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Updated Surveillance and Monitoring of Vascular Access Function

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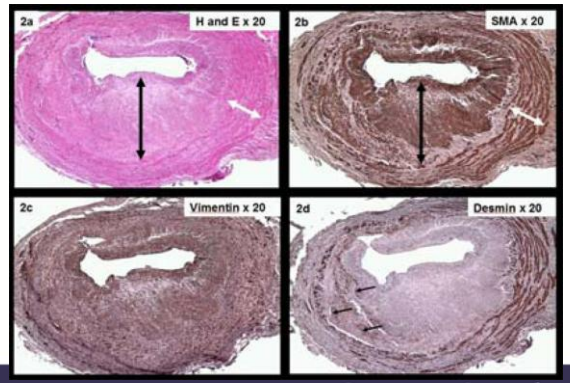
Pathogenesis of stenosis

- Dialysis vascular accesses, arteriovenous fistula (AVF) and graft (AVG), are man-made structures created for the sole purpose of dialysis
- Neo-intimal hyperplasia within the dialysis vascular access circuit is the main pathophysiology reason for access failure



Roy-Chaudhury et al. Am J Kidney Dis 2008

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Burden of vascular access dysfunction

- Missed hemodialysis session
- Hospitalisation
- Urgent interventions to restore patency
- Permanent loss of function requiring new access creation

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Burden of dialysis dysfunction

Top 2 diagnosis for admission to renal department in SGH	2020 admission n = 1291	2021 admission n = 1263	2022 admission n = 2141	2023 admission n = 1878
1st	Other complications of cardiac and vascular prosthetic devices, implants and grafts = 523 (40.5%)	Other complications of cardiac and vascular prosthetic devices, implants and grafts = 590 (46.7%)	Other complications of cardiac and vascular prosthetic devices, implants and grafts = 446 (20.8%)	Other complications of cardiac and vascular prosthetic devices, implants and grafts =548 (29.1%)
2nd	Type 2 diabetes mellitus with established diabetic nephropathy = 103	Type 2 diabetes mellitus with established diabetic nephropathy = 161	Fluid overload =214	Fluid overload = 194

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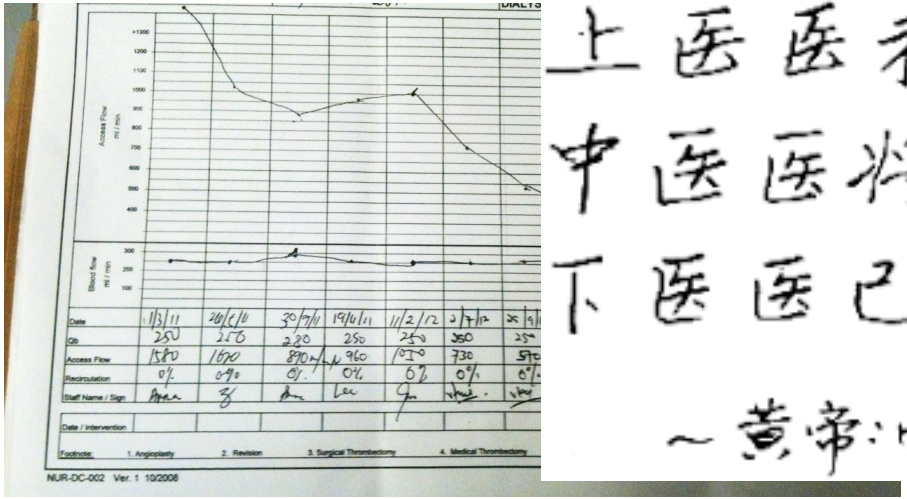
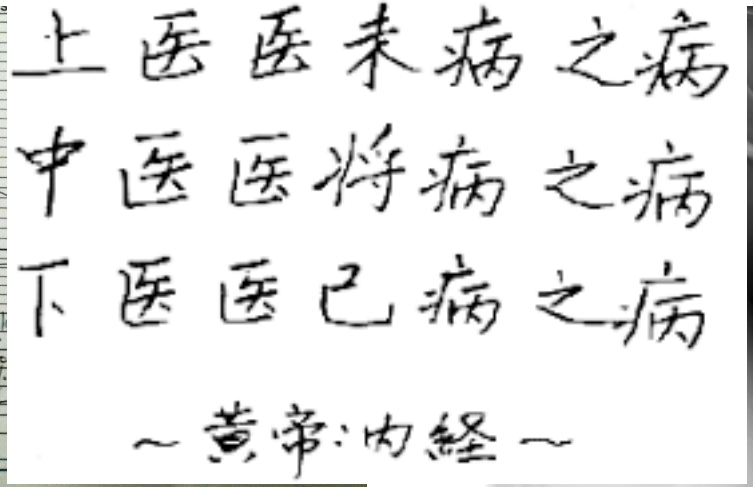
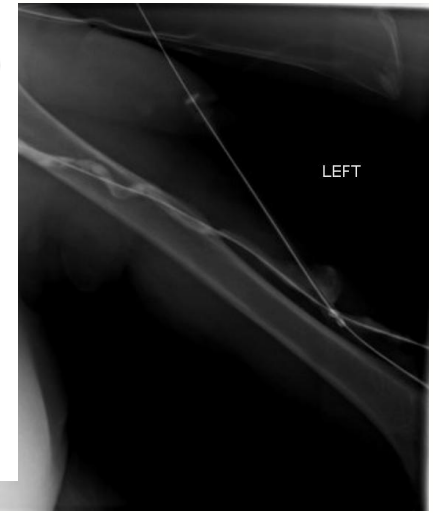
Is surveillance useful to prevent access dysfunction?







Surveillance with access flow → Intervention to prevent → Thrombosis

KDOQI 2006 vs KDOQI 2019

KDOQI	Surveillance AVG	Surveillance of AVF
2006	Recommend: • Intra access flow measurement • Directly measured of derived static venous dialysis pressure • Duplex ultrasound	Recommend: • Direct flow measurement • Duplex ultrasound • Abnormal physical examination findings
2019	KDOQI does not suggest routine AVG surveillance by measuring access blood flow, pressure monitoring or imaging for stenosis, that is additional to regular clinical monitoring, to improve AVG patency	Inadequate evidence for KDOQI to make a recommendation on routine AVF surveillance by measuring access blood flow, pressure monitoring or imaging for stenosis, that is additional to routine clinical monitoring to improve access patency

KDOQI 2006 vs KDOQI 2019

KDOQI	Surveillance AVG	Surveillance ofAVF
2006	Referral for diagnostic and Interventions: • Not based on single abnormal reading but trend • An access flow rate less than 600 mL/min • A venous segment static pressure (mean pressures) ratio greater than 0.5 • An arterial segment static pressure ratio greater than 0.75	Referral for diagnostic and Interventions: • Not based on single abnormal reading but trend • An access flow rate less less than 400 to 500 mL/min • A venous segment static pressure (mean pressures) ratio greater than 0.5
2019	• Does not recommend pre-emptive angioplasty of AVG with stenosis, not associated with clinical indictors to improve access patency • Reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo pre-emptive angioplasty of their AV access to reduce risk of thrombosis and AV access loss	• Does not recommend pre-emptive angioplasty of AVG with stenosis, not associated with clinical indictors to improve access patency • Reasonable for patients with consistently persistent clinical indicators and underlying AV access stenosis to undergo pre-emptive angioplasty of their AV access to reduce risk of thrombosis and AV access loss

ESVS 2018 vs KDOQI 2019

	Surveillance AVG	Surveillance of AVF
European Society of Vascular Surgery 2018	It is recommended that vascular access surveillance is performed by flow measurement of arteriovenous grafts monthly	It is recommended that vascular access surveillance is performed by flow measurement of arteriovenous fistulas every 3 months.
KDOQI 2019	KDOQI does not suggest routine AVG surveillance by measuring access blood flow, pressure monitoring or imaging for stenosis, that is additional to regular clinical monitoring, to improve AVG patency	Inadequate evidence for KDOQI to make a recommendation on routine AVF surveillance by measuring access blood flow, pressure monitoring or imaging for stenosis, that is additional to routine clinical monitoring to improve access patency

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ESVS 2018 vs KDOQI 2019

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Surveillance with pre-emptive angioplasty

- Balloon angioplasty, which is used to treat stenosis, also induced endothelial injuries, resulting in recurrent stenosis
- Balloon angioplasty may not correct the underlying etiology of neointimal hyperplasia

- Angioplasty is a mechanical solution for a “biological” problem
  - Recurrence post angioplasty is high

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Patency rate with current angioplasty technique

- Percutaneous transluminal angioplasty (PTA) has been the standard of care for AV access stenosis

	6-month Patency	
	AVF	AVG
Plain old balloon angioplasty (POBA)	61%	21%
High-pressure balloon	40%	23%
Cutting balloon	68%	38%

J Vasc Interv Radiol 2016;27:1518–1530 .

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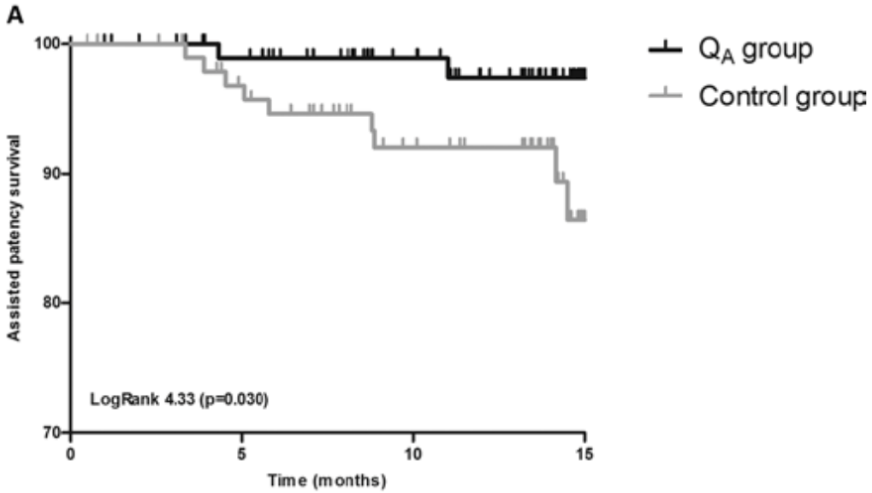
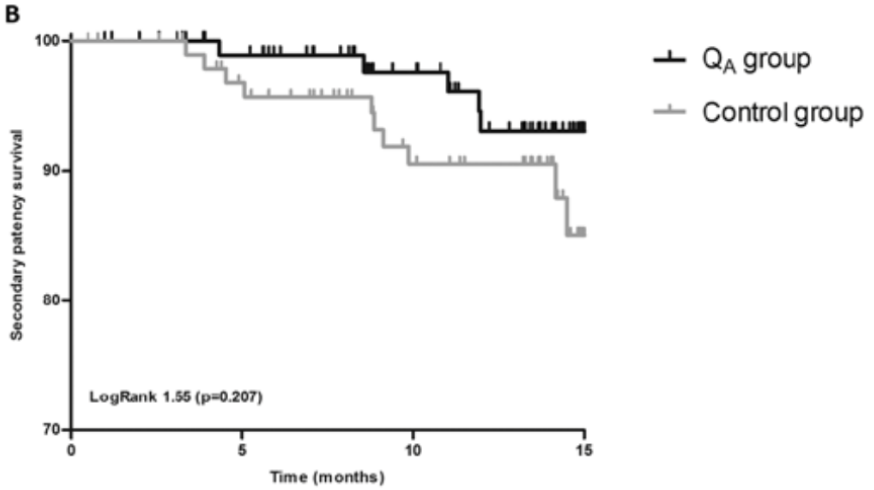
Surveillance + pre-emptive angioplasty





Patients: 196 chronic hemodialysis patients
Intervention: Monitoring + dialysis parameter
Control: Monitoring + dialysis parameter + ultrasound + transonic
Outcome: Reduced thrombosis rate but no difference in secondary patency

J Vasc Access 2016; 17 (1): 13-19

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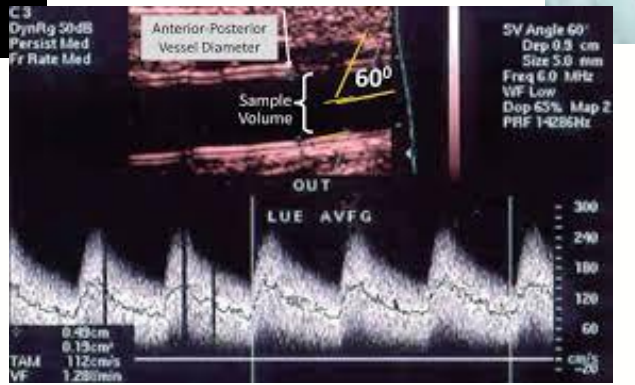
So should we do surveillance?



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Monitoring vs Surveillance

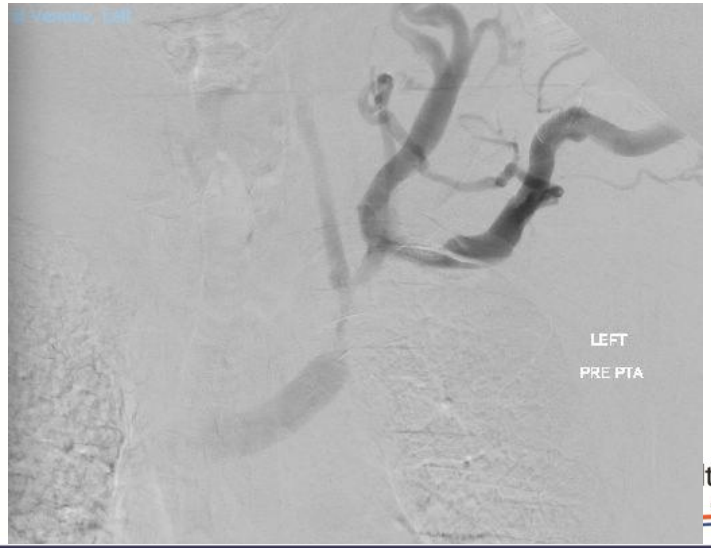
Table 13.2. Clinical Indicators (Signs and Symptoms) Suggesting Underlying Clinically Significant Lesions During Access Monitoring

Procedure	Clinical Indicators	
Physical examination or check	• Ipsilateral extremity edema	354,365
	• Alterations in the pulse, with a weak or resistant pulse, difficult to compress, in the area of stenosis	378
	• Abnormal thrill (weak and/or discontinuous) with only a systolic component in the region of stenosis	239
	• Abnormal bruit (high pitched with a systolic component in the area of stenosis)	360
	• Failure of the fistula to collapse when the arm is elevated (outflow stenosis) and lack of pulse augmentation (inflow stenosis)	267
	• Excessive collapse of the venous segment upon arm elevation	
Dialysis	• New difficulty with cannulation when previously not a problem	379
	• Aspiration of clots	239
	• Inability to achieve the target dialysis blood flow	360
	• Prolonged bleeding beyond usual for that patient from the needle puncture sites for 3 consecutive dialysis sessions	
	• Unexplained (>0.2 units) decrease in the delivered dialysis dose (Kt/V) on a constant dialysis prescription without prolongation of dialysis duration	

Clinical indications for intervention

- Arm swelling due to central vein stenosis

- Confirmation on angiogram
- Resolution of symptoms with treatment

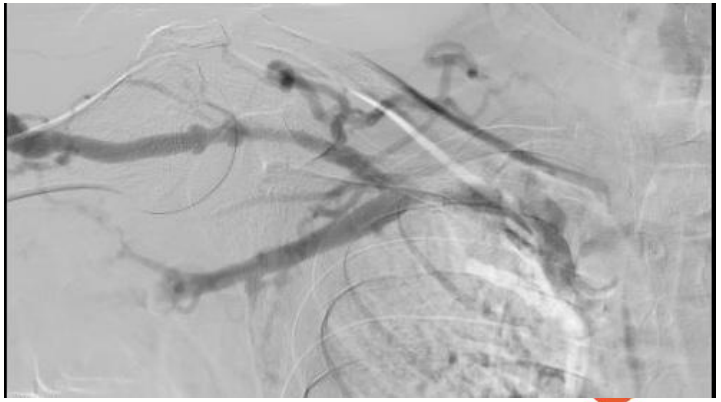


Dialysis indication for intervention

Avg BFR (ml/min)	Avg AP (mmHg)	Avg VP (mmHg)	Dialysis Time	Eff. Kt/V
250	-129	189	3:54	1.16
250	-116	200	3:55	1.39
280	-113	195	3:50	1.37
277	-128	234	3:51	1.44

- Physical examination
  - Pulsatile AVF
  - No arm swelling

- Severe subclavian vein stenosis on fistulogram



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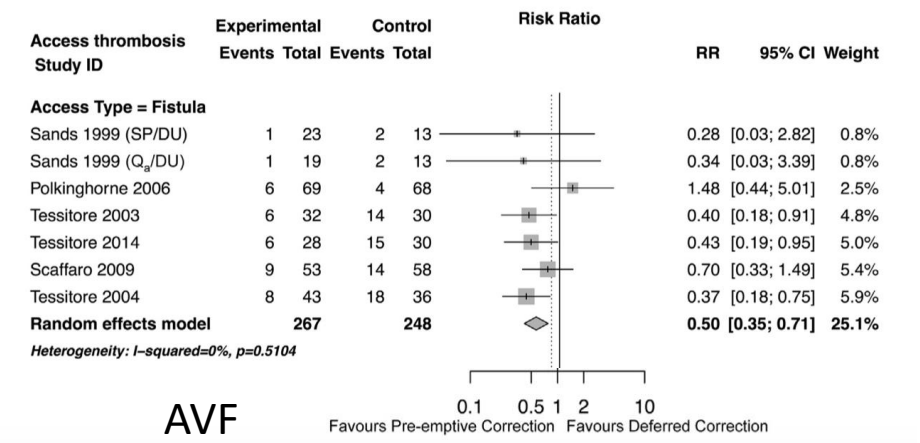
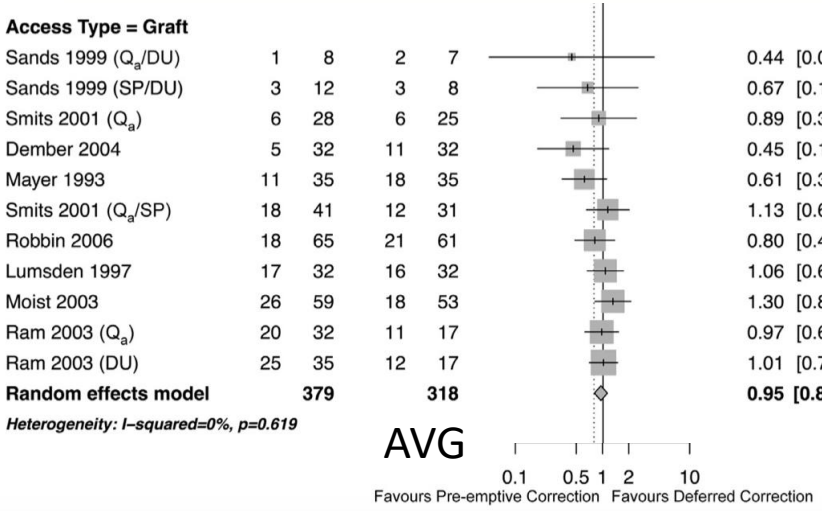
Meta-analysis – Surveillance prevent access thrombosis

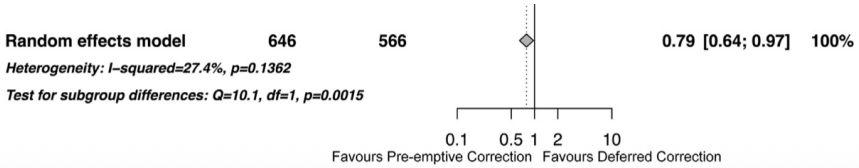


AVF



AVG

Overall



Am J Kidney Dis. 2016;67(3):446-460

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Monitoring vs Surveillance RCT

A multicenter randomized clinical trial of hemodialysis access blood flow surveillance compared to standard of care
The Hemodialysis Access Surveillance Evaluation (HASE) Study

COHORT

- 436 ESRD patients on hemodialysis
- arteriovenous fistula or arteriovenous grafts
- prospectively randomized using shift randomization

DESIGN

Control group
Standard of care
n = 207

Surveillance group
standard of care + monthly UDT-flow
n = 229

UDT = Ultrasound dilution technique

FINDINGS

HASE study primary and secondary outcome results

	Control	UDT	P-value
Number of Patients	207	229	
Total thrombotic events	47	28	
Thrombotic events / patient	0.227	0.122	0.012
Total number of procedures (with thrombectomies) / patient	0.981	0.991	0.95
Number of angiograms (without thrombectomies) / patient	0.715	0.834	0.18

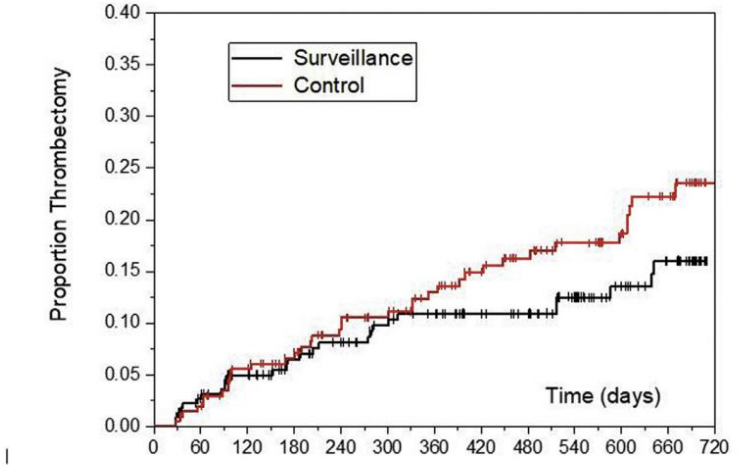
CONCLUSION:
The use of UDT-flow measurement monthly AV access surveillance reduced per patient thrombotic events without significantly increasing angiographic procedures

KI REPORTS
KIReports.org

Salman et. al, 2020

Indication for referral

- Surveillance protocol
  - With monthly flow measurement
  - Intervention when
    - AVF flow < 500 mls/min
    - AVG flow < 600 mls/min
    - For flow > 1000mls/min, decline by more than 25% over 4 month
- Monitoring
  - As per KDOQI 2019



At Risk

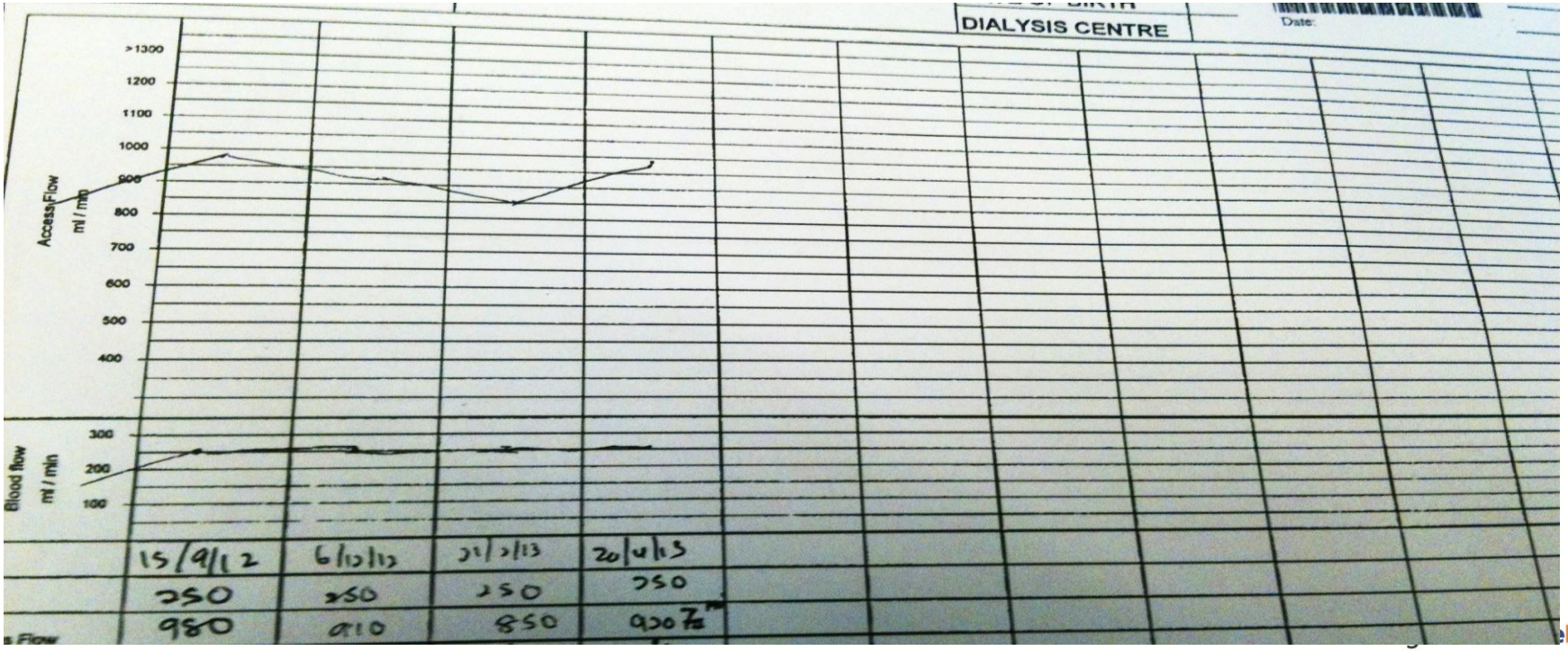
Control	207	198	180	170	158	150	137	126	116	103	92	81	2
Surveillance	229	215	196	179	169	159	150	140	133	106	79	66	27

Kidney Int Rep. 2020 Aug 4;5(11):1937-1944.

Surveillance of dialysis access

- Not associated with improved longevity of dialysis access
- Reduce thrombosis rate and its downstream effect
  - Hospitalisation
  - Missed dialysis
  - Urgent procedures
- May be beneficial in large dialysis program where thrombosis rate is high

Thrombosis despite surveillance



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Predictor of patency after successful thrombolysis

- N= 294 thrombosed access

Predictors	Primary patency	
	HR (95% CI)	*P* value
Access age	0.99 (0.99-1.00)	.02
Age	1.00 (0.99-1.02)	.74
Diabetes mellitus	1.16 (0.82-1.63)	.40
AVG vs AVF	1.58 (1.13-2.21)	<.01
Prior thrombolysis within 90 days	1.90 (1.21-2.98)	<.01
Alteplase vs urokinase	0.82 (0.58-1.16)	.27
No. of previous interventions	1.02 (0.97-1.08)	.46

J Vasc Surg. 2020 Apr;71(4):1333-1339

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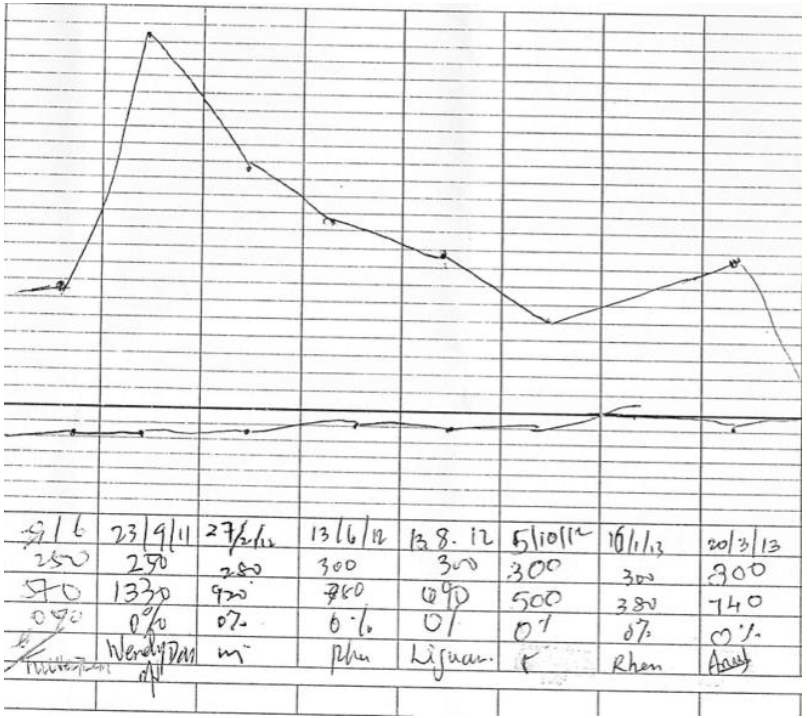
Flow trend post successful salvage



- Elective angioplasty before the next thrombotic episode?

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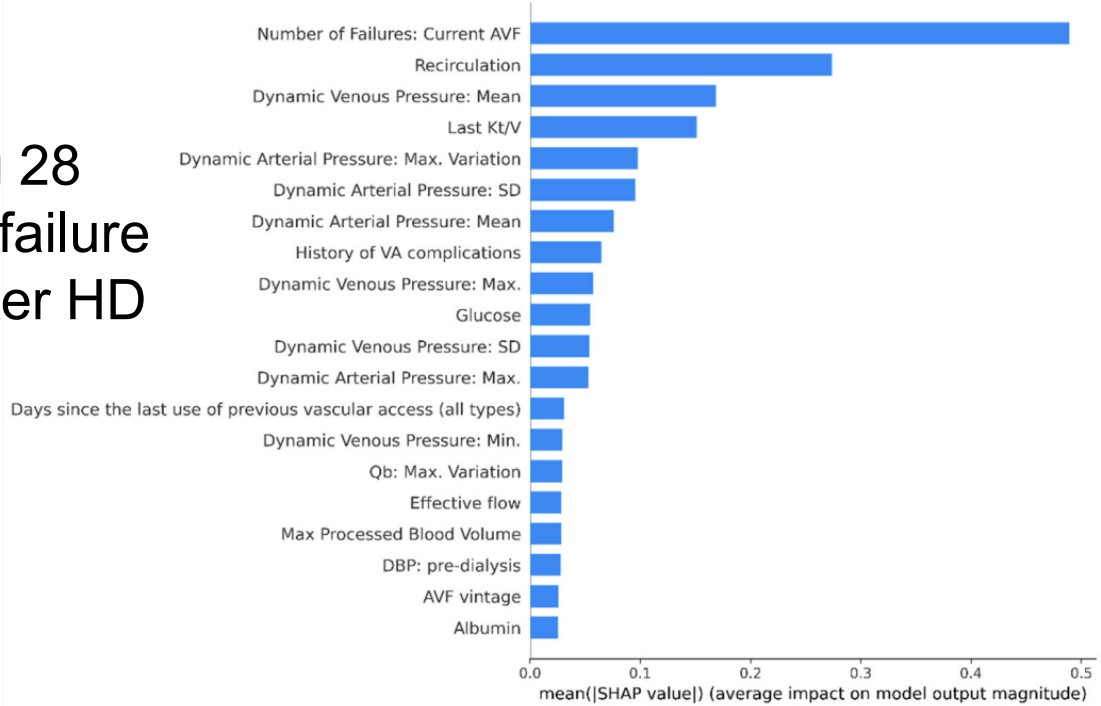
Machine learning to predict access failure

- N= 13,369
- AVF Failure model using 28 variables to predict AVF failure within 3 month of in-center HD patient



Int. J. Environ. Res. Public Health 2021, 18, 12355.

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Machine learning to predict thrombosis

- Monitoring for the low/moderate risk group
- Monitoring + Surveillance for the high/very high group

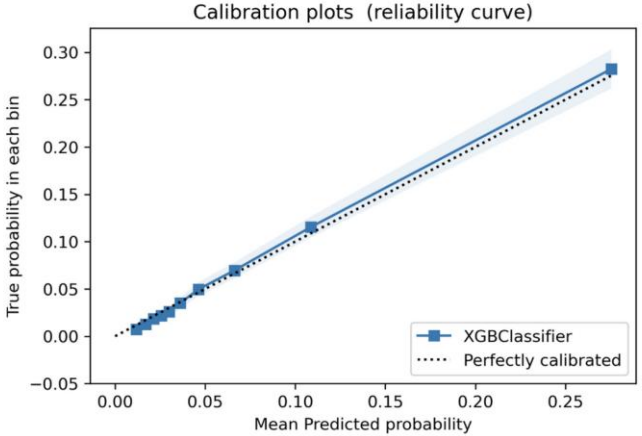


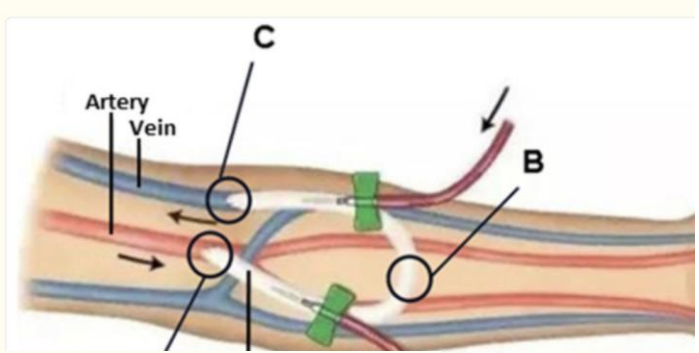
Table 2. Arteriovenous fistula risk score classes.

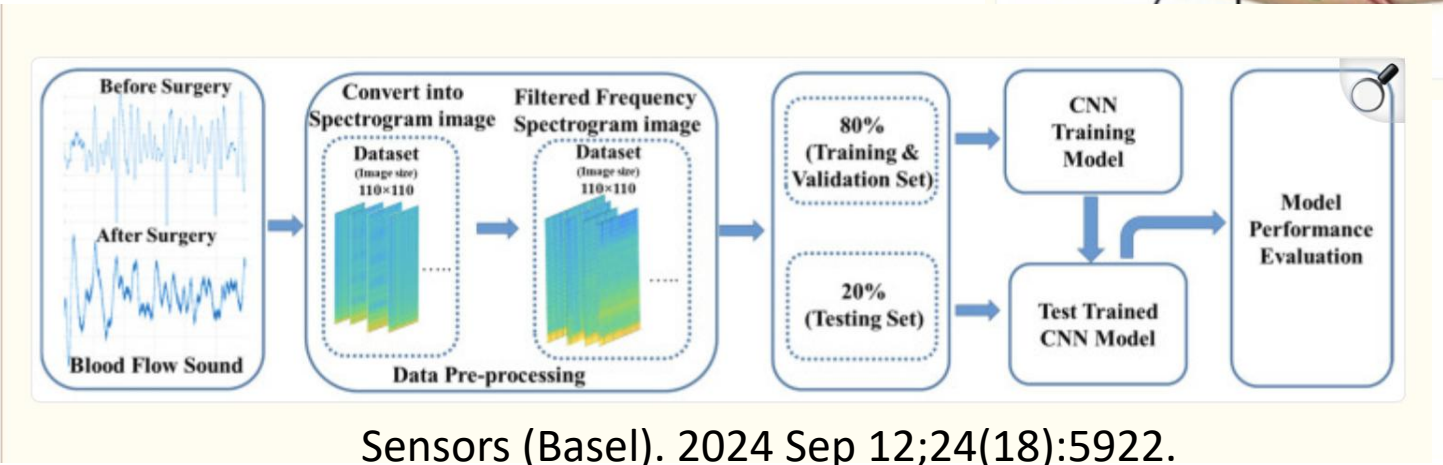
Risk Class	Prevalence (%)	AVF Failure Risk *	Risk Rate Ratio
Low	45.0 (95% CI: 44.9–45.1)	1.61 (95% CI: 1.57–1.64)	Ref.
Moderate	38.9 (95% CI: 38.8–39.0)	5.29 (95% CI: 5.22–5.36)	3.29 (95% CI: 3.2–3.38)
High	15.7 (95% CI: 15.7–15.8)	21.46 (95% CI: 21.23–21.68)	13.37 (95% CI: 13.04–13.72)
Very high	0.4 (95% CI: 0.3–0.4)	65.76 (95% CI: 63.16–68.45)	41.18 (95% CI: 39.29–43.17)

Int. J. Environ. Res. Public Health 2021, 18, 12355.

Blood flow sound signal to detect dysfunction

- Vascular phonoangiography
  - Convert blood flow sound acquired through auscultation into spectrogram
- Analysis with Deep learning model

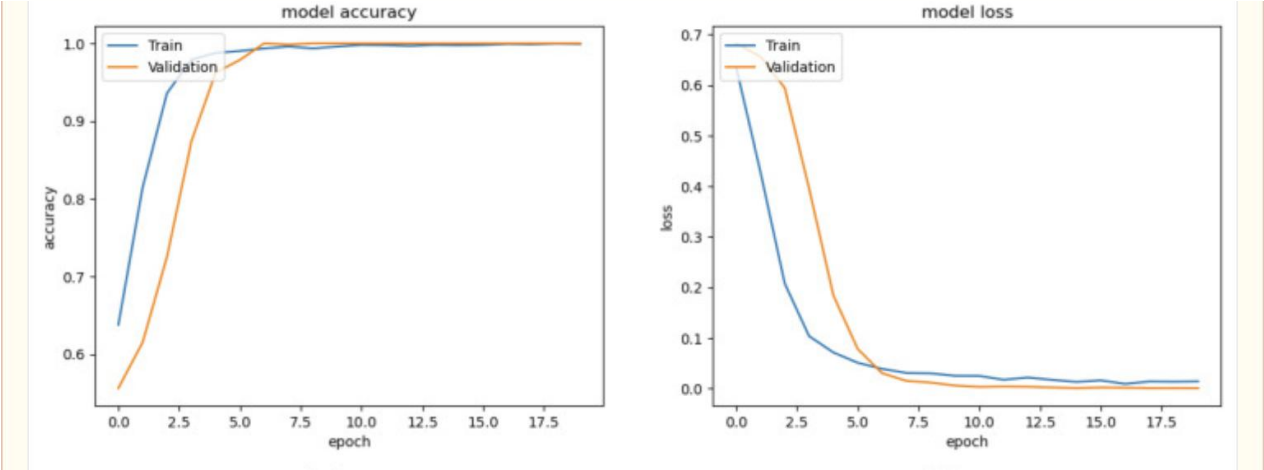




Sensors (Basel). 2024 Sep 12;24(18):5922.

Blood flow sound signal to detect dysfunction

- Good performance of light weight Convoluted Neural Network in detecting stenosis through sound signal picked up using a recording stethoscope



Sensors (Basel). 2024 Sep 12;24(18):5922.

Paclitaxel coated balloon for dialysis access

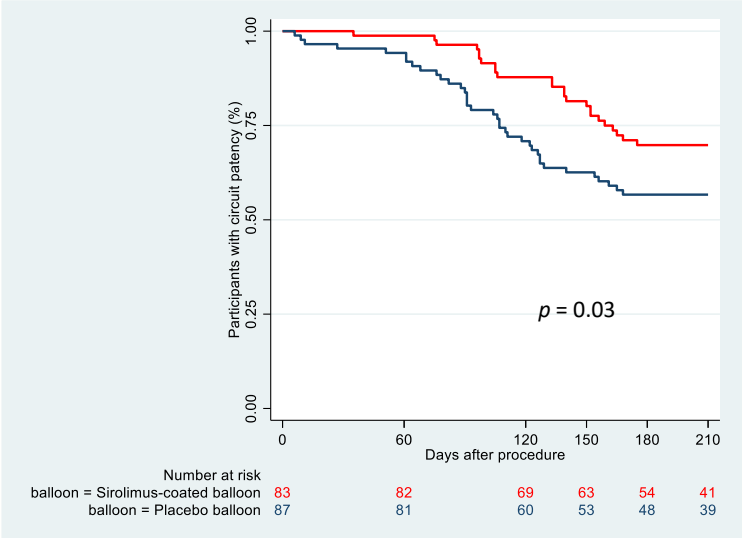
- Retard neo-intimal hyperplasia associated with barotrauma induced by plain balloon angioplasty

18 Randomised controlled trials that include AVF	Plain balloon pooled target primary patency rate (%)	Paclitaxel pooled primary target patency rate (%)
6 month follow up	56.3	77.0
12 month follow up	37.7	52.4

Adopted from J Am Heart Assoc. 2021 Dec 7;10(23)

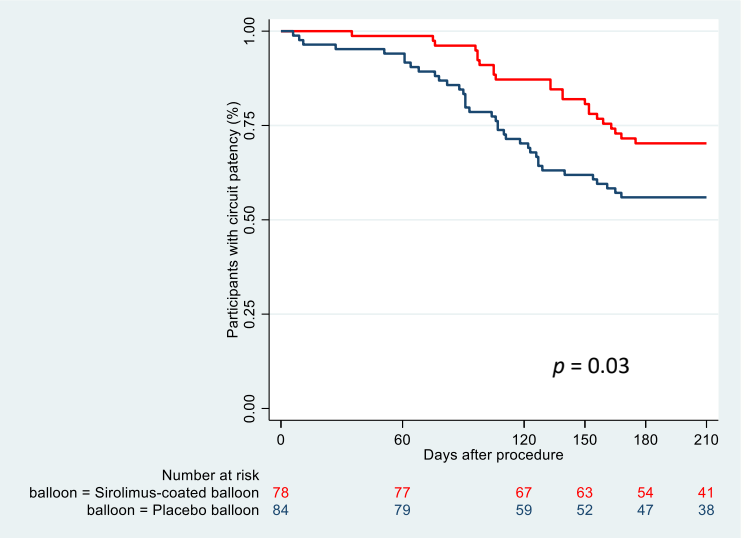
Sirolimus coated balloon for dialysis access

Kaplan-Meier analyses of circuit patency during 6 months after index intervention (ITT analyses)



	90 days	150 days	180 days
Sirolimus-coated balloon	96.4 (95% CI 89.2, 98.8)	80.1 (95% CI 69.6, 87.3)	69.8 (95% CI 58.4, 78.7)
Placebo balloon	83.8 (95% CI 74.1, 90.0)	62.6 (95% CI 51.4, 71.9)	56.7 (95% CI 45.5, 66.4)

Kaplan-Meier analyses of circuit patency during 6 months after index intervention (PP analyses)



	90 days	150 days	180 days
Sirolimus-coated balloon	96.2 (95% CI 88.6, 98.7)	80.7 (95% CI 70.0, 87.9)	70.3 (95% CI 58.7, 79.1)
Placebo balloon	83.3 (95% CI 73.5, 89.8)	61.9 (95% CI 50.6, 71.3)	56.0 (95% CI 44.7, 65.8)

Conclusion

- Value of Surveillance of dialysis access
  - Debatable
  - Prevention of thrombosis
  - High risk population with high incidence of thrombosis
- Monitoring of access should be part of routine care
  - Physical examination
  - Dialysis parameters
- Artificial Intelligence may be useful to help us monitor dialysis access in future
- Improvement in angioplasty technology can potentially improve the longevity of dialysis access interventions

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"Do what you can, with what you have, where you are" Theodore Roosevelt

Thank You 謝謝

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