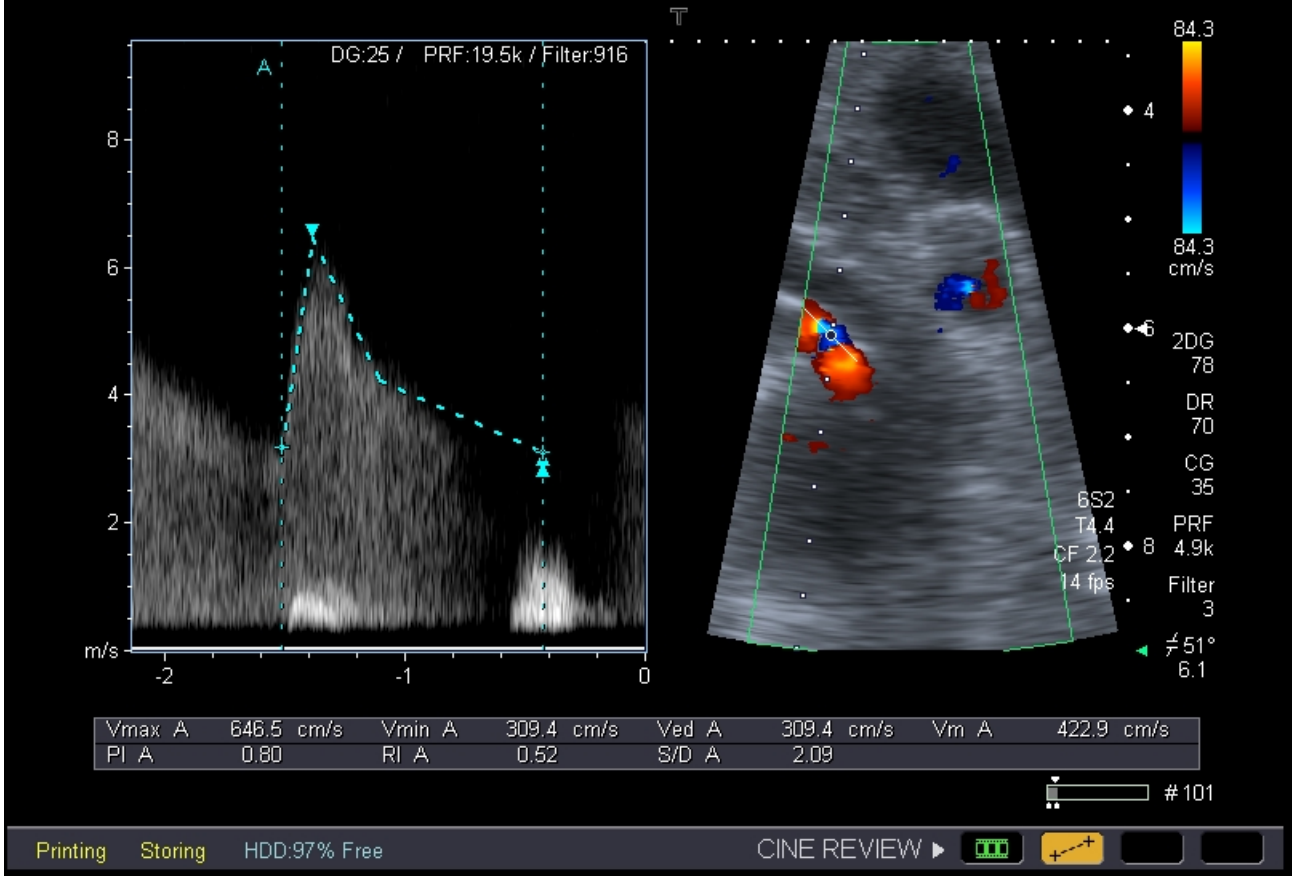
Practical aspects of renal Doppler ultrasonography



J. Radermacher

Gent, Sept 14th 2013

Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

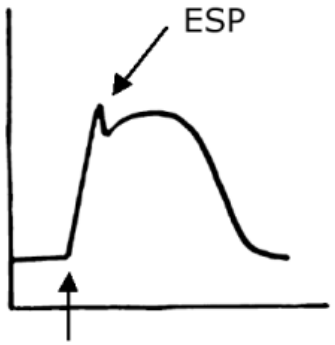
What is there?

Early systolic peak	ESP
Pulsatility Index , Gosling Index	PI
Resistive Index, Pourcelot Index, Resistance Index	RI
Acceleration Index	AI
Acceleration time	AT

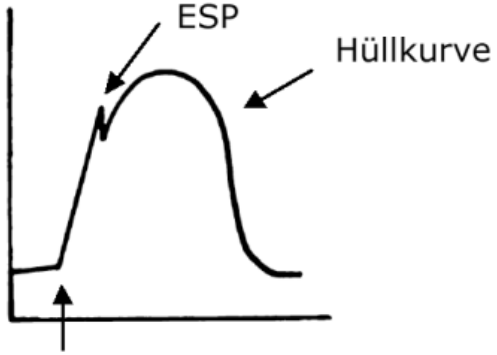
What is there?

Early systolic peak	ESP
Pulsatility Index , Gosling Index	PI
Resistive Index, Pourcelot Index, Resistance Index	RI
Acceleration Index	AI
Acceleration time	AT

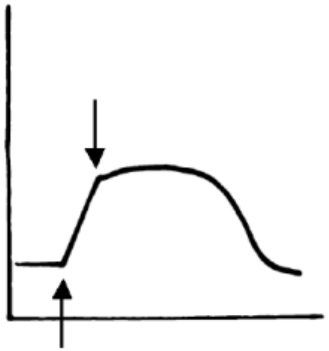
Early systolic peak ESP



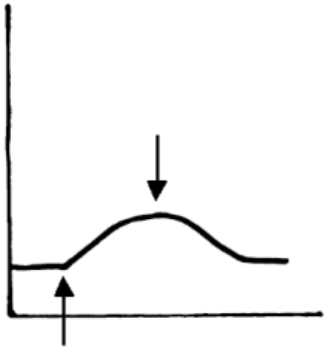
3a) Normales Dopplerspektrum



3b) Normales Dopplerspektrum (Variante)



3c) 60-79%-ige Stenose

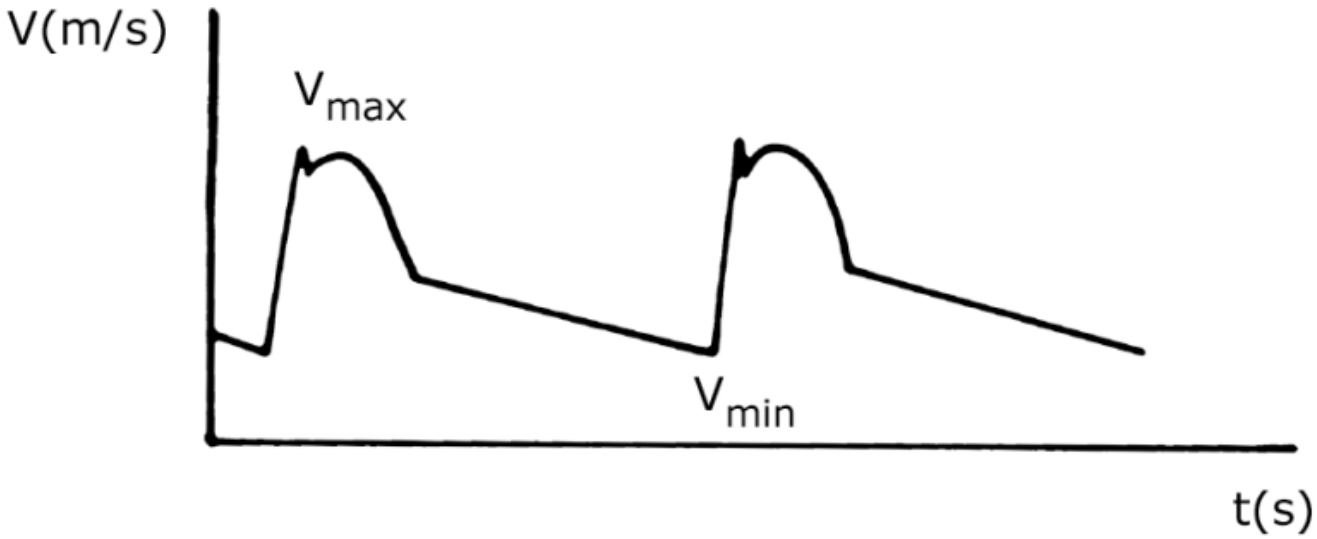


3d) ≥ 80%-ige Stenose oder Verschluß

What is there?

Early systolic peak	ESP
Resistive Index, Pourcelot Index, Resistance Index	RI
Pulsatility Index , Gosling Index	PI
Acceleration Index	AI
Acceleration time	AT

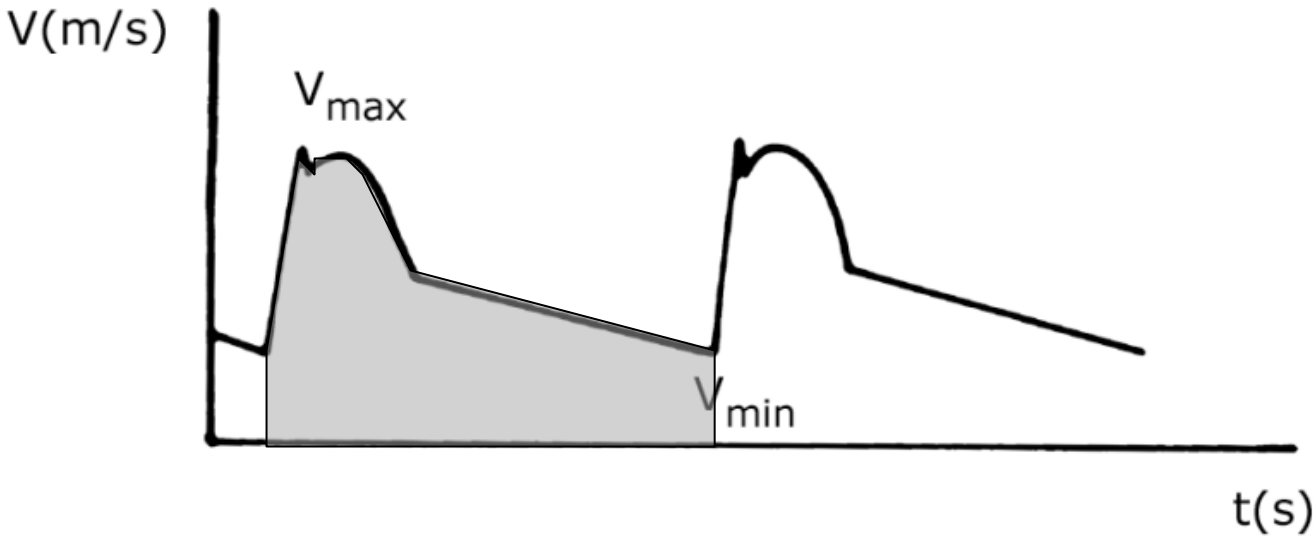
Resistive Index RI



Calculation of the Resistive Index

$$RI = \frac{V_{max} - V_{min}}{V_{max}}$$

Pulsatility Index PI



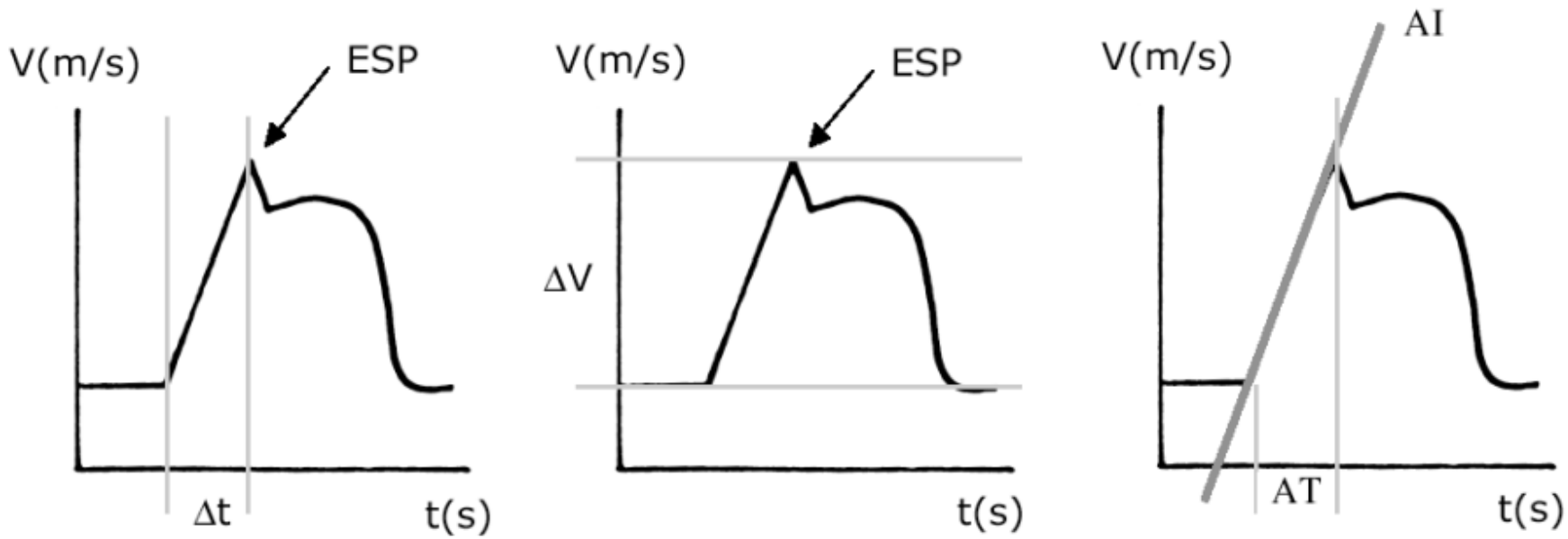
Calculation of the Pulsatility Index

$$PI = \frac{V_{max} - V_{min}}{V_{mittel}}$$

What is there?

Early systolic peak	ESP
Pulsatility Index , Gosling Index	PI
Resistive Index, Pourcelot Index, Resistance Index	RI
Acceleration Index	AI
Acceleration time	AT

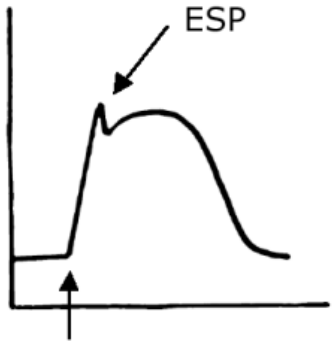
Acceleration Time AT
Acceleration Index AI



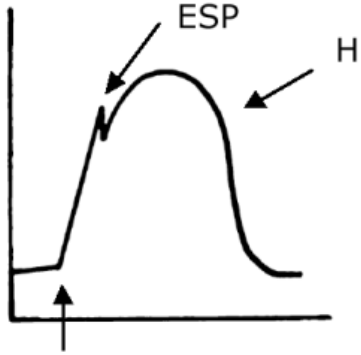
AT is Δt in msec (normal = < 70 msec)

AI = ΔV/Δt in m/s^2 (normal > 3 m/sec^2)

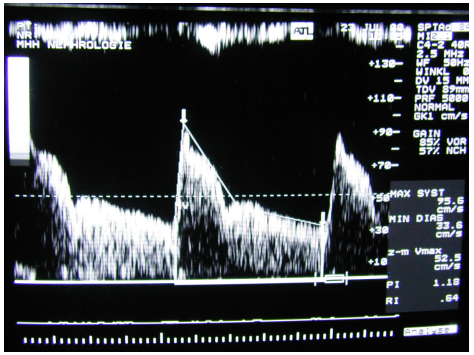
Acceleration time AT
Acceleration index AI

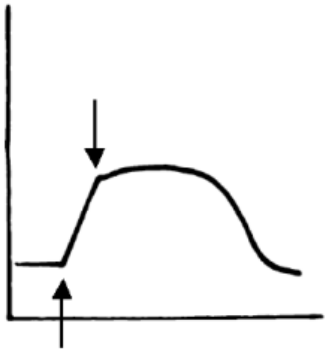


Normal Doppler spectrum

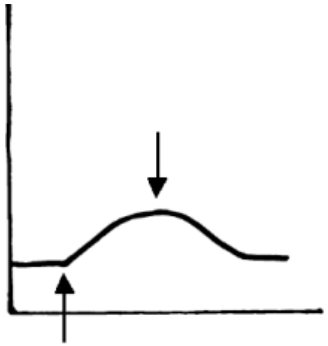


Normal Doppler spectrum (variant)





60-79% stenosis



> 80% stenosis or occlusion

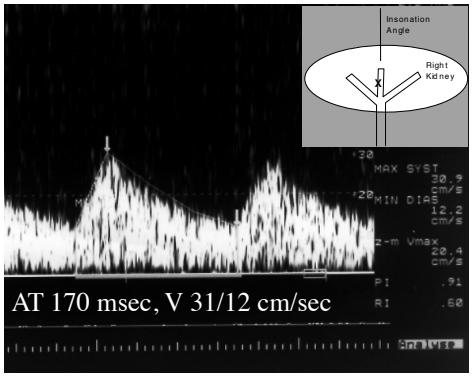


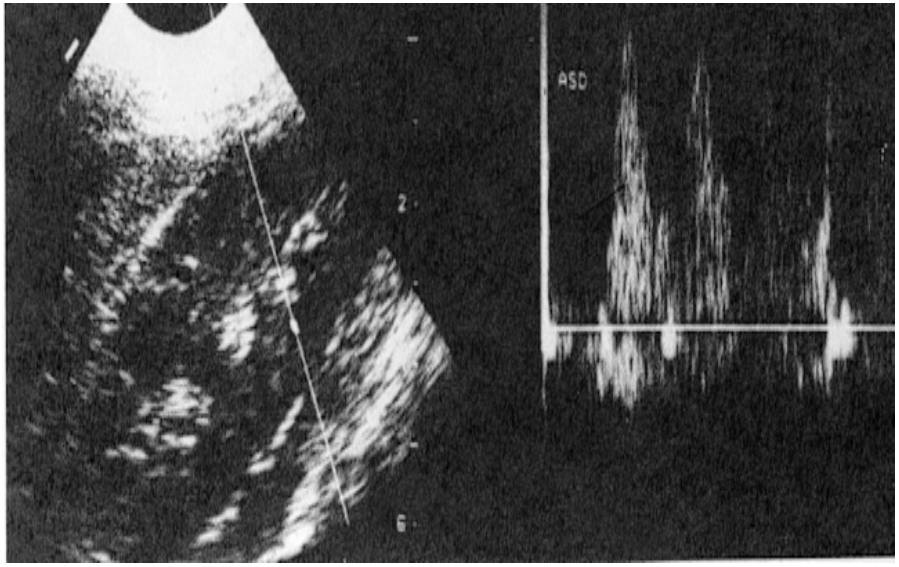
Abbildung 3 : Dopplerspektren bei verschiedenen Stenosegraden. Die Pfeile bedeuten die Meßpunkte der Akzelerationszeit (AT).

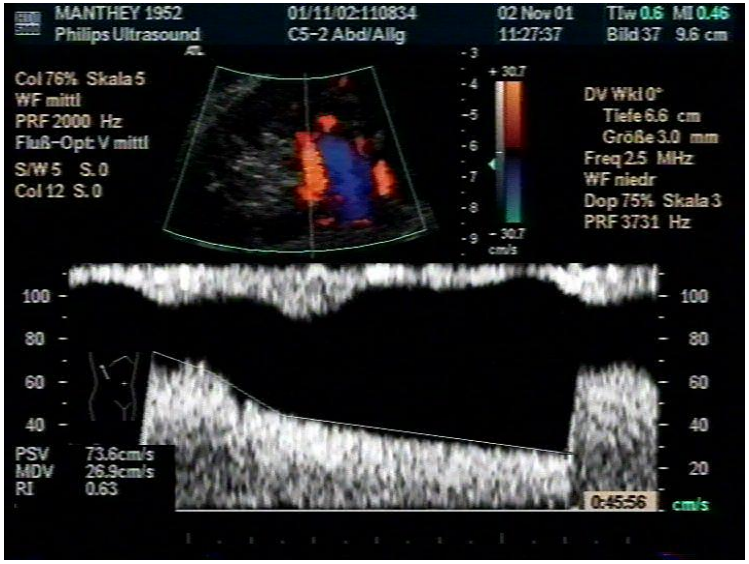
JWK Minden

Potential Problems

Potential Problems

- ESP, AT, AI, PI
  - Clear Doppler signals required, angle dependant.
  - Signals from segmental arteries prefered over interlobar signals

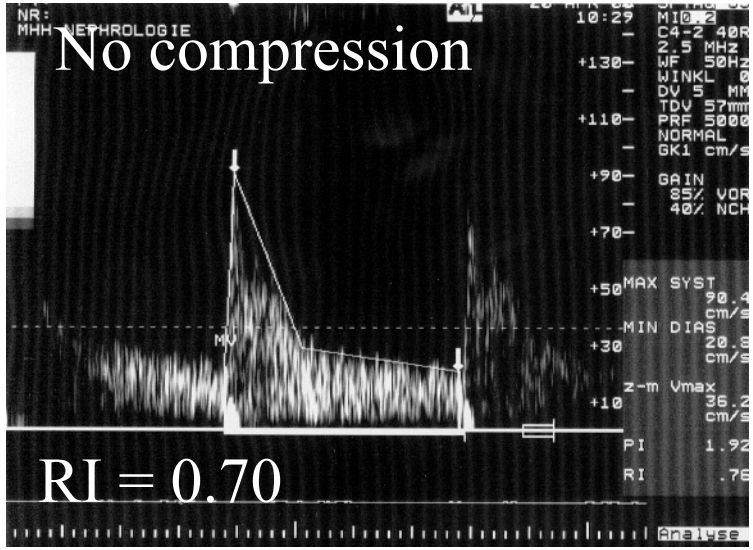


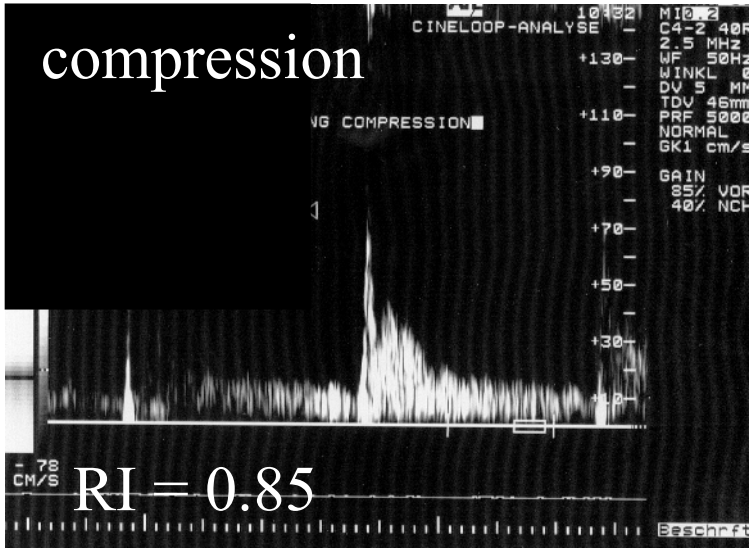



SIEMENS
5.0HDPL40/7.2
MI 0.5
Abdomen
100%
18dB RS6
10.0cm 4fps

Potential Problems

- RI
  - Avoid valsalva when possible = inspiration breath hold,
  - No heavy hand – avoid manual compression (RTX)
  - Tachycardia > 100 false low RI, Bradycardia < 50 false high RI



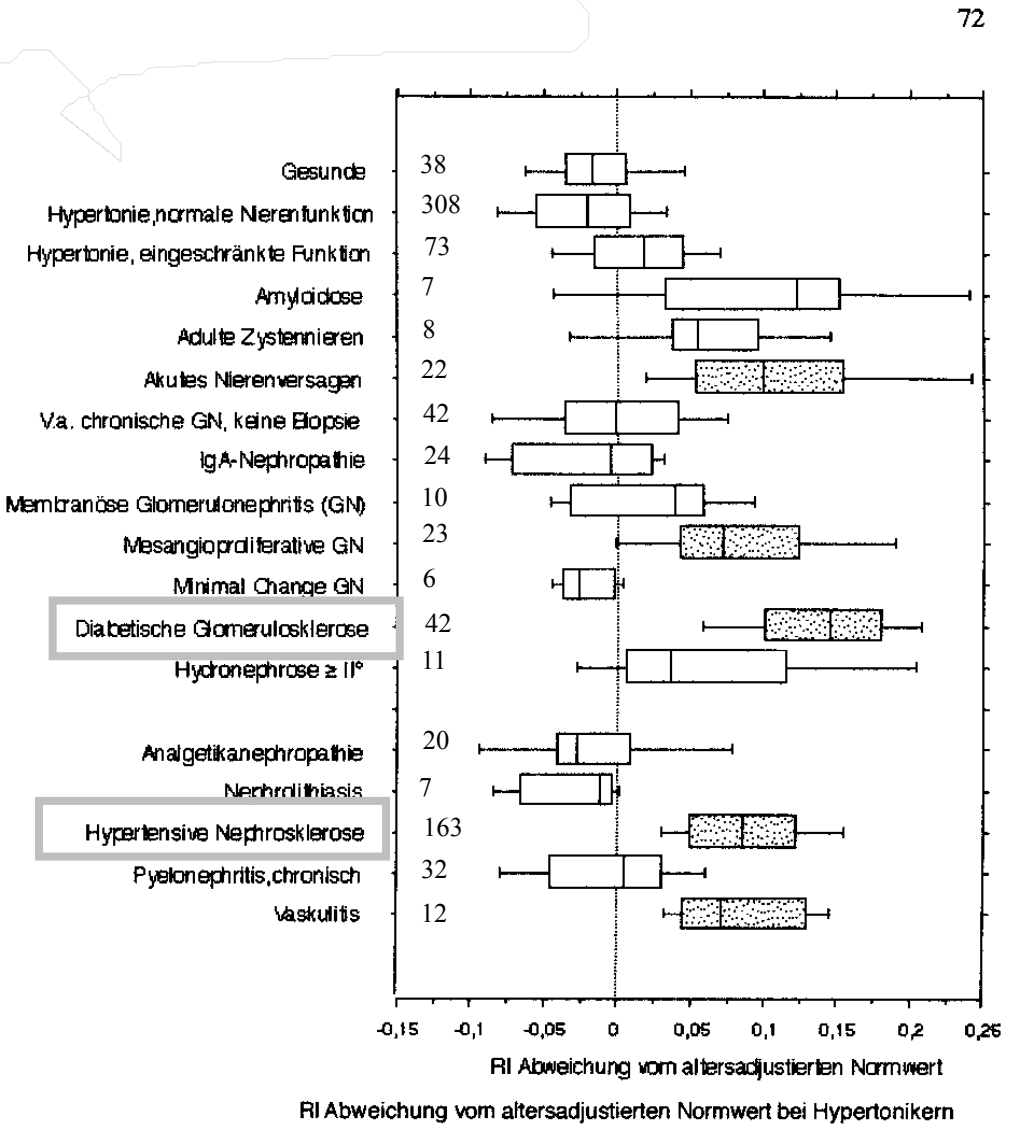


Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

CDS and renal disease: Native kidney

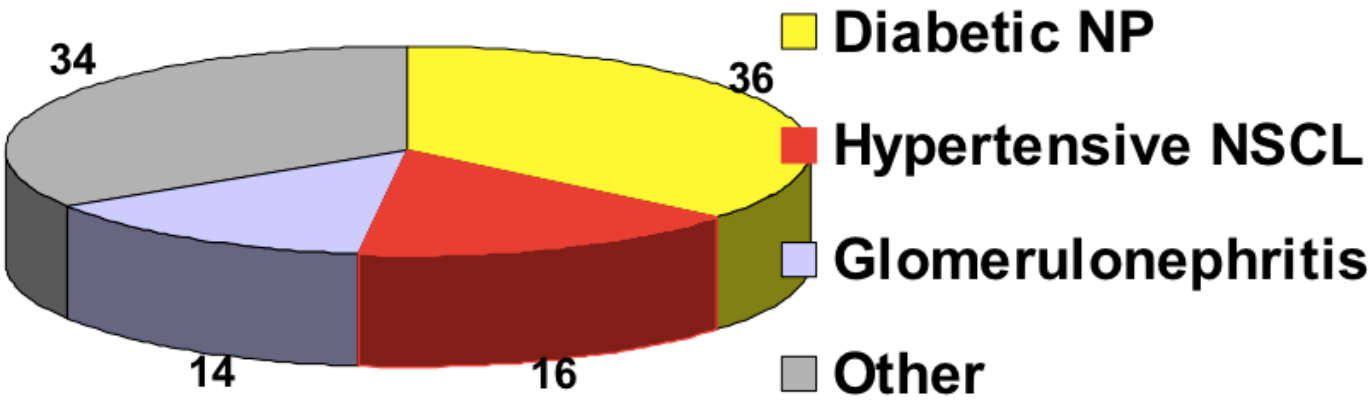
Renoparenchymatous disease and RRI



RI Abweichung vom altersadjustierten Normwert bei Hypertonikern

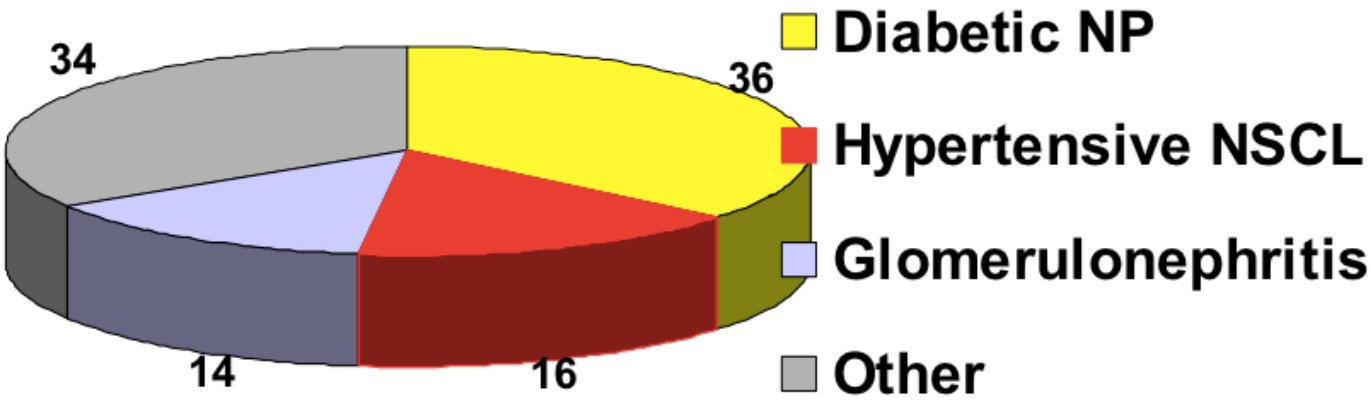
Radermacher,. thesis

Ultrasonography of the most frequent renal diseases



- Diabetic NP
  - Large Kidney, high RI
- Hypertensive NSCL
  - Small kidney, high RI

Ultrasonography of the most frequent renal diseases



- Diabetic NP
  - Large Kidney, high RI
- Hypertensive NSCL
  - Small kidney, high RI

CDS and renal disease: Native kidney

RI useful

RI increased – more rapid progression (n=940)

- *Petersen NDT 1997 12:1376-80 (n=21)*
- *Turkmen et al. J Clin Ultrasound 2000 28:73 (n=30 Kinder)*
- *Radermacher et al. Hypertension 2002 39:699-703 (n=162)*
- *Splendiani et al. Clin Nephrol 2002 57:45-50 (n=28)*
- *Ikee Am J Kidney Dis 2005 46:603-9 (n=33)*
- *Nosadini Diabetes 2006 55:234-9 (n=157)*
- *Parolini Radiology 2009 252: 888-96 (n=86*
- *Sugiura NDT 2009 24:2780-5 (n=311)*
- *Okura J Nephrol 2010 23:175-80 (n=112)*

RI of no use

- *No articles in Peer reviewed Journals*

Kidney and RI: Diabetes and Hypertension

RI useful

Diabetes

- *Nosadini Diabetes 2006 55:234-9 (n=157)*
  GFR Decline RR=3; proteinuria RR=5
- *Ghaffar Pediatr Diabetes 2010 11:479-86 (n=100)*
- *Nakamori J Clin Ultrasound 2011 (EPUB) (n=113)*
- *Bruno Diabetologica 2011 54:2430-9 (n=81)*

Hypertensives

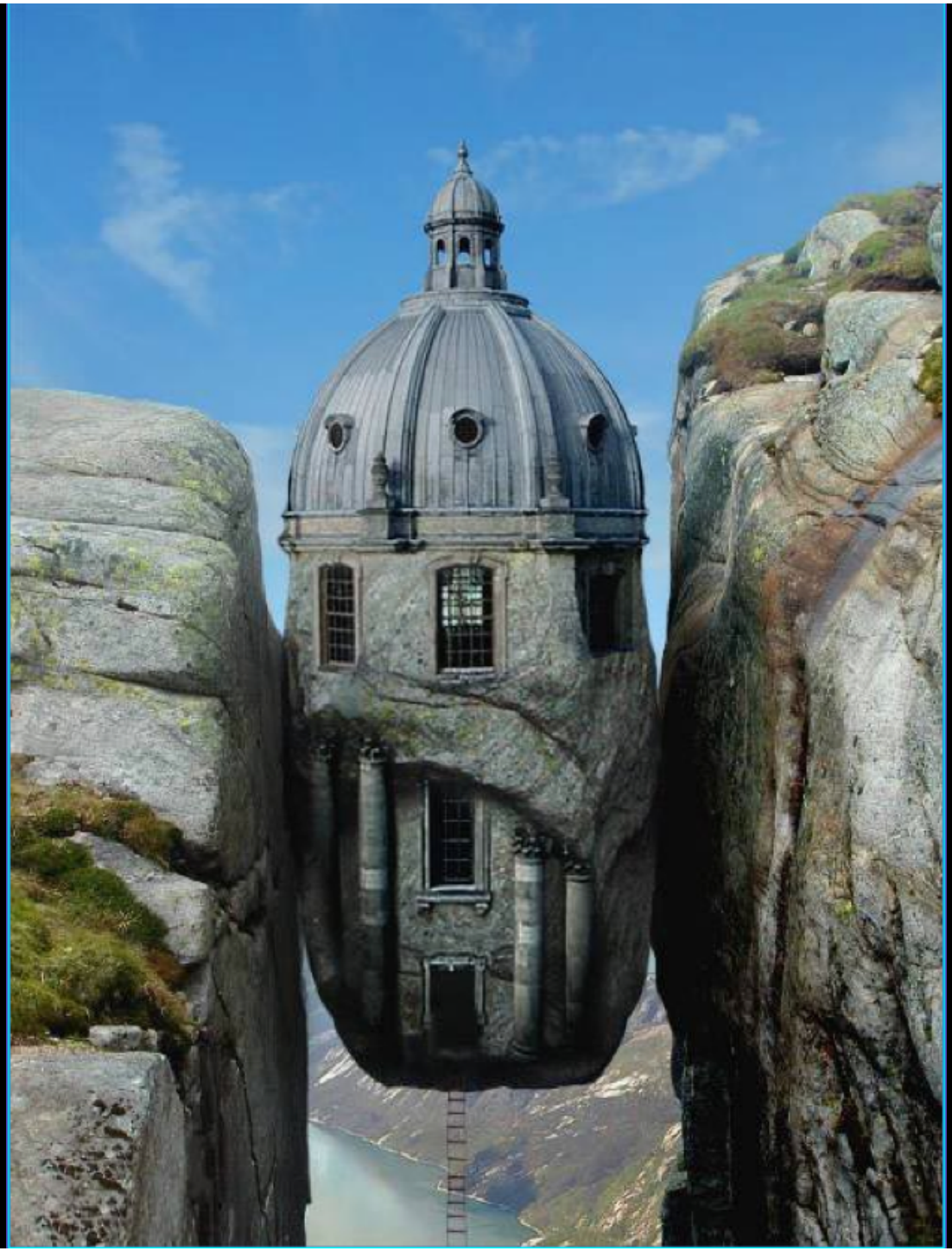
- *Derchi Am J Hypertens 2005 18:966-71 (n=291)*
- *Shimizu Hypertens Res 2001 24:13-7 (n=102)*
- *Raff J Hypertens. 2010 28:608-14 (n=84)*
- *Bruno Diabetologica 2011 54:2430-9 (n=81)*

RI of no use

- *No articles in Peer reviewed Journals*

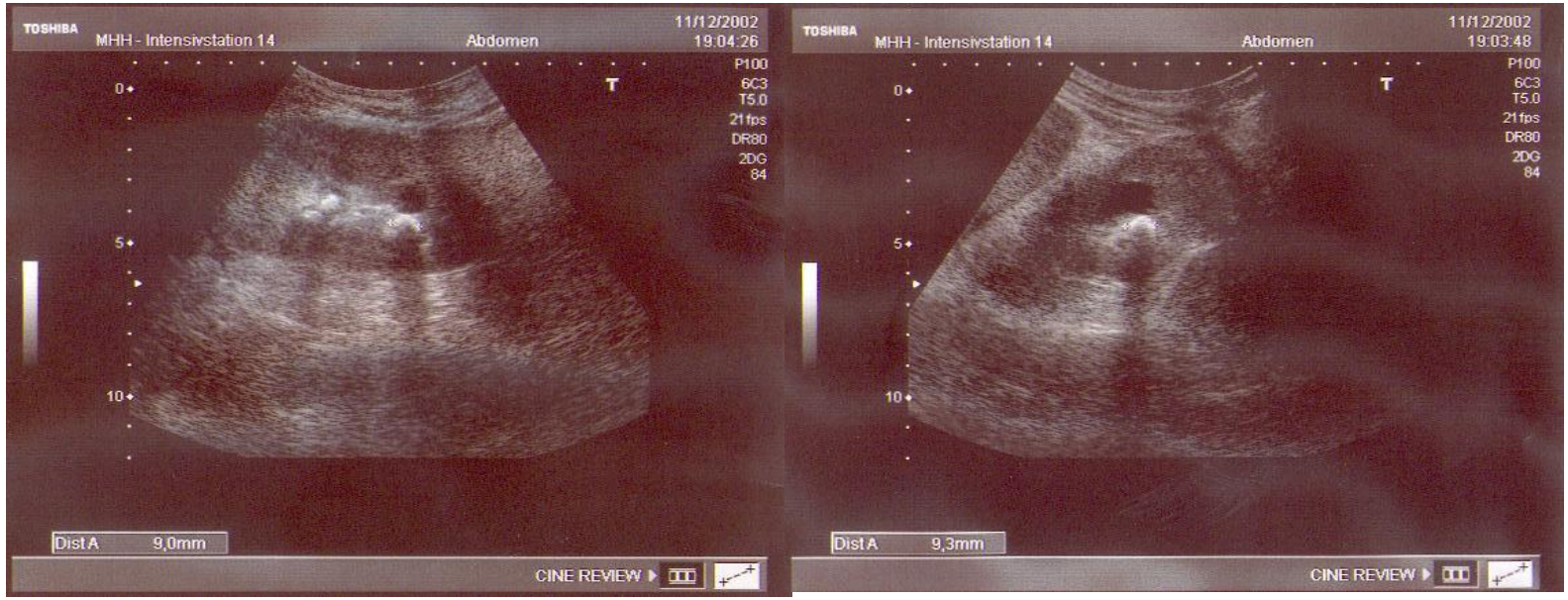
Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

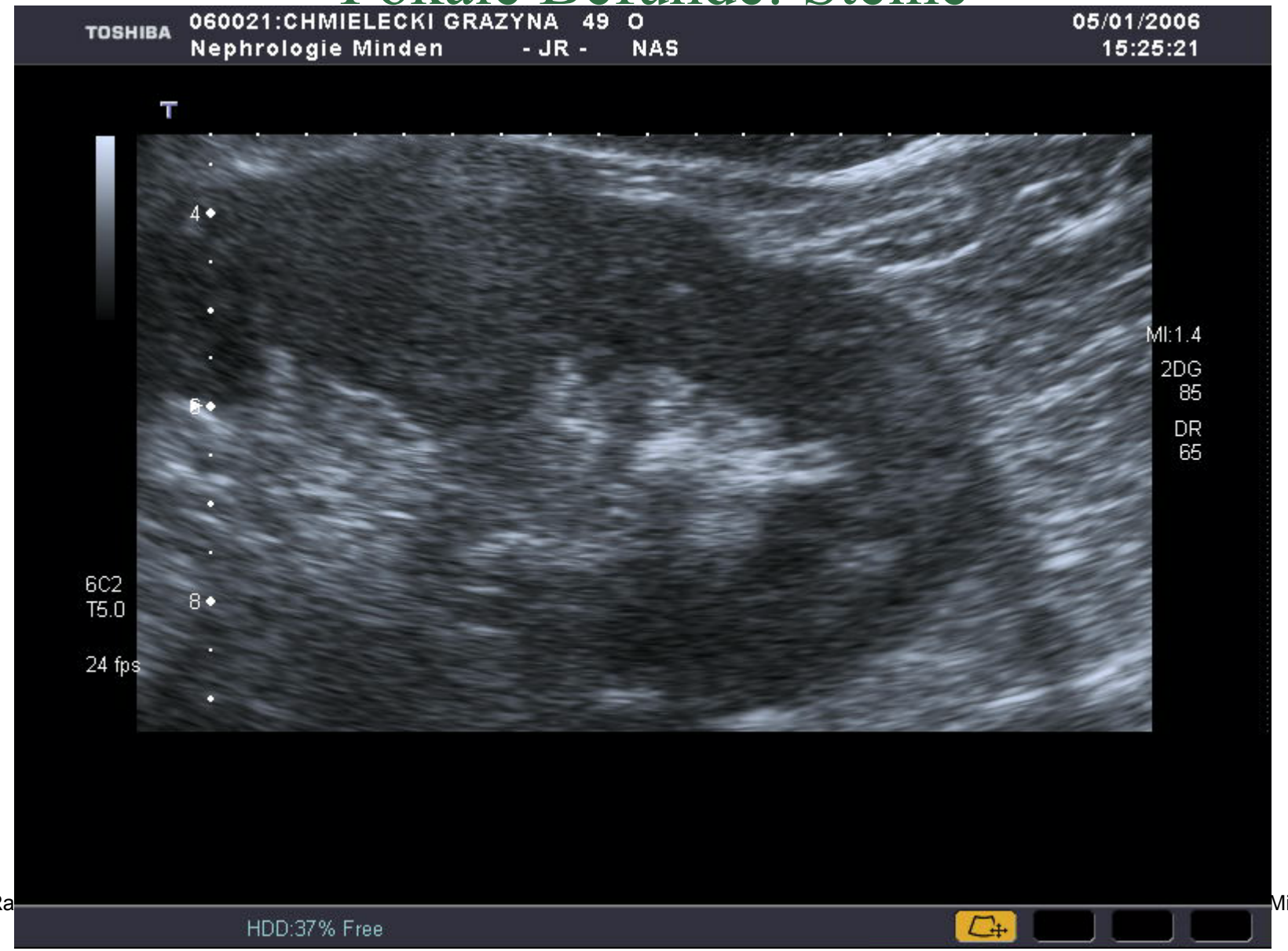


Focal findings: stones

- CT and not ultrasonography is gold standard
- Sensitivity 60% Specificity 90%



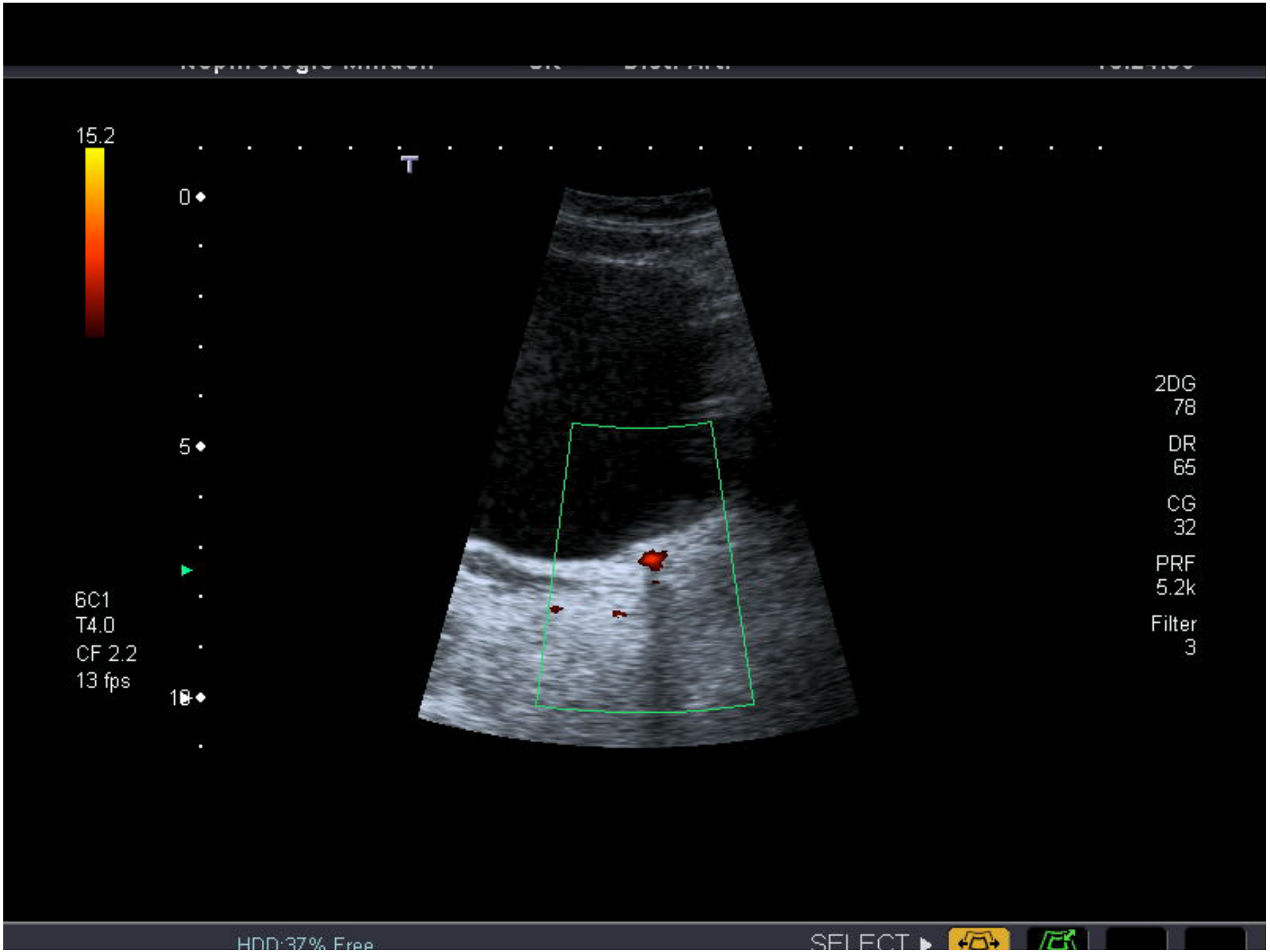
Fokale Befunde: Steine



Twinkling sign

- 77 renal stones detected in 41 patients with Nativ-CT
  - *B-mode ultrasonography:* *66% Detection*
  - *Color Doppler sono.:* *97% Detection*

Mitterberger et al. 2009 Int Braz J Urol 35: 532


15.2
0
5
6C1
T4.0
CF 2.2
13 fps
2DG
78
DR
65
CG
32
PRF
5.2k
Filter
3
HDD:37% Free
SELECT

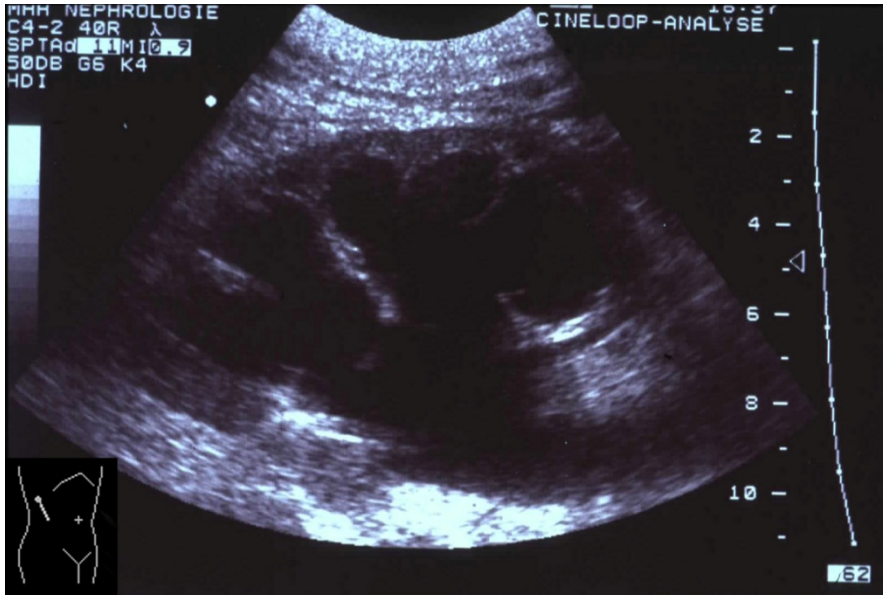
Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

Hydronephrosis: Classification

Grade III/IV

Grade IV/IV

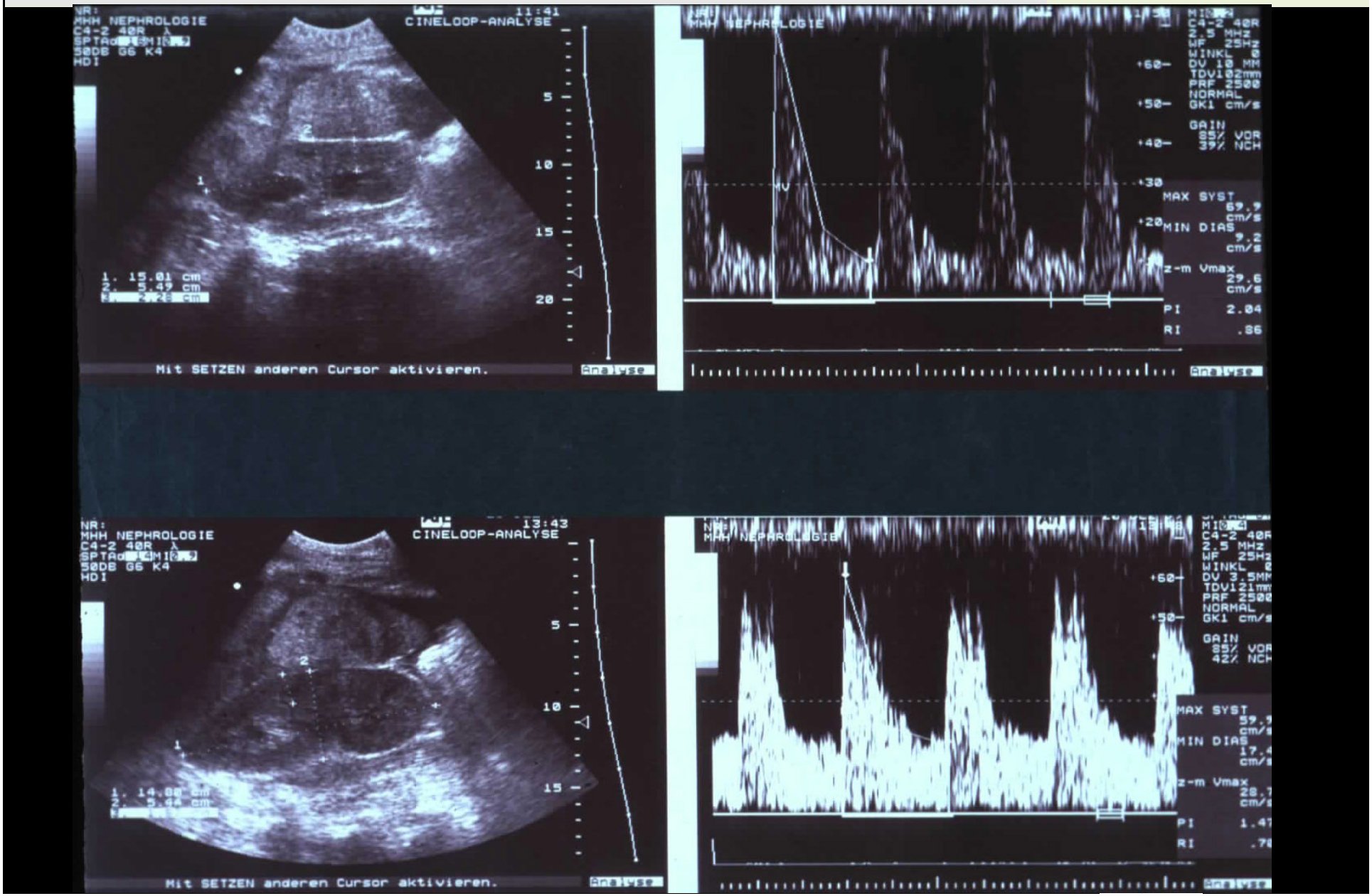


Hydronephrosis: Classification

- Classification does not mean urodynamically relevant
- RI > 0.7 diagnostic for relevant obstruction
  - Sensitivity 64%, specificity 82%
- Delta-RI >0.05-0.10 (0.07) diagnostic
  - Sensitivity 100%, specificity 89%
- RRI difference occurs before pyelocaliectasia

Cauni et al. 2009 Chirurgica 103:665-8
Geavlette et al 2001 Chirurgica 36:373-92

How to detect urodynamically relevant hydronephrosis



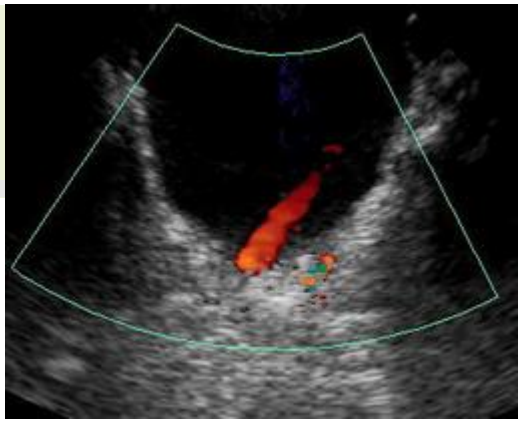
Urodynamically relevant hydronephrosis

RI prognostic

- *Shokeir 2000 Urology 55:344*
- *Shokeir 2002 Urology 59:506*
- *Patti 2000 BJU Int 85:308*
- *Bertolotto 2003 Radiol Med 106:370*
- *Rawashdeh 2003 Invest Radiol 38:153*
- *Soria-Galvez 2007 Actas Urol Esp 31:38*
- *Onur 2007 Urol Res 6:307*
- *Mohseni 2007 Urol J 4:217*
- *Andreoiu 2009 Urology 74:757*
- *Kavakli 2011 Singapore Med J 52:271*
- *Rud BJU Internat 2012 (EPUB)*

RI no use

- *Gurel 2006 J Ultrasound Med 25:1113*



Ureter-jet analysis

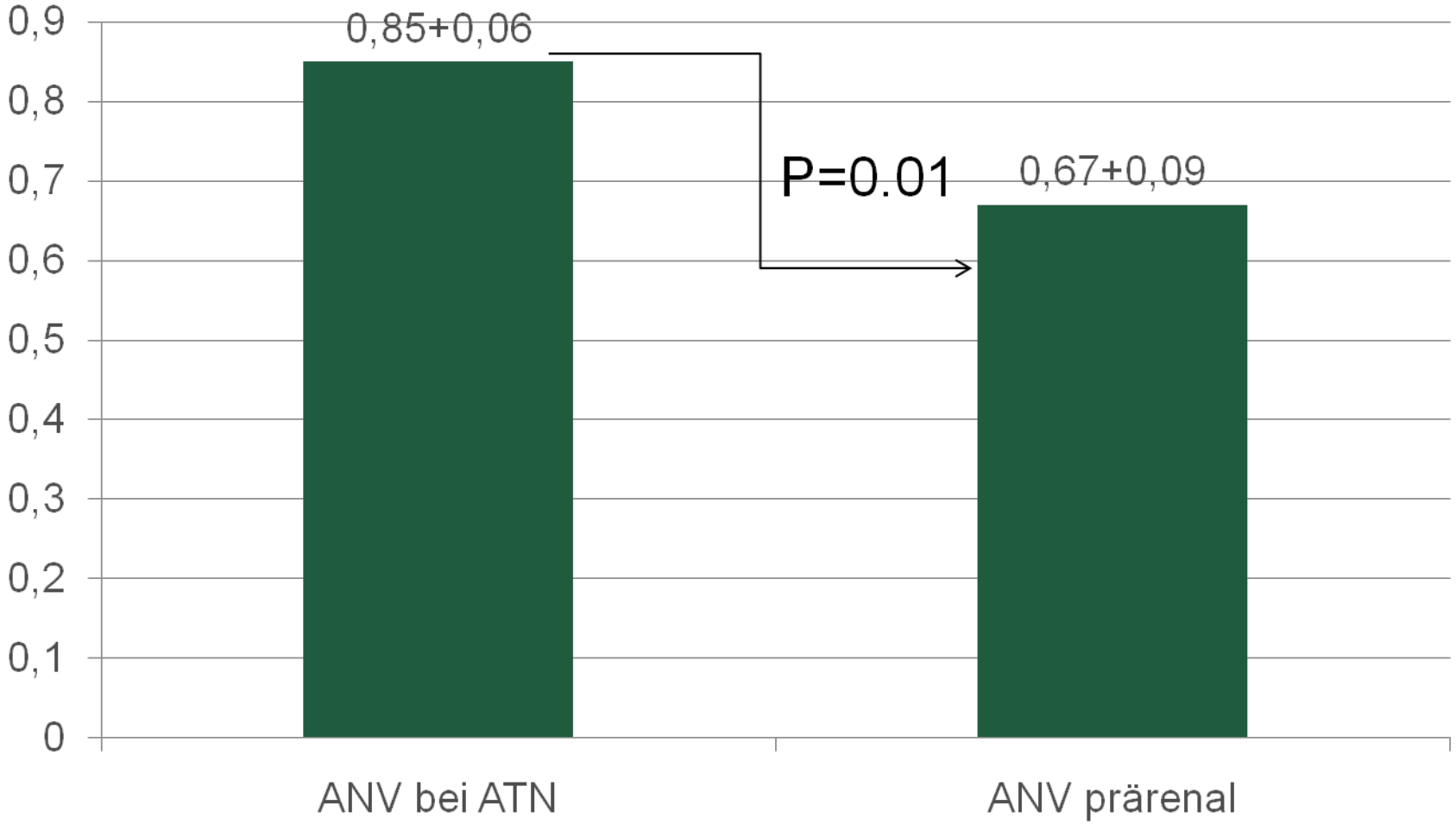
- Number of jets is reduced in upper urinary tract obstruction
- Evaluation takes at least 10 minutes
- No consensus on routine use
  - RI > 0.7 and jet present: 63% spontaneous stone passage
  - RI > 0.7 and jet missing: 5% spontaneous stone passage

Cauni et al. 2009 Chirurgica 103:665-8
Geavlette et al 2001 Chirurgica 36:373-92

Renal Doppler

- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

CDS and renal disease: ARF/AKI



Gheisari et al. Saudi J Kidn Dis Transp*2006 17:168-70*

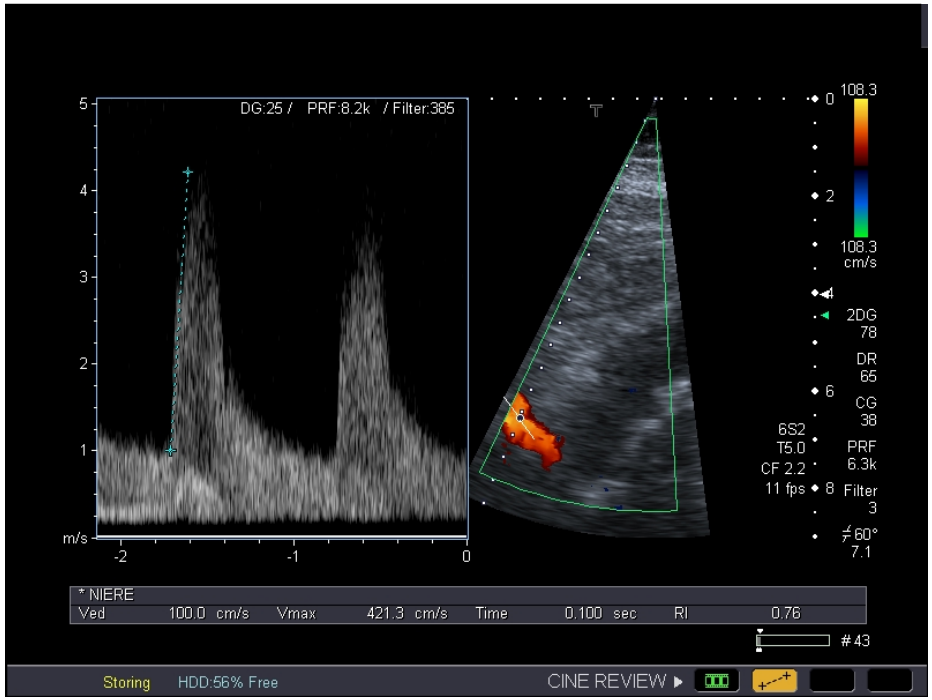
Renal Doppler

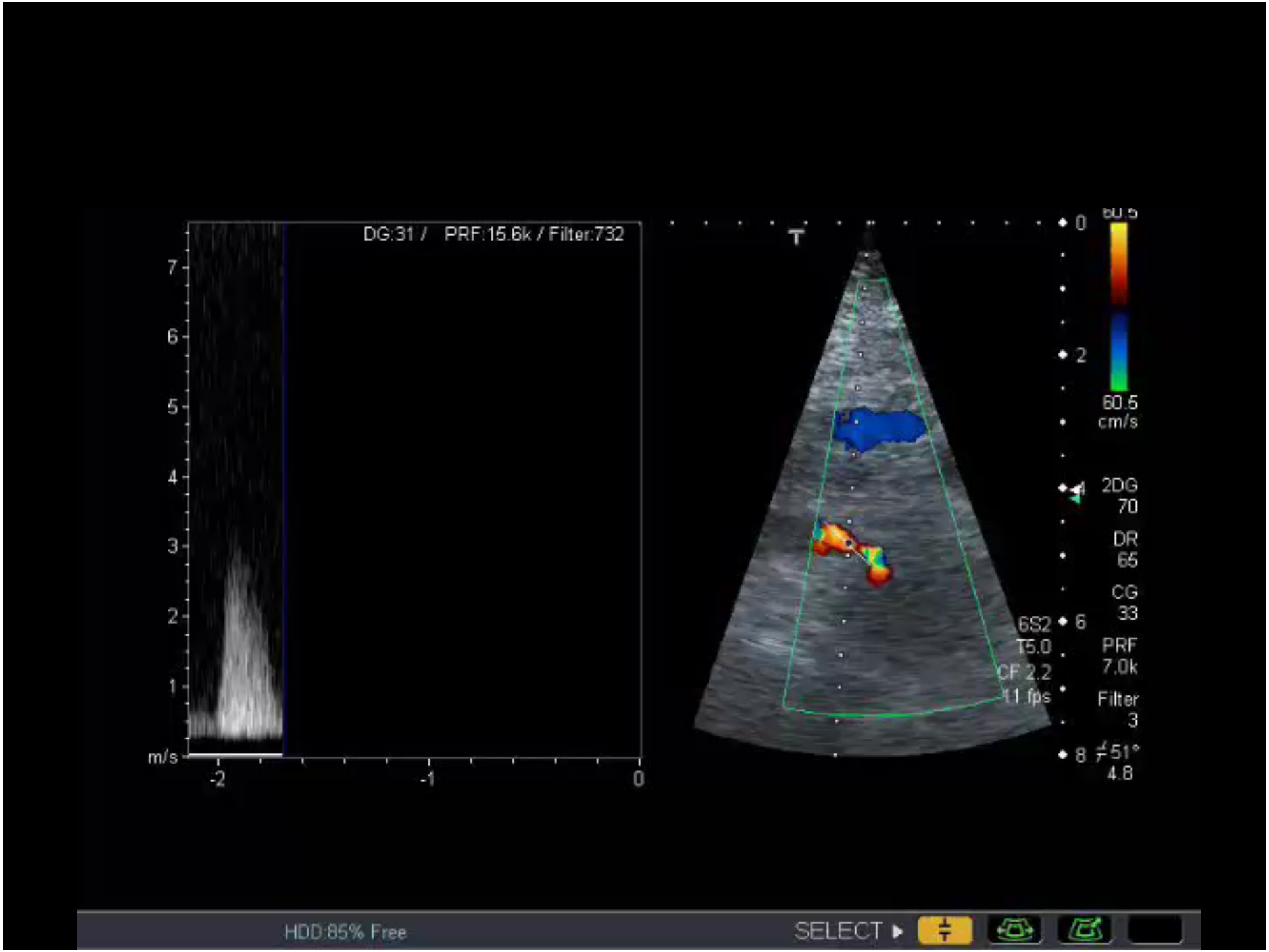
- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

CDS native kidney: RAS

Direct

Indirect




DG:31 / PRF:15.6k / Filter:732
7
6
5
4
3
2
1
m/s
-2
-1
0
T
0
2
60.5
cm/s
2DG
70
DR
65
CG
33
6S2
T5.0
CF 2.2
11 fps
6
PRF
7.0k
Filter
3
8
51°
4.8
HDD:85% Free
SELECT

CDS native kidney: RAS

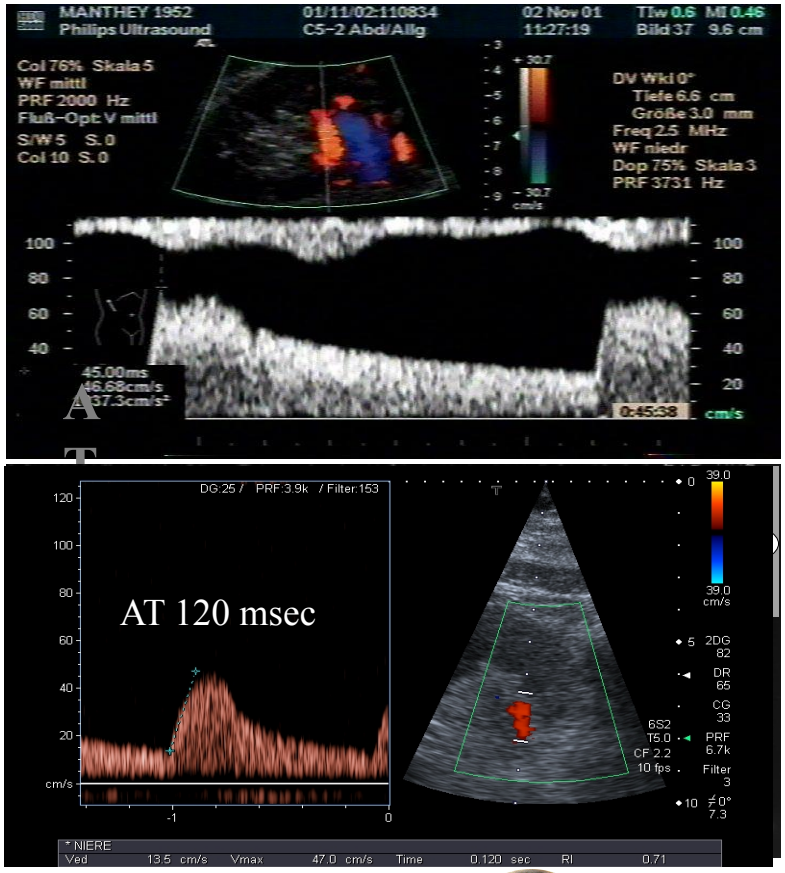
Stenosis criteria and sensitivity and specificity to detect renal artery stenosis with Doppler ultrasound in angiographically controlled studies

	Patient-number	Stenosis-criteria	Technical failure (%)	Detected Degree of sten (%)	Sensitivity / specificity (%)
Direct stenosis criteria					
Hansen 1990 [16]	74	RAR > 3.5	8	≥ 60	93 / 98
Postma 1992 [35]	61	Doppler frequ.>4KHz und verbreitertes Dopplerspektrum	25	≥ 50	63 / 86
Schäberle 1992 [45]	76	Vmax > 140 cm/s	n.v.	≥ 50	86 / 83
Karasch 1993 [20]	53	Vmax > 180 cm/s	15	≥ 50	92 / 92
Olin 1995 [31]	102	Vmax > 200 cm/s oder RAR > 3.5	10	≥ 60	98 /98
Vigna 1998 [62]	104	Vmax ≥ 200 cm/s	6	≥ 50	89 / 97
Leung 1999 [23]	60	RAR > 3.5	20	≥ 60	81 / 87
Claudon 2000 [5]	191	Vmax > 140-200 cm/s oder RAR ≥ 3-3.5	36	≥ 50	80 / 81
Claudon 2000 [5]	191	Ohne Echokontrast Vmax > 140-200 cm/s oder RAR ≥ 3-3.5 Mit Echokontrastmittel	16	≥ 50	84 / 84
mean:	**721**		**20**		**85 /89**

CDS native kidney: RAS

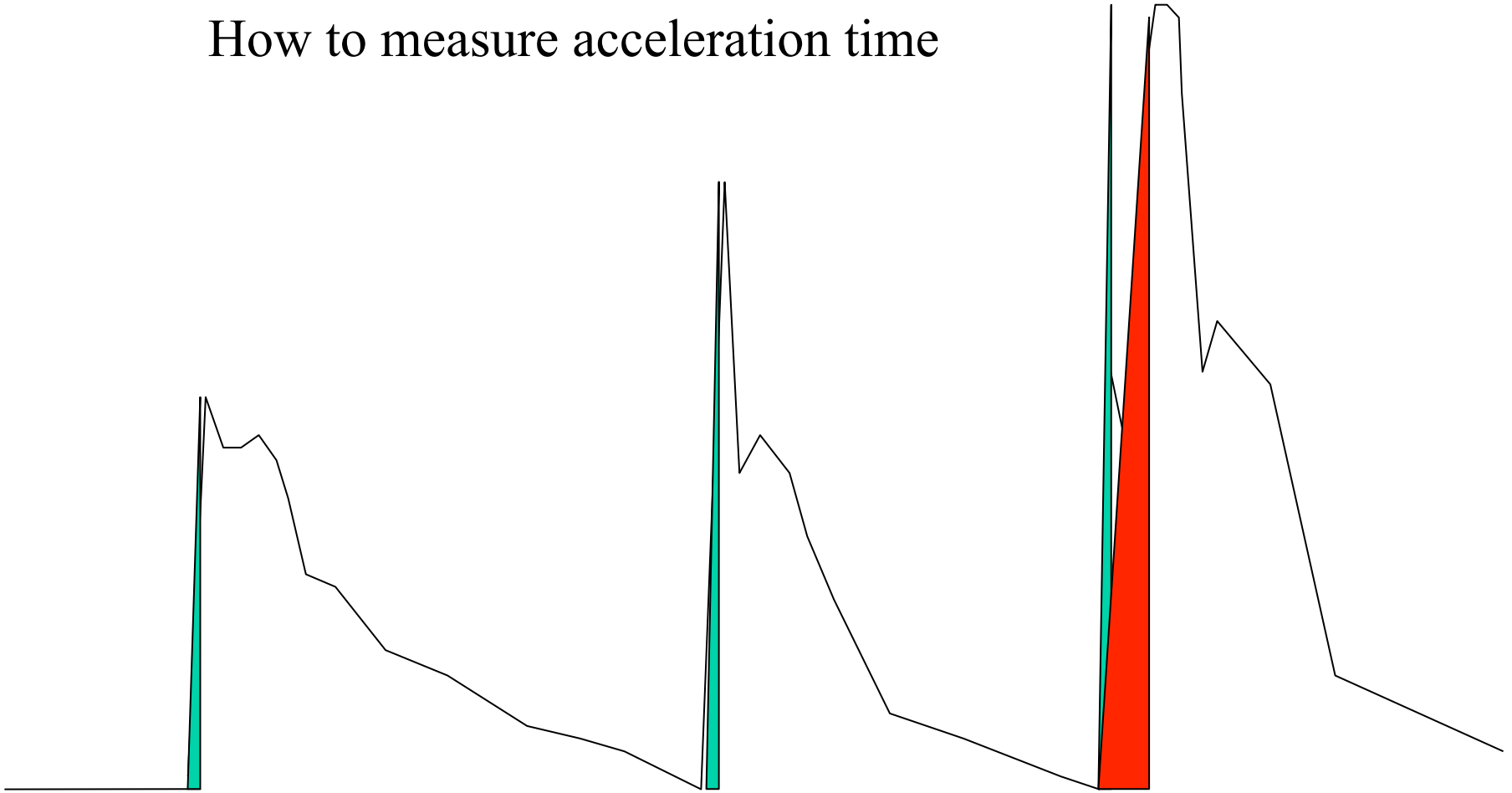
Direct

Indirect



CDS native kidney: RAS

How to measure acceleration time



CDS native kidney: RAS

	Patient-number	Stenosis-criteria	Technical failure (%)	Detected deg. Of stenosis (%)	Sensitivity / specificity (%)
Indirect stenosis criteria (Paravus -Tardus)					
Stavros 1992 [51]	56	Verlust des ESP	0	≥ 60	95 / 97
Kliewer 1993 [21]	57	AT ≥ 70 ms	0	≥ 50	82 / 20
Schwerk 1994 [46]	72	Delta RI ≥ 5 %	0	≥ 50	82 / 92
			0	≥ 60	100 / 94
Speckamp 1995 [50]	123	Delta AI ≥ 80%	n.v.	≥ 70	100 / 94
Strunk 1995 [53]	50	AT ≥ 70 ms	4	≥ 50	77 / 46
Baxter 1996 [3]	73	AT > 70 ms	16	≥ 70	89 / 97
Riehl 1997 [41]	214	RI < 0.45 oder Delta RI ≥ 8 %	0	≥ 70	93 / 96
Ripolles 2001 [42]	65	AT ≥ 80 ms	0	≥ 75	89 / 99
Mean value	**710**		**2**		**92 / 86**

Combination of direct and indirect (intrarenal) Doppler parameters to diagnose renal artery stenosis

	Patient number	Tech failure	Detected degree of stenosis	Sensitivity	Specificity
Direct parameters	973	14%	50%	89	94
(9 studies)					
Indirect parameters	592	0,5%	64%	94	96
(7 studies)					

Combination of direct and indirect (intrarenal) Doppler parameters to diagnose renal artery stenosis

	Patient number	Tech failure	Detected degree of stenosis	Sensitivity	Specificity
Direct parameters	973	14%	50%	89	94
(9 studies)					
Indirect parameters	592	0,5%	64%	94	96
(7 studies)					
Combination	343	0	50	94	96
(2 studies)					
Krumme 1996	135	0	50	89	92
Radermacher 1999	208	0	50	97	98

Combination of direct and indirect (intrarenal) Doppler parameters to diagnose renal artery stenosis

	Summe Patientenzahl	Techn. Versagen	Detektierter Stenosegrad	Sensitivität	Spezifität
Krumme 1996	**135**	**0**	**50**	**89**	**92**
Vmax > 200 cm/sec		**18,4**		**71**	**96**
Delta RI ≥ 5%		**0**		**64**	**82**
Radermacher 1999	**208**	**0**	**50**	**97**	**98**
RRR > 4		**16**		**97**	**98**
AT ≥ 70 msec		**0**		**87**	**87**

RRR = Renal Renal Ratio, d.h. Verhältnis

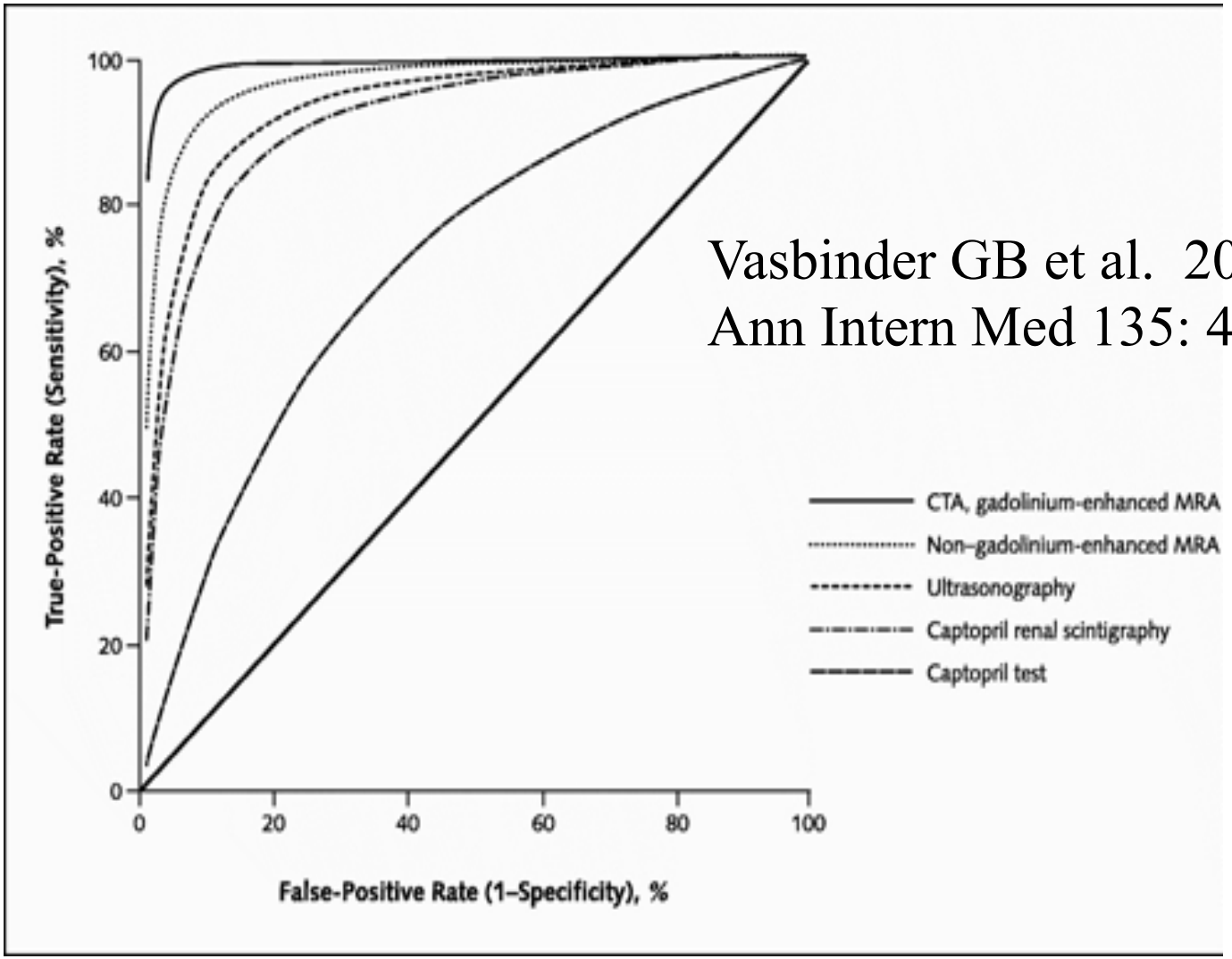
$$\frac{\text{V max intrastenotisch}}{\text{Vmax poststenotisch}}$$ zu

Sensitivität, Spezifität, positiver und negativer prädiktiver Wert der farbkodierten Duplexsonographie verglichen mit der Angiographie zur Diagnose einer Transplantatnierenarterienstenose =50% (Diameterreduktion)

	Sensitivität	Spezifität	Positiver prädiktiver Wert	Negativer prädiktiver Wert
Vmax intrastenotisch = 4x Vmax prä-oder poststenotisch	100	93	97	100
Vmax = 180 cm/sec	100	64	88	100

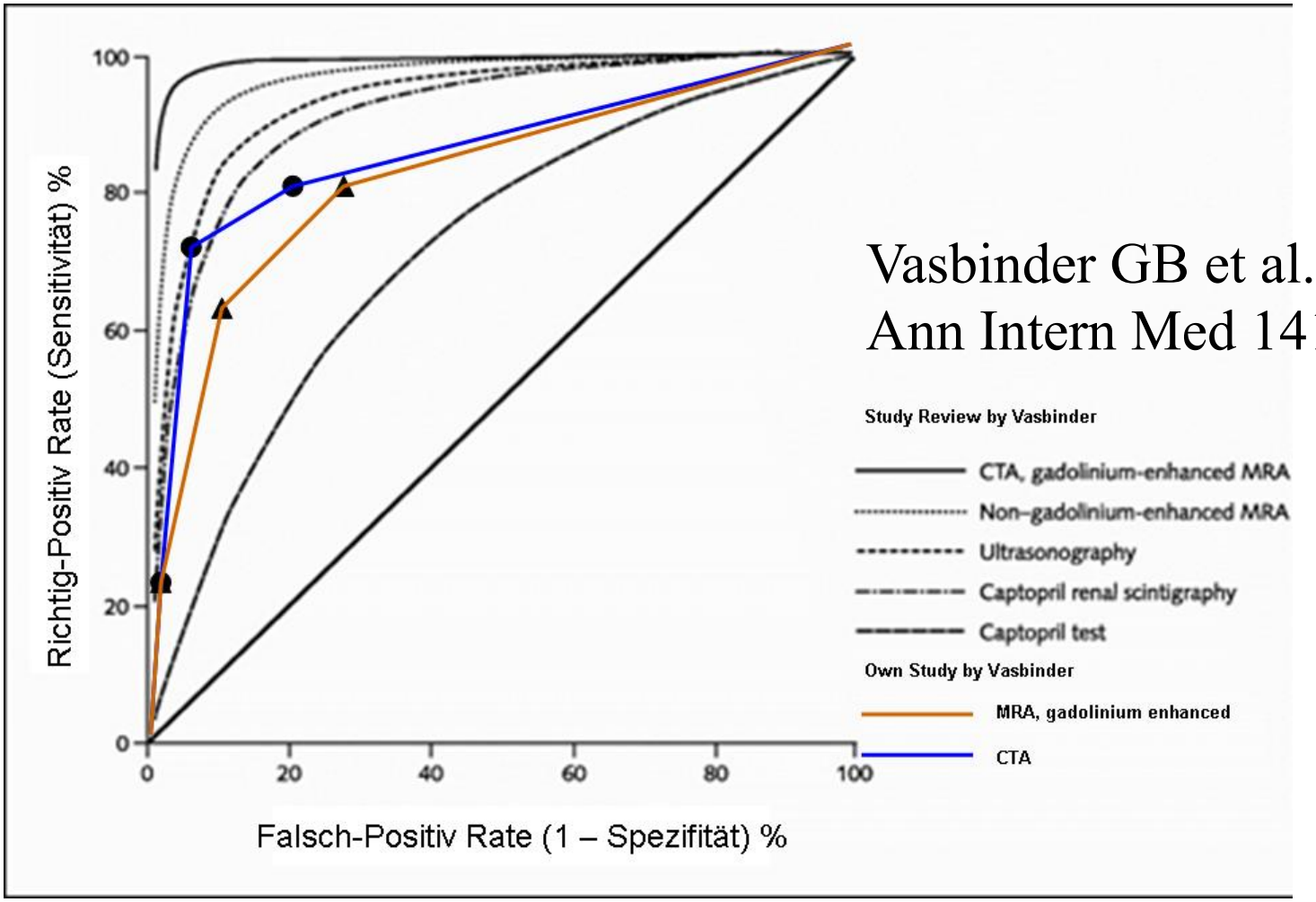
Why CDS

CDS native kidney: RAS



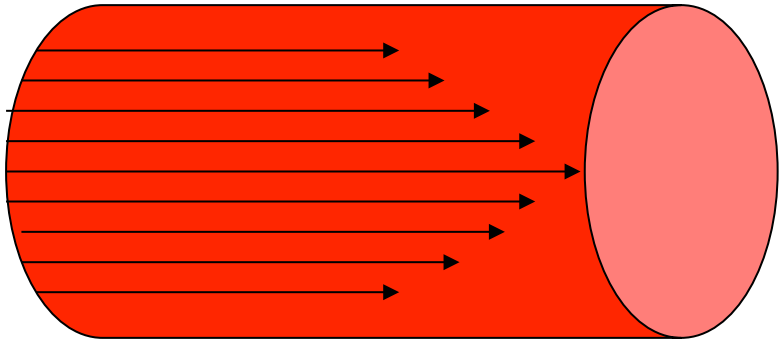
Vasbinder GB et al. 2001
Ann Intern Med 135: 401-11

CDS native kidney: RAS

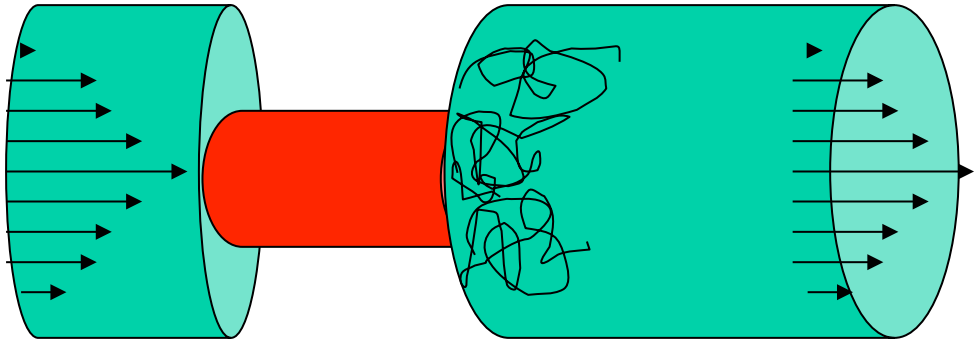


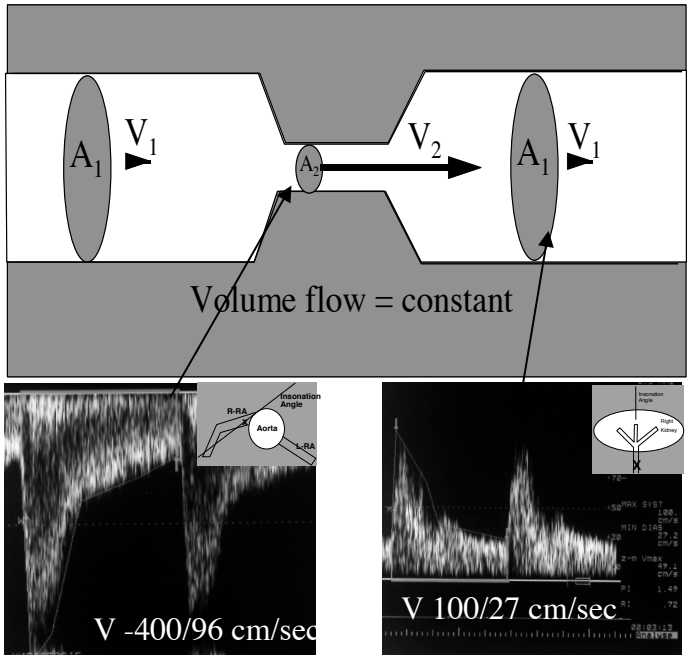
Vasbinder GB et al. 2004
Ann Intern Med 141: 674-82

Quantification with CDS

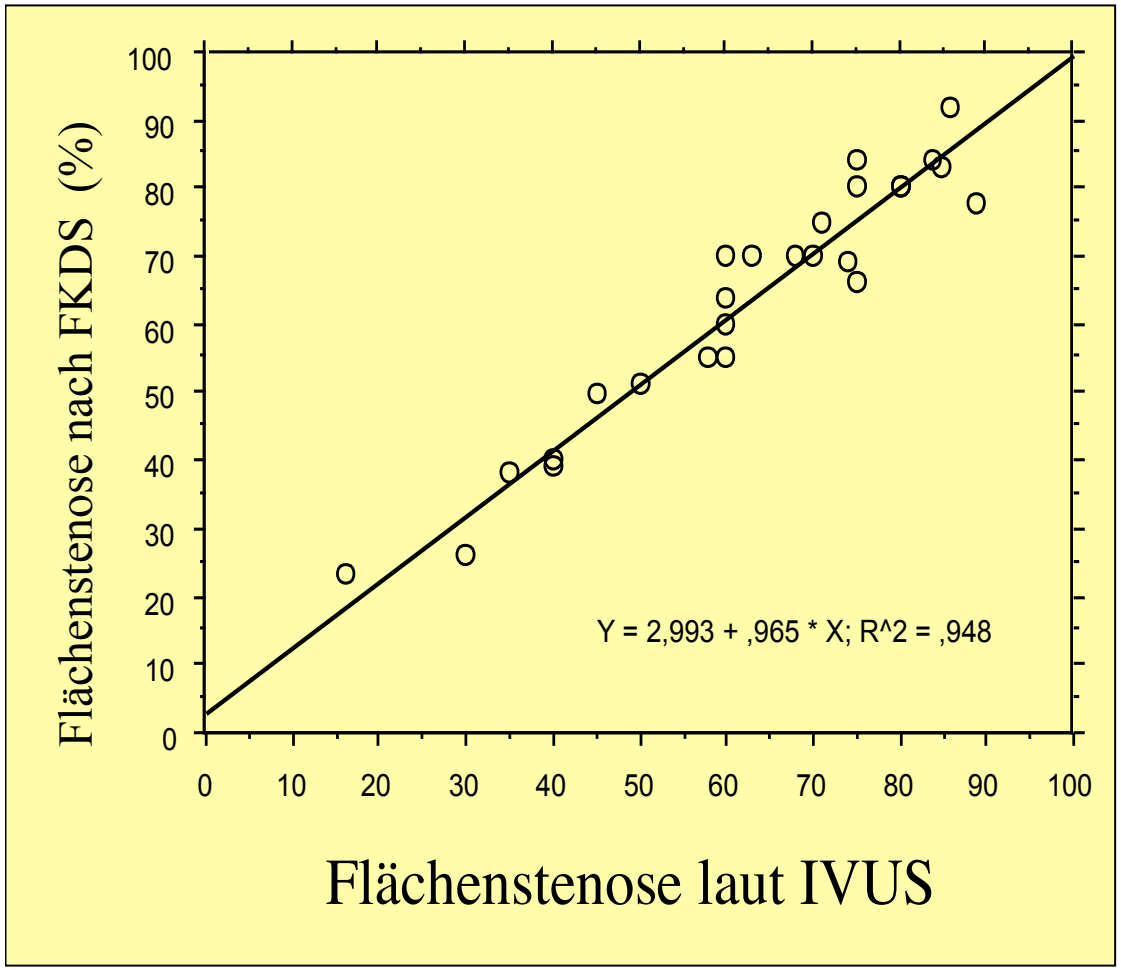


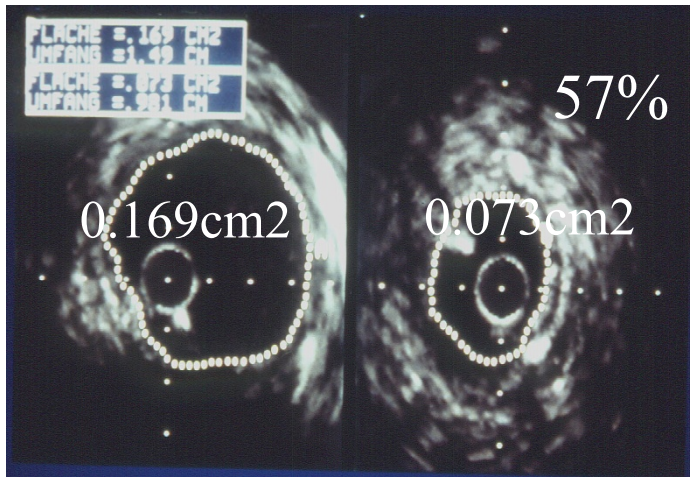
Quantification with CDS





Quantification with CDS





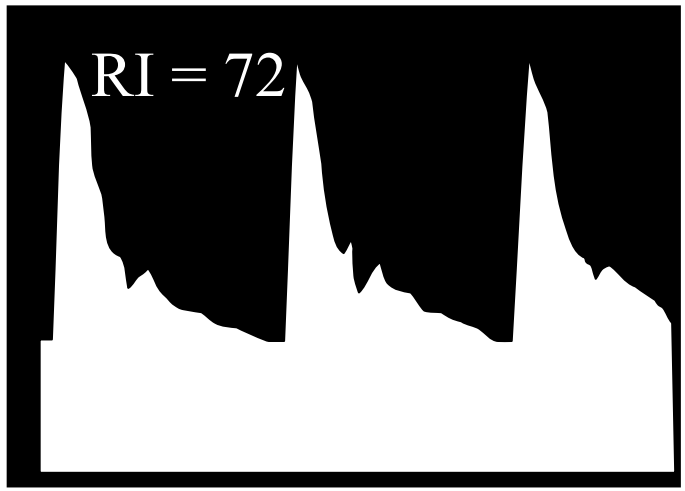
Renal Doppler

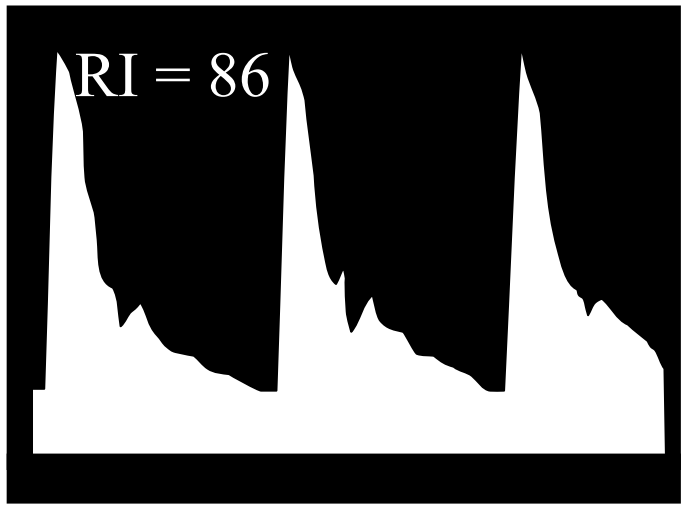
- Doppler Measurements
  - What is there
  - How to detect
    - diabetic nephropathy
    - hypertensive Nephrosclerosis
    - Renal stones
    - Relevant hydronephrosis
    - Prerenal renal failure
    - renal artery stenosis
    - renal artery stenosis which should be corrected

Who is more likely to be a responder?

- Clinical clues:
  - proteinuria < 1g/Tag
  - GFR > 40 ml/min
  - no CHD, AOL, CVD
  - age < 65 a
- Resistive Index (RI) < 0.80

Nephrosklerose/Glomerulosklerose





Randomized studies: RPTA+OMT vs OMT

DRASTIC: van Jaarsveld NEJM 2000 342: 1007-14

- 106 patients, **no significant effect**

EMMA: Plouin Hypertension 1998 31: 823-9

- 49 patients, **no significant effect**

Webster et al. J Hum Hypertens. 1998 12: 329-35

- 55 patients, **no significant effect**

NITER trial (Italy): WCN 2009

- 100 patients with RAS > 70%, at 52 pts. **no significant effect**

STAR trial: Annals Int Med 2009 150:840-48

- 140 patients GFR< 80 ml/min, **no significant effect**

ASTRAL Trial (UK): NEJM 2009 361: 1953-62

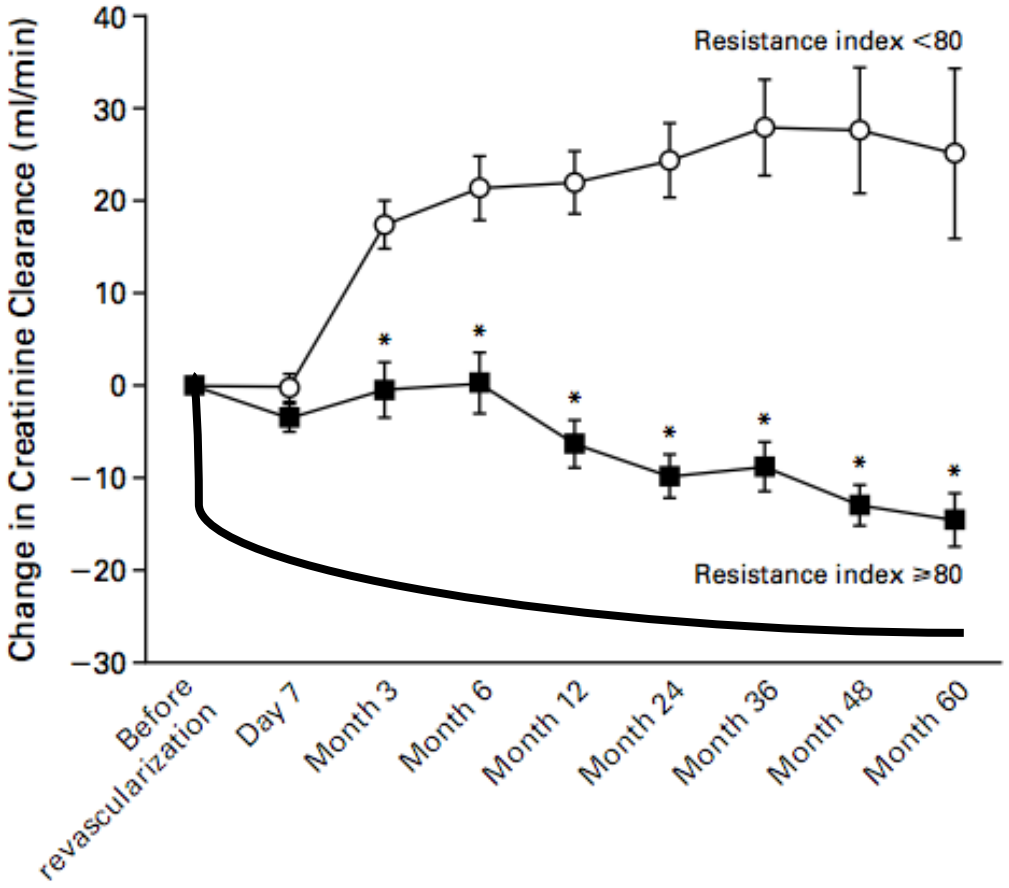
- *806* patients , **no significant effect**

RASCAD (Italy): AJKD 2012 60: 39-46

- 84 patients , **no significant effect on LVH**

CDS native kidney: RAS

Prognosis of renovascular azotemia: value of RRI



No. with Follow-up Data									
Resistance index <80	96	96	95	83	73	59	43	34	21
Resistance index ≥80	35	35	33	31	26	21	16	8	5

Radermacher et al. 2001 NEJM 344: 410-417

Renal Doppler as a prognostic tool in nephrology?

RRI and renal artery stenosis: Prognosis of blood pressure and renal function

RI useful(n=900)

- *Radermacher et al. NEJM 2001 344:410-17 (n=131)*
- *Crutchley et al. J Vasc Surg 2009 49: 148-55 (n=86)*
- *Bommart et al AJR 2010 194: 1365-72 (n=51)*
- *Davies et al.JVascSurg 2010 51:1222-9 (n=592*
- *Cianci et al RenFail 2010 32:1167-71 (n=40)*

RI no use (n=329)

- *Zeller et al. 2003 Catheterization and Cardiovasc. Interventions 58:510-15 (n=241)*
- *Garcia-Criado et al. 2005 J Ultrasound Med 12:1641-7 (n=36)*
- *Rivolta et al. 2005 J Nephrol 18:749-54 (n=52)*
- *Eklof et al. 2009 Acta Radiol 26:1-9*

Kidney and RI: Diabetes and Hypertension

RI useful

Diabetes

- *Nosadini Diabetes 2006 55:234-9 (n=157)*
  GFR Decline RR=3; proteinuria RR=5
- *Ghaffar Pediatr Diabetes 2010 11:479-86 (n=100)*
- *Nakamori J Clin Ultrasound 2011 (EPUB) (n=113)*
- *Bruno Diabetologica 2011 54:2430-9 (n=81)*

Hypertensives

- *Derchi Am J Hypertens 2005 18:966-71 (n=291)*
- *Shimizu Hypertens Res 2001 24:13-7 (n=102)*
- *Raff J Hypertens. 2010 28:608-14 (n=84)*
- *Bruno Diabetologica 2011 54:2430-9 (n=81)*

RI of no use

- *No articles in Peer reviewed Journals*

FKDS der Nativniere