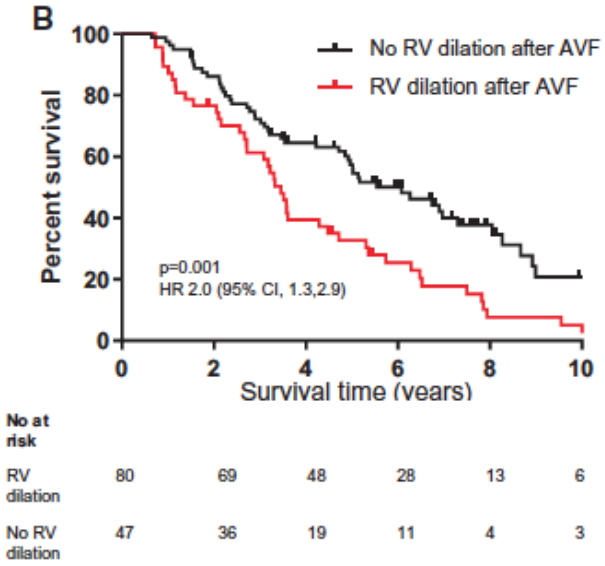
Table 2 Summary of changes in cardiac structure and function following fistula-creation

Cardiac structure and function	Baseline	Post-fistula-creation	*P*-value
LV end-systolic size (mL)	43±16	52±24 (up 21%)	*P*=0.014
LV end-diastolic size (mL)	149±31	175±43 mL (up 17%)	*P*<0.0001
LVEF (%)	72±7	71±9	*P*=0.60
LVSV (mL)	107±24	124±29 (up 16%)	*P*<0.0001
LV CO (L/min)	7.5±1.5	9.4±2.2 (up 25%)	*P*<0.0001
LVM (g)	132±32	149±35 (up 13%)	*P*<0.0001
RV end-systolic size (mL)	49±14	56±18 (up 15%)	*P*=0.0014
RV end-diastolic size (mL)	142±32	167±42 (up 18%)	*P*<0.0001
RVEF (%)	66±5	67±6	*P*=0.45
RVSV (mL)	93±24	112±27 (up 20%)	*P*<0.0001
LA (cm^2)	27±6	30±6 (up 11%)	*P*=0.0003
RA (cm^2)	23±6	25±6 (up 9%)	*P*=0.0046

Dundon, et al. Int J Nephrol Renovasc Dis 2014

Right ventricular dysfunction upon AVF creation





Reddy et al. Eur Heart Journal 2017

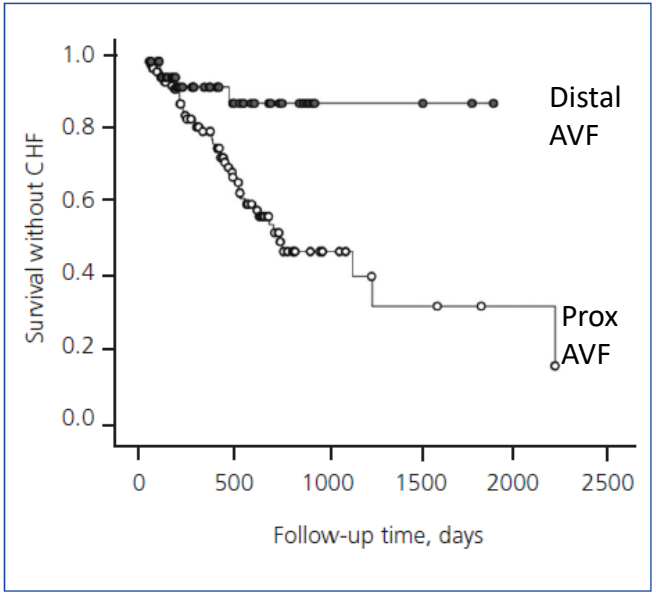
A functioning AVF is a risk factor for decompensated heart failure

n = 562 HD patients

Table 2. Influential factors in the development of decompensated heart failure in our patients, as determined by multiple logistic regression

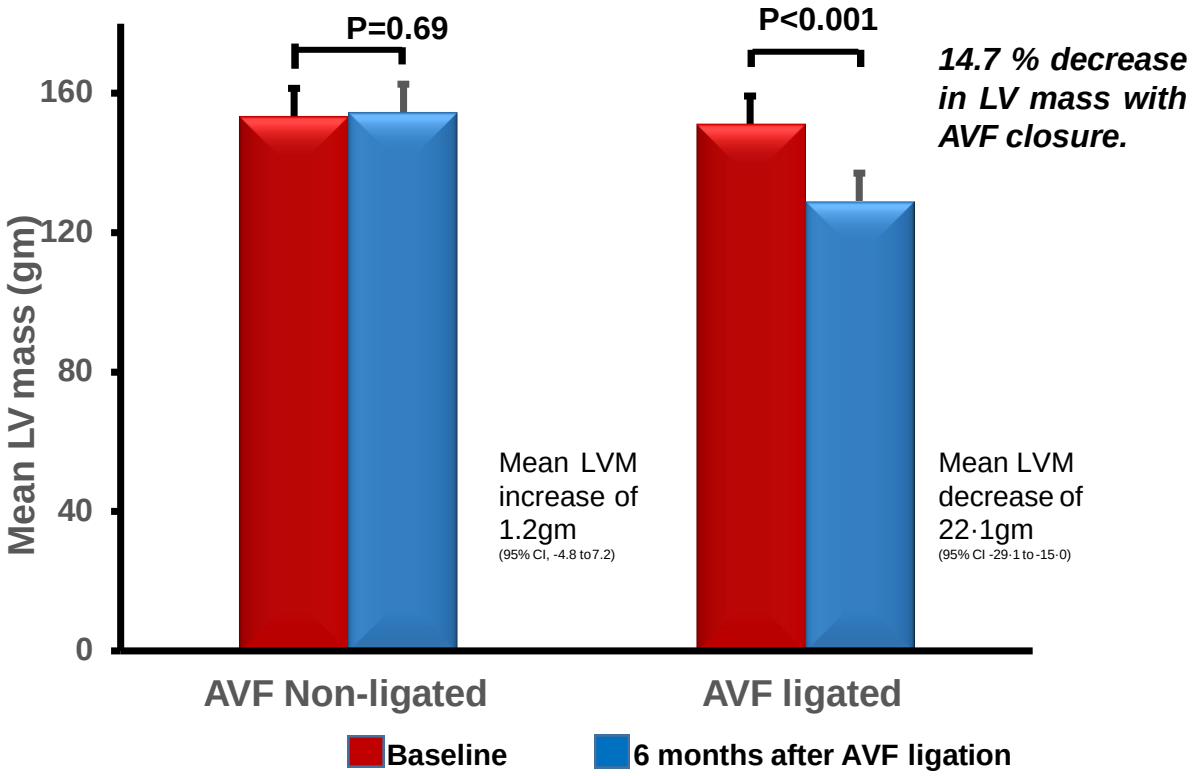
Variable	OR	95% CI OR	*P*
Age, years	1.052	1.022; 1.082	<0.0001
Sex (male 1, female 0)	0.523	0.308; 0.888	0.016
Systolic blood pressure (mm Hg)	1.013	1.002; 1.023	0.017
Baseline GFR (ml/min/1.73m^2)	1.101	1.039; 1.167	0.001
History of ischaemic heart disease (0.1)	2.488	1.276; 4.852	0.007
History of CHF (0.1)	2.517	1.283; 4.939	0.007
History of atrial fibrillation (0.1)	2.820	1.304; 6.101	0.008
Beta blockers (0.1)	1.805	1.010; 3.224	0.046
Functioning AVF (0.1)	9.541	4.841; 18.806	<0.0001

Variables that were not included in the equation: comorbidity index, body mass index, diastolic blood pressure, haemoglobin, phosphorous, calcium, bicarbonate, albumin, parathyroid hormone, diabetes, cerebral ischaemia, peripheral ischaemia, chronic obstructive pulmonary disease, treatment with angiotensin-converting enzyme inhibitors/angiotensin receptor blockers, and treatment with erythropoietin.
AVF: arteriovenous fistula; GFR: glomerular filtration rate; CI: confidence interval; CHF: congestive heart failure; OR: odds ratio.



Martínez-Gallardo et al Nefrologia 2012

AVF ligation result in reduction in LV mass



Indexed to BSA, the LV mass reduction was 11·8 gm/m² (95 % CI 15·2 to 7·8, p<0.001)

Rao et al. Circulation 2019

Case

74 year old patient

Medical history: T2DM, CABG, femoropopliteal bypass

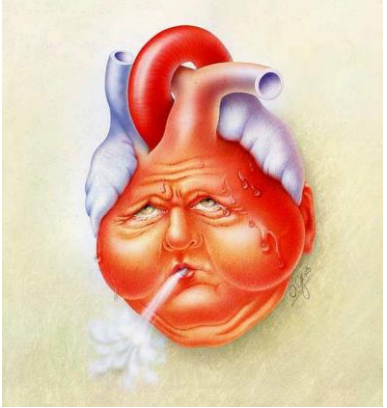
eGFR 12 ml/min, anticipated start HD in 4 months

Received a brachiocephalic fistula as he had no suitable vessels for an RCAVF

AVF flow is 2500 ml/min, no cardiac symptoms

Is an AVF of 2.5 liter too much for him?

When is a high flow AVF considered too high?



No strict definition

Symptoms of heart failure

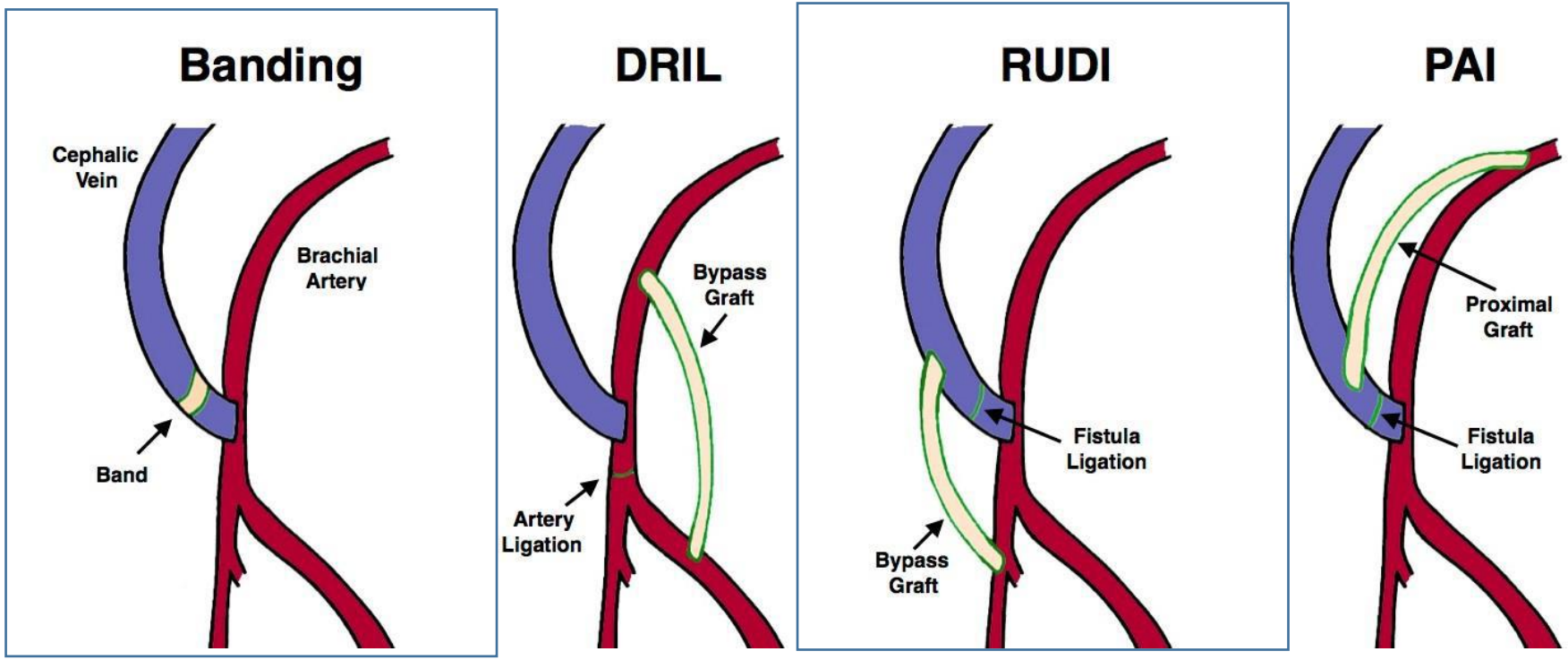
+

- AVF blood flow (Qa) > 1500-2000 ml/min
- Qa > 30% of cardiac output

How to intervene?

Basile et al. NDT 2008, MacRae et al. AJKD 2004

Flow reducing interventions



DRIL – a distal revascularization and interval ligation

RUDI – revision using distal inflow

PAI – proximalization of the arterial inflow

Suggesties voor beleid

Cardiale follow up

Jaarlijkse cardiale controle bij patiënten met een flow > 2.0 liter/min

Corrigeer de flow als de echocardiografische afwijkingen mogelijk gerelateerd zijn aan de shunt

Corrigeer de flow in asymptomatische patienten als de flow > 3 liter/min is.

* Richtlijn vaattoegang hemodialyse 2022

Flow reducerende interventies

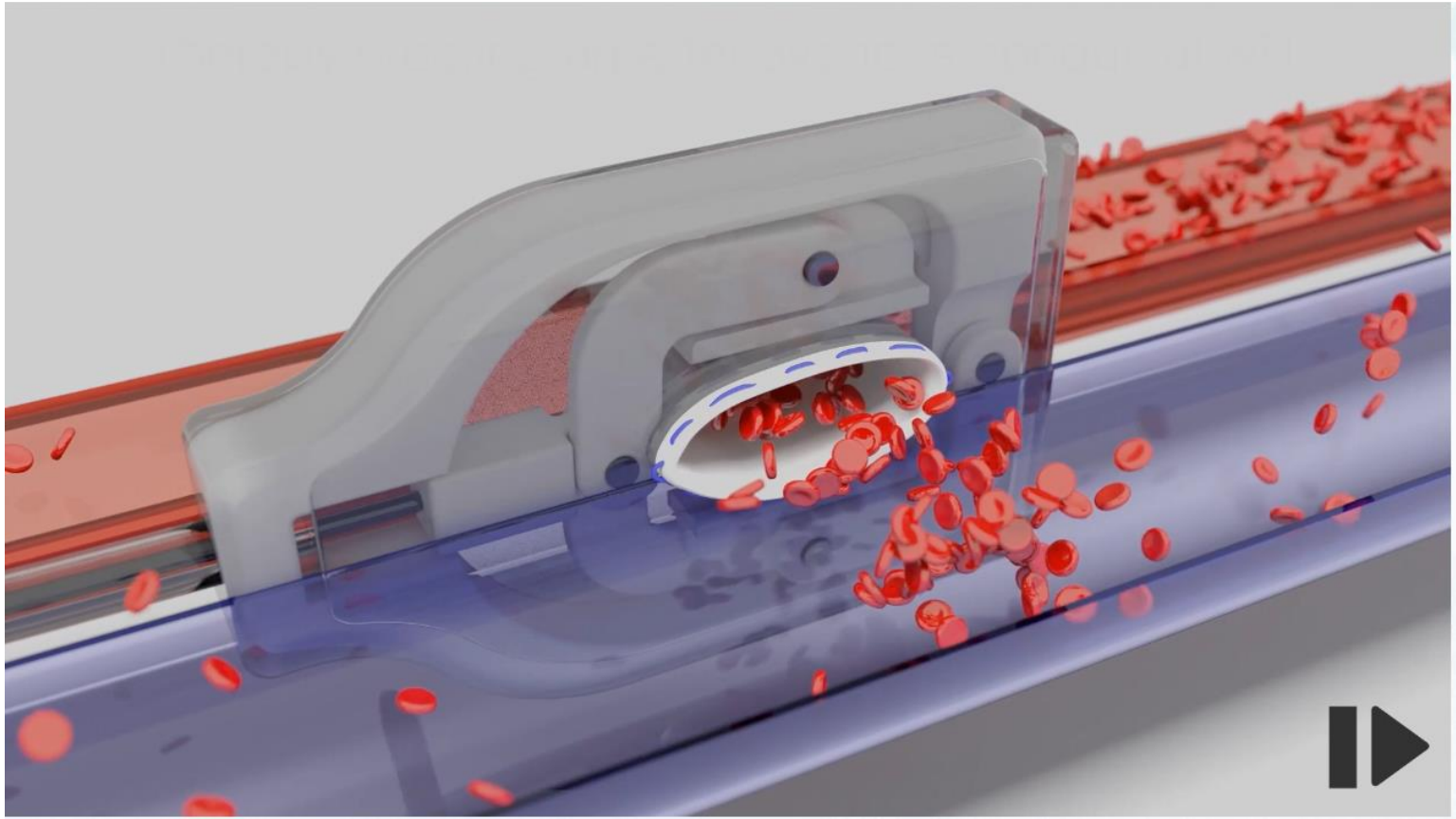
Operatietechniek voor flow reductie: banding of RUDI?

Voer een banding van de arterioveneuze fistel of een revision using distal inflow (RUDI) operatie uit wanneer een flow reductie van een high-flow vaattoegang is geïndiceerd.

Overweeg om bij jongere patiënten de RUDI operatie uit te voeren, omdat dit mogelijk leidt tot een duurzamere flow reductie in vergelijking met een banding van de arterioveneuze fistel.

Overweeg om bij patiënten met een verhoogd operatief risico een banding van de arterioveneuze fistel uit te voeren, omdat deze operatie onder lokale verdoving kan worden uitgevoerd

The Dynamic AVF: option for the future?



CVCs as dialysis access

FISTULA FIRST
CATHETER LAST

2006

The ESKD life PLAN

provides a patient's individualized lifetime map of dialysis modalities by creating a "P-L-A-N" (patient life-plan first, then access needs)

Right access for the right patient at the right time

2019

Lok et al. K-DOQI guidelines on vascular access 2019

Is this the right access for this patient?

AJKD

Case Report

Successful Hemodialysis Arteriovenous Fistula Creation in a Patient With Continuous-Flow Left Ventricular Assist Device Support

Andrew I. Chin, MD,[1] Kathleen Tong, MD,[2] and John P. McVicar, MD[3]

Heart failure necessitating left ventricular assist device (LVAD) support can lead to kidney failure requiring dialysis. Some of these patients may require long-term hemodialysis (HD). Optimal vascular access for a patient on long-term HD therapy with an LVAD remains a complex issue. The majority of LVADs are of the continuous-flow type, and it has been theorized that native arteriovenous fistula maturation may be impaired in a setting of decreased pulsatile arterial flow. We describe a case of successful creation and use of an arteriovenous fistula in an HD-dependent patient with a continuous-flow LVAD.

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INDEX WORDS: Left ventricular assist device (LVAD); arteriovenous fistula (AVF); dialysis access; vascular access; hemodialysis; heart failure; end-stage renal disease; case report.

Vascular access in HD patients with cardiac failure

TABLE I - Proposed approach to select the vascular access in end-stage renal disease patients with heart failure at hemodialysis inception

Clinical presentation	Type of vascular access proposed
NYHA Class I, II and certain III	Distal arm AVF
ACC/AHA Stage A, B and certain C	Distal arm AVF
Most NYHA Class III and ACC/AHA Stage C	TCC
NYHA Class IV and ACC/AHA Stage D	TCC
LVEF <30%	TCC
Life-threatening pulmonary edema	UCC

Roca-Tey Journal of Vascular Access 2016

Conclusies

Arterioveneuze fistels resulteren in een hyperdynamische circulatie, die bedraagt aan de ontwikkeling van linkerventrikel hypertrofie en pulmonale hypertensie

Voorkom AV fistels met een hoge flow in patiënten met cardiale disfunctie

Pre-operatieve consultatie door een cardioloog in hoog-risico patiënten

Flow reducerende ingrepen zijn vaker geïndiceerd dan we geneigd zijn te doen

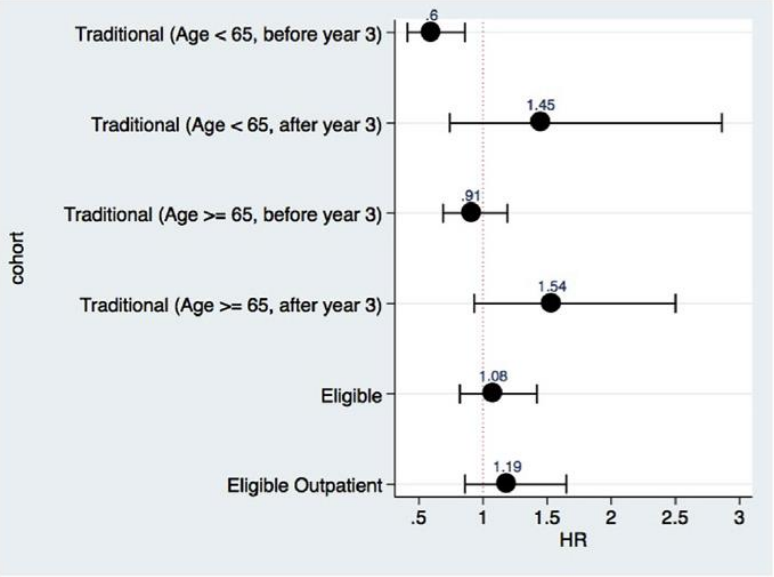
Een centraal veneuze catheter is een betere optie voor patienten met ernstig hartfalen

Would PD be a better option? Not necessarily

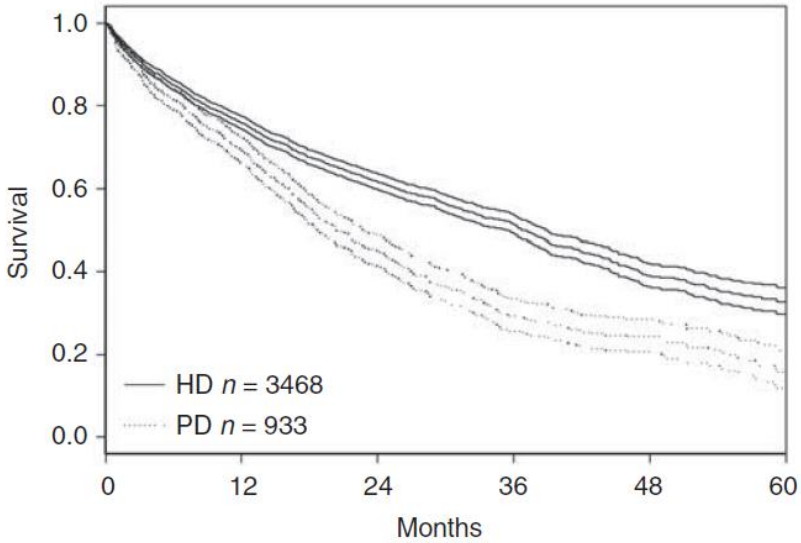
Cardiovascular burden of dialysis: PD vs HD

Patients with heart failure seem to have lower survival on PD compared to HD

Canadian registry
(2000 dialysis patients)



French registry
(4500 dialysis patients with heart failure)



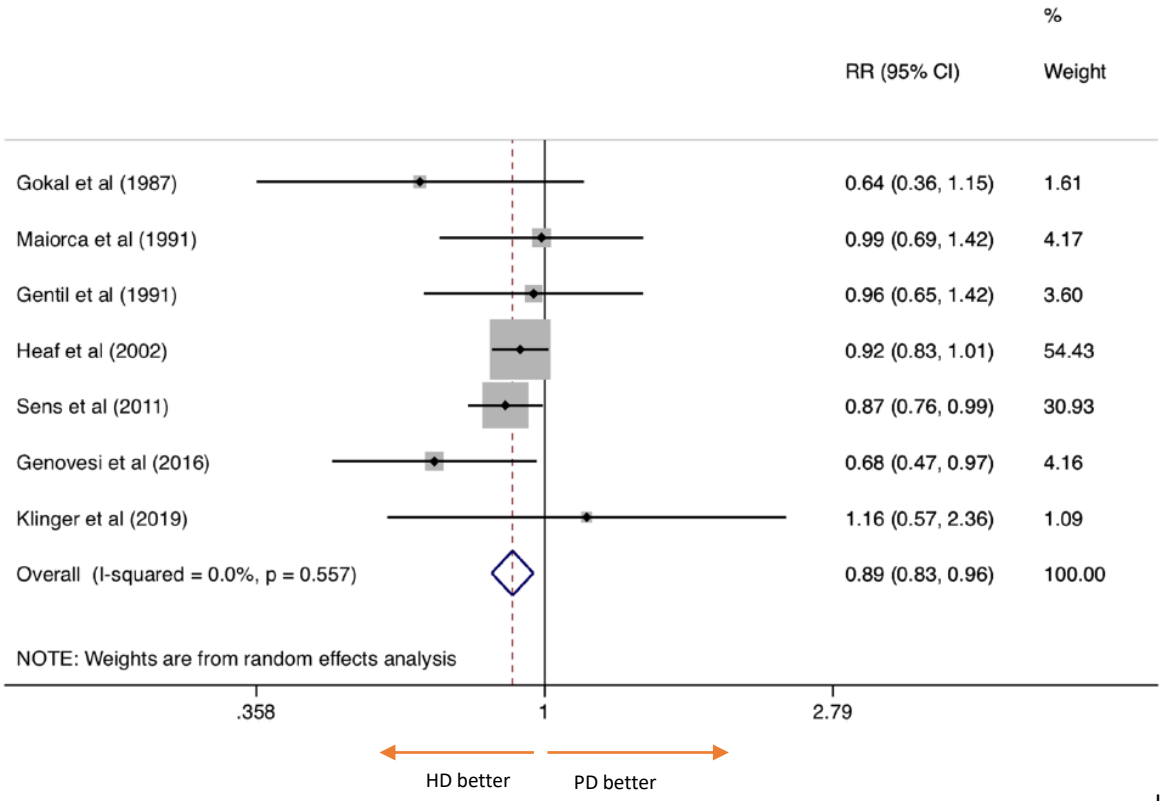
Wong et al. AJKD 2017

PD better ← → HD better

Sens et al. Kidney Int 2011

Would PD be a better option? Not necessarily

Patients with heart failure have higher risk of CV death on PD compared to HD



- Fluid overload in PD?
- Glucose exposure?
- Residual confounding?

Hang Ng et al. Int J of Urology and Nephrology 2021