The Pulse of Asia 2009

Dynamic Arterial Stiffness During Exercise

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Why we need to assess arterial stiffness during exercise ?

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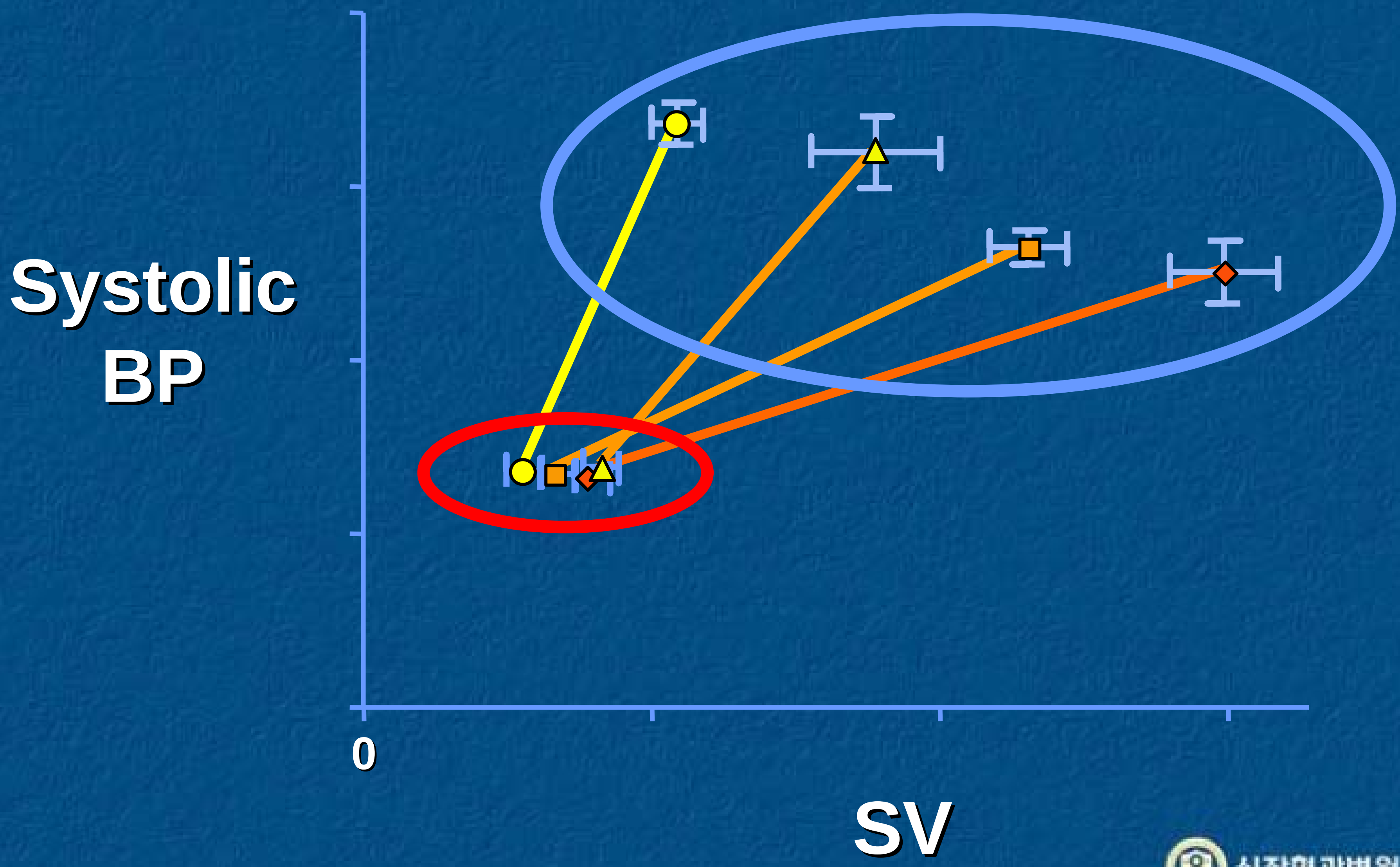
Change in SV and Systolic BP with Exercise



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Hypothesis #1

Arterial stiffness assessed during exercise would be more predictive for exercise capacity than that at rest

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Study subjects

123 consecutive subjects

(43 males, age; 58 ± 11, HTN 69.1 %)

Diastolic stress echocardiography

Radial artery tonometry

Simultaneously

(From Nov. 2007 to Sep. 2008)

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Study subjects

- **Exclusion criteria**

  Valvular heart disease

  Peripheral vascular disease

  History of significant CAD or inducible ischemia

  Atrial fibrillation or significant arrhythmia

  Severe hypertension (> 180/ 110 mmHg)

  Renal insufficiency (Cr > 1.4 mg/dL)

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Methods -1

- **Diastolic stress echo**

  Symptom-limited multistage exercise test

  with a variable load bicycle ergometer

  (Medical Positioning Inc, Kansas City, Mo, USA)

  Incremental workload of 25 W every 3 minutes

  Peripheral SBP, DBP, HR : at each stage

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Methods -2

- **Assessment of central blood pressure and arterial transfer function**

1. At rest

2. Immediately (< 1 min) after peak exercise

(Supine position)

**** Pulse wave velocity at rest**

Radial artery tonometry

(SphygmoCor®, AtCor Medical)

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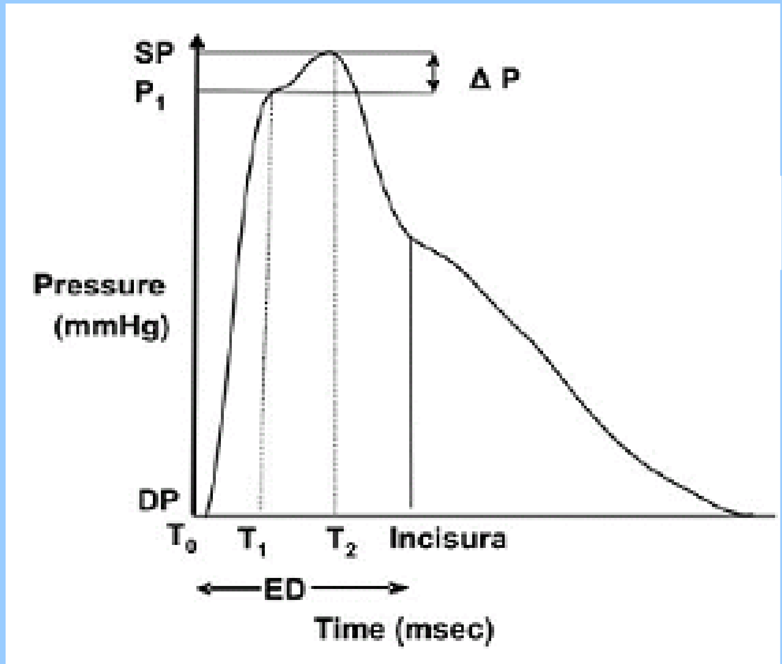
Methods -3



- Central Systolic BP
- Central Diastolic BP
- Central PP (pulse pressure)
- Augmentation index

Augmentation index

= (Δ P/PP) x 100

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Demographic characteristics

	n = 123
Age, years	58 ± 11
Male gender, n (%)	43 (35.0)
HTN, n (%)	85 (69.1)
DM, n (%)	13 (10.6)
Smoking, n (%)	35 (28.5)
Dyslipidemia, n (%)	52 (42.3)
Body mass index, kg/m^2	25.5 ± 3.0
Exercise duration, sec	560.6 ± 188.7

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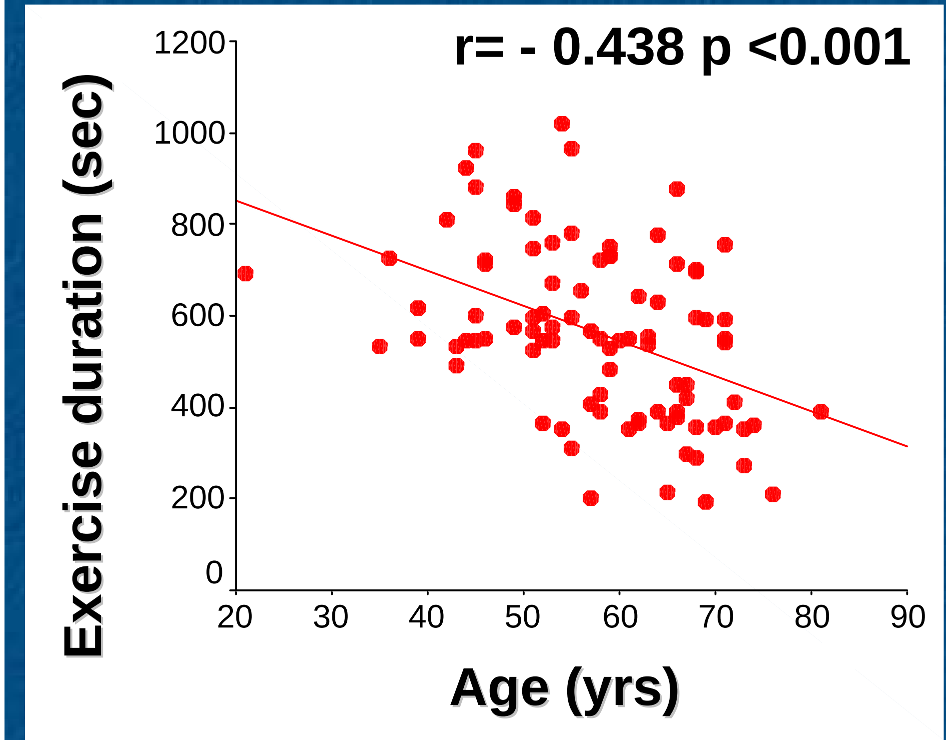
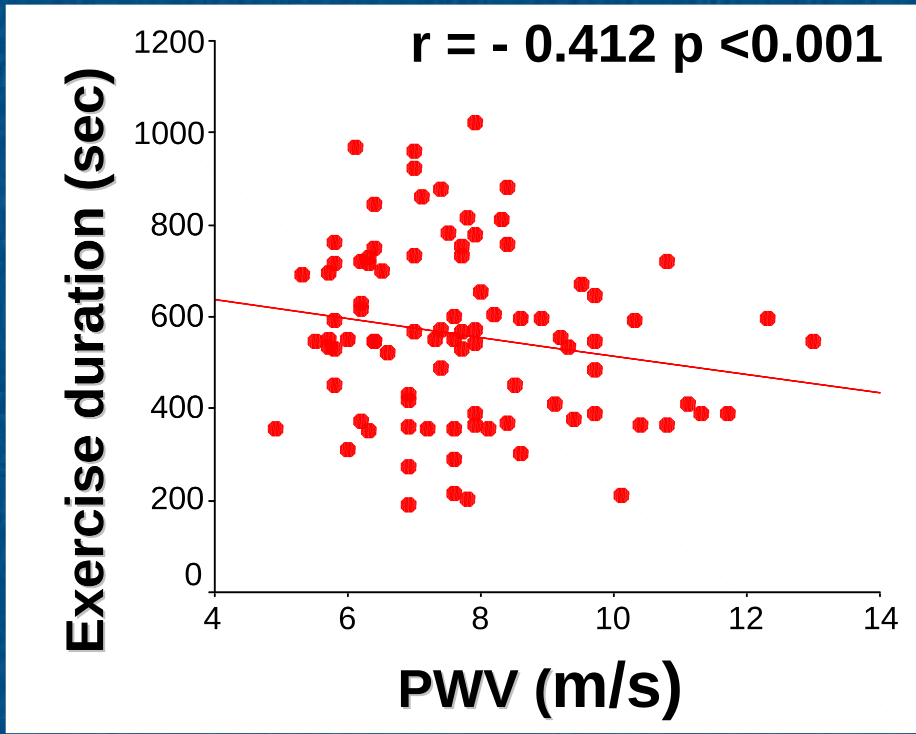
Simple correlation

Age, PWV and Exercise duration





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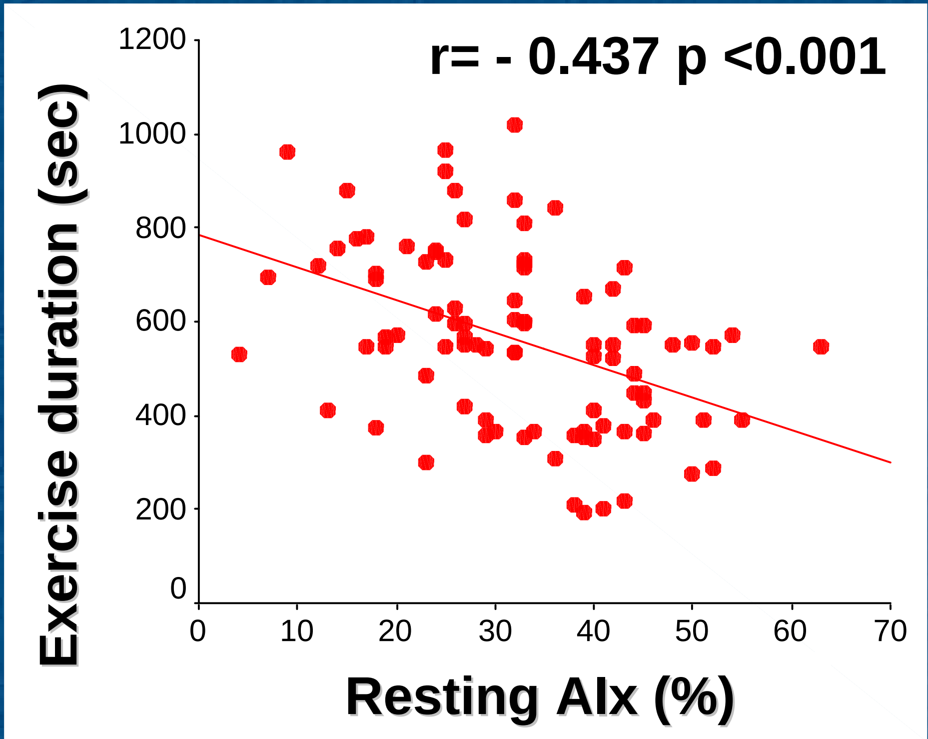
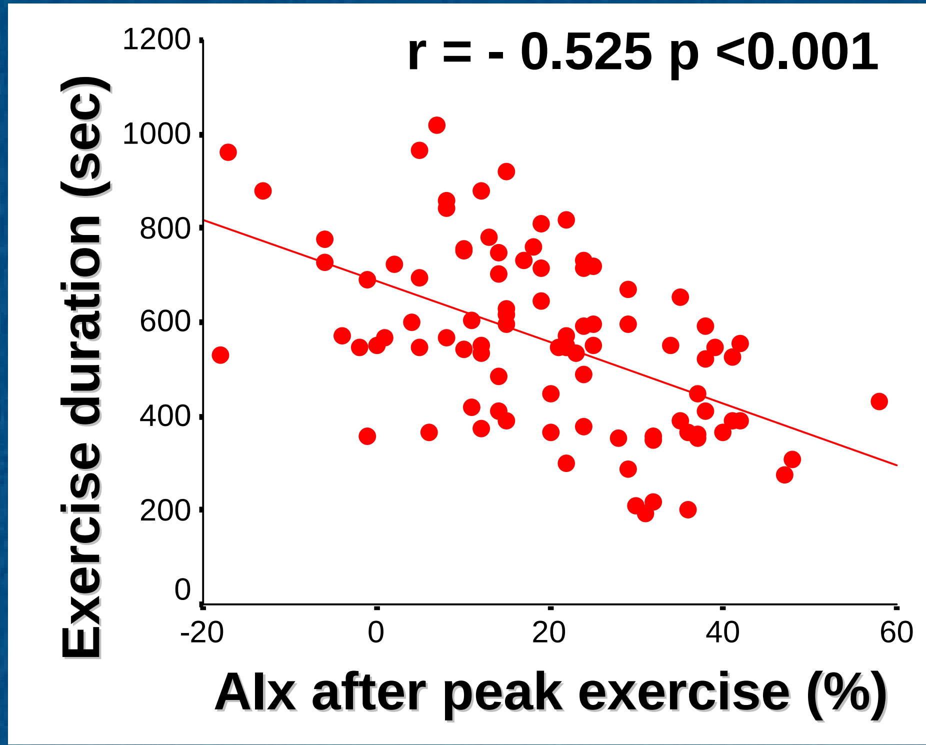
Simple correlation

AIx and Exercise duration





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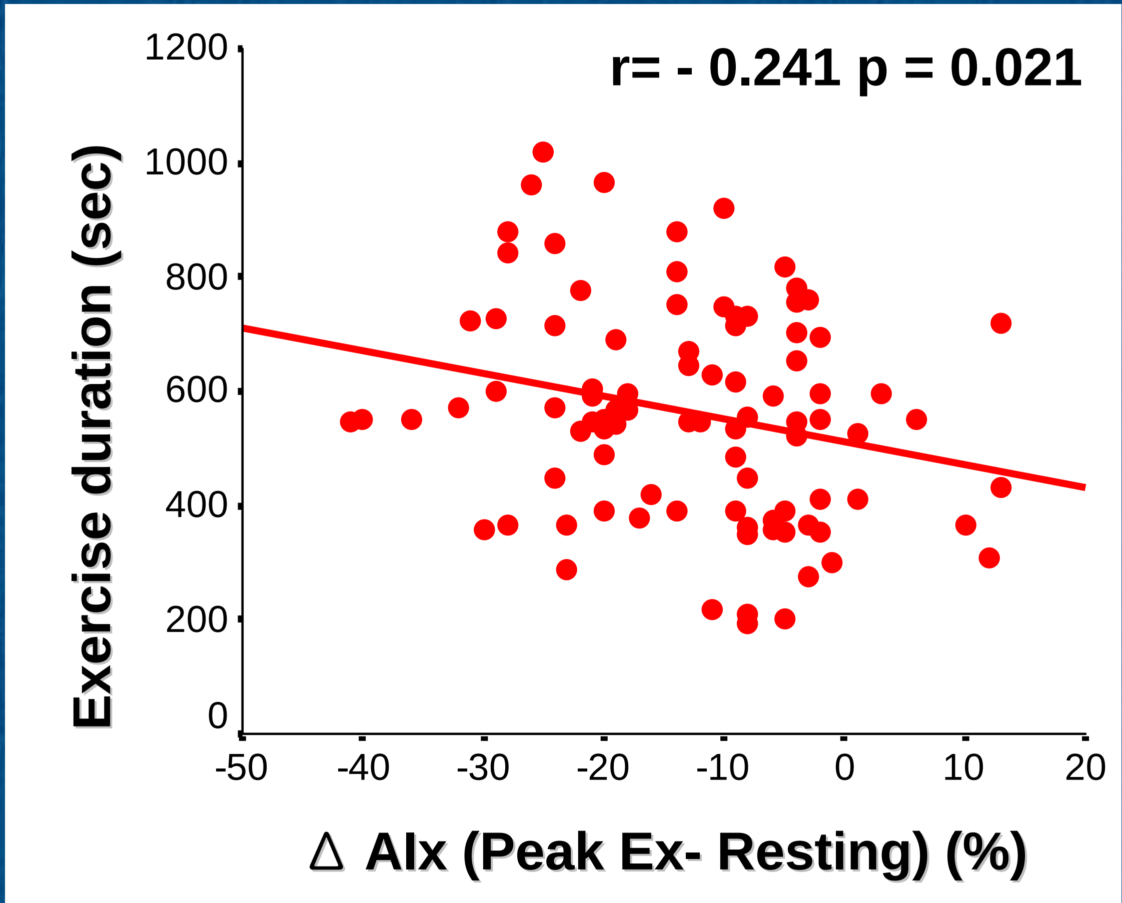
Simple correlation

Change of AIx during exercise & Exercise duration



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Multiple regression analysis

Resting AIx vs. Exercise duration

	β	t	P-value
Age	-0.399	-5.215	< 0.001
Male gender	0.613	7.512	< 0.001
LV mass index	0.149	2.149	0.034
PWV	0.106	1.387	0.169
Resting AIx	-0.023	-0.268	0.789

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Multiple regression analysis

AIx after peak Ex vs. Exercise duration

	β	t	P-value
Age	-0.337	-4.397	< 0.001
Male gender	0.578	7.295	< 0.001
LV mass index	0.175	2.604	0.011
PWV	0.082	1.111	0.270
Resting AIx	0.123	1.290	0.201
AIx after peak Ex	-0.264	-2.834	0.006

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Multiple regression analysis

∆ AIx (Peak Ex- Resting) vs. Exercise duration

	β	t	P-value
Age	-0.337	-4.397	< 0.001
Male gender	0.578	7.295	< 0.001
LV mass index	0.175	2.604	0.011
PWV	0.082	1.111	0.270
Resting AIx	-0.084	-1.006	0.318
∆ AIx (peak Ex-Resting)	-0.198	-2.834	0.006

Implications

- Unlike AIx and PWV measured at rest, AIx immediately after peak exercise and change of AIx from rest to exercise were independent predictors of exercise capacity

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Limitations

1. At rest
2. Immediately (< 1 min) after peak exercise

Not technically feasible during exercise

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Diastolic Stress Echocardiography: A Novel Noninvasive Diagnostic Test for Diastolic Dysfunction Using Supine Bicycle Exercise Doppler Echocardiography

Jong-Won Ha, MD, PhD, Jae K. Oh, MD, Patricia A. Pellikka, MD, Steve R. Ommen, MD,
Vicky L. Stussy, RN, RDCS, Kent R. Bailey, PhD, James B. Seward, MD, and
A. Jamil Tajik, MD, *Rochester, Minnesota*

evere exertional symptoms, it
measure the hemodynamic
to ensure that these symptoms
tory dysfunction.

olic Stress

olic dysfunction, the abnormal
augmentation of relaxation as
luring exercise.[11-13] Therefore,
lic functional reserve (defined
he ventricle to accommodate
ssary for increased cardiac de-

Advantage of the Current Diastolic Stress Echocardiography Protocol

Supine bicycle exercise echocardiography allows continuous imaging of the heart during exercise and acquisition of the LV filling pattern in the immediate recovery phase, which may be helpful in interpreting changes in diastolic function. An increase in end-systolic and end-diastolic ventricular volumes occurs in the supine position at rest and during exercise.[17,18] Therefore, myocardial wall tension (directly related to volume and pressure) increases precipitously with supine exercise, increasing myo-

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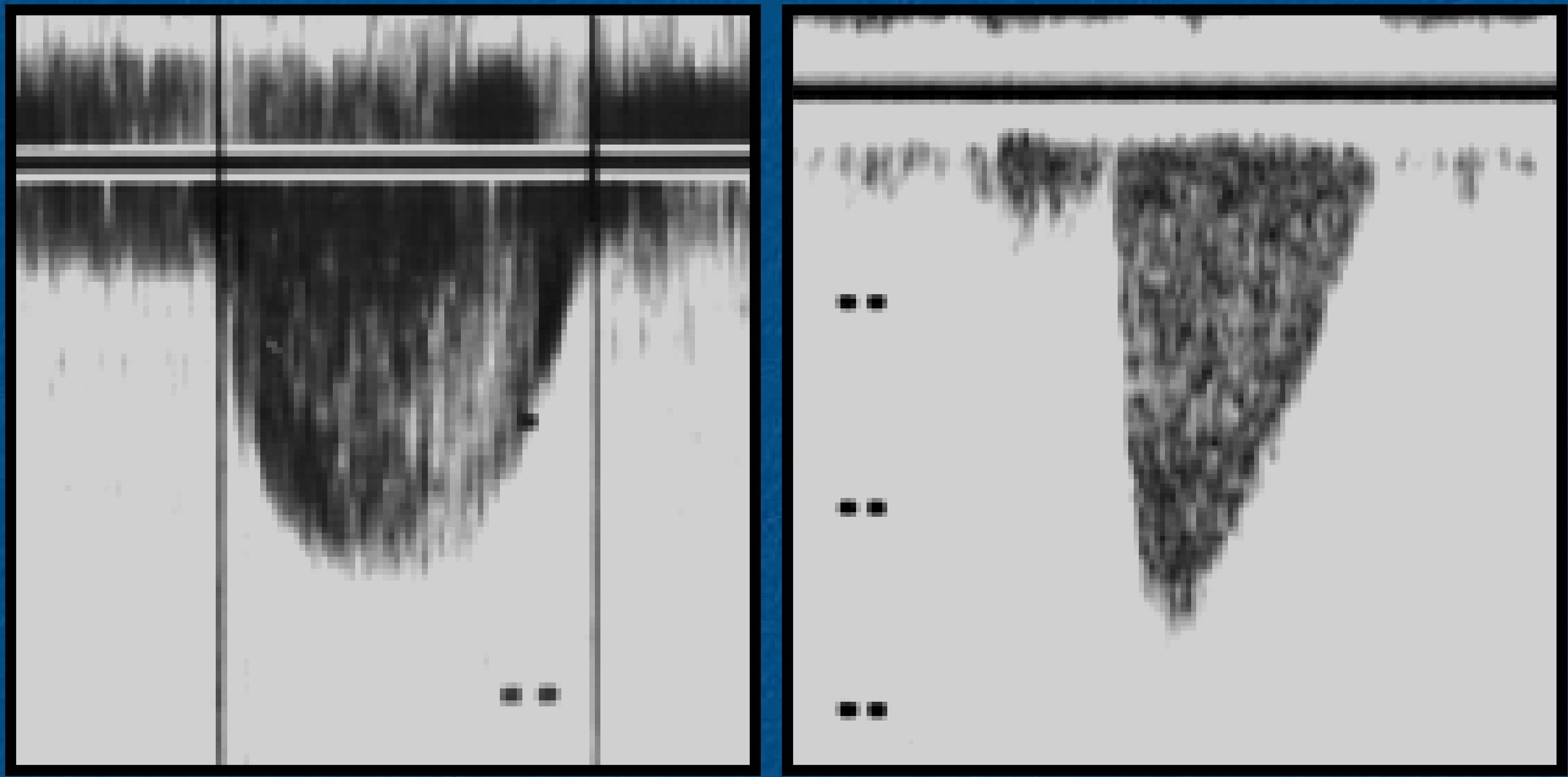
Two different TR signals



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Simplified Bernoulli Equation

$$\Delta P = 4V^2$$

mayo

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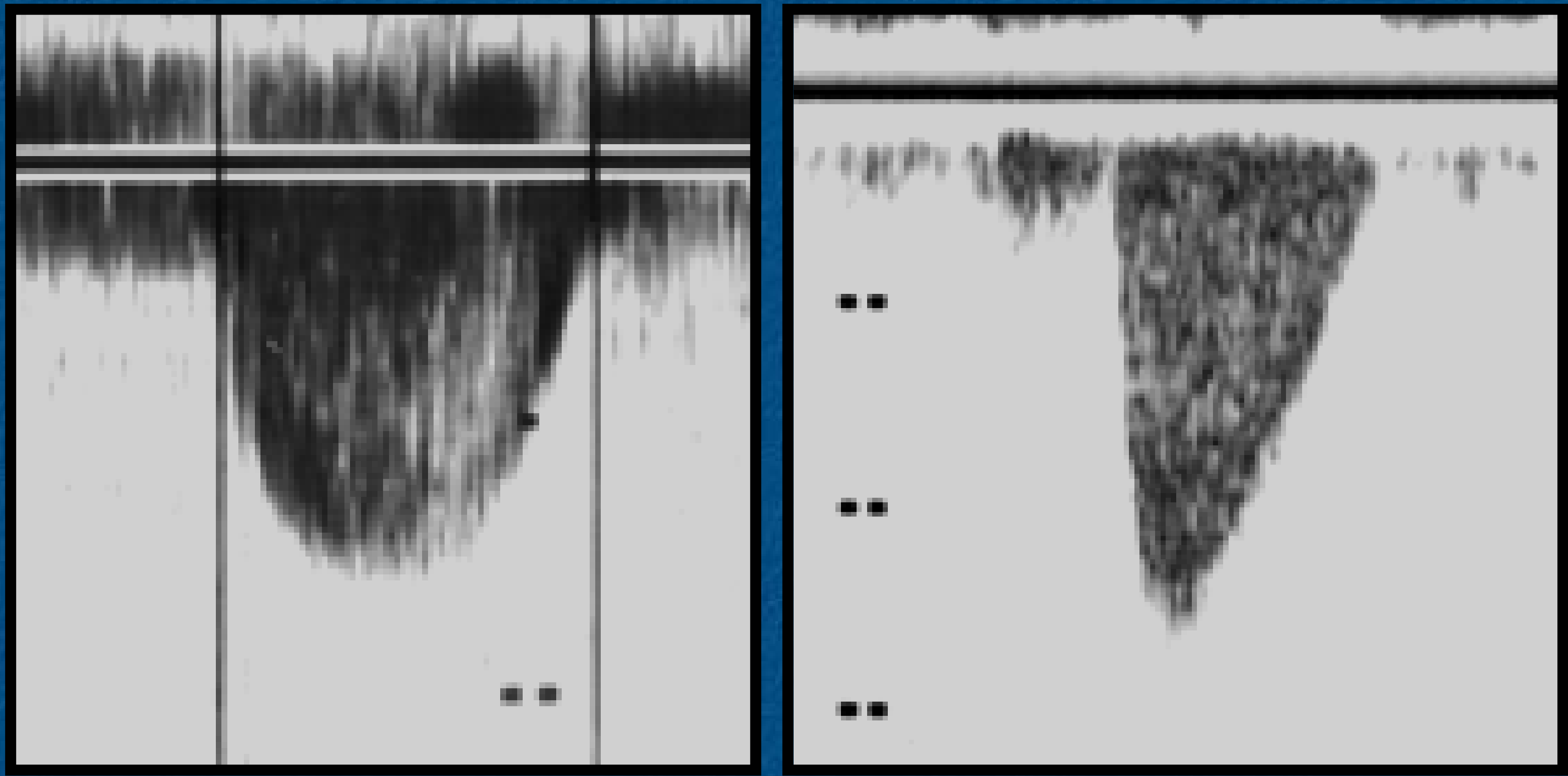
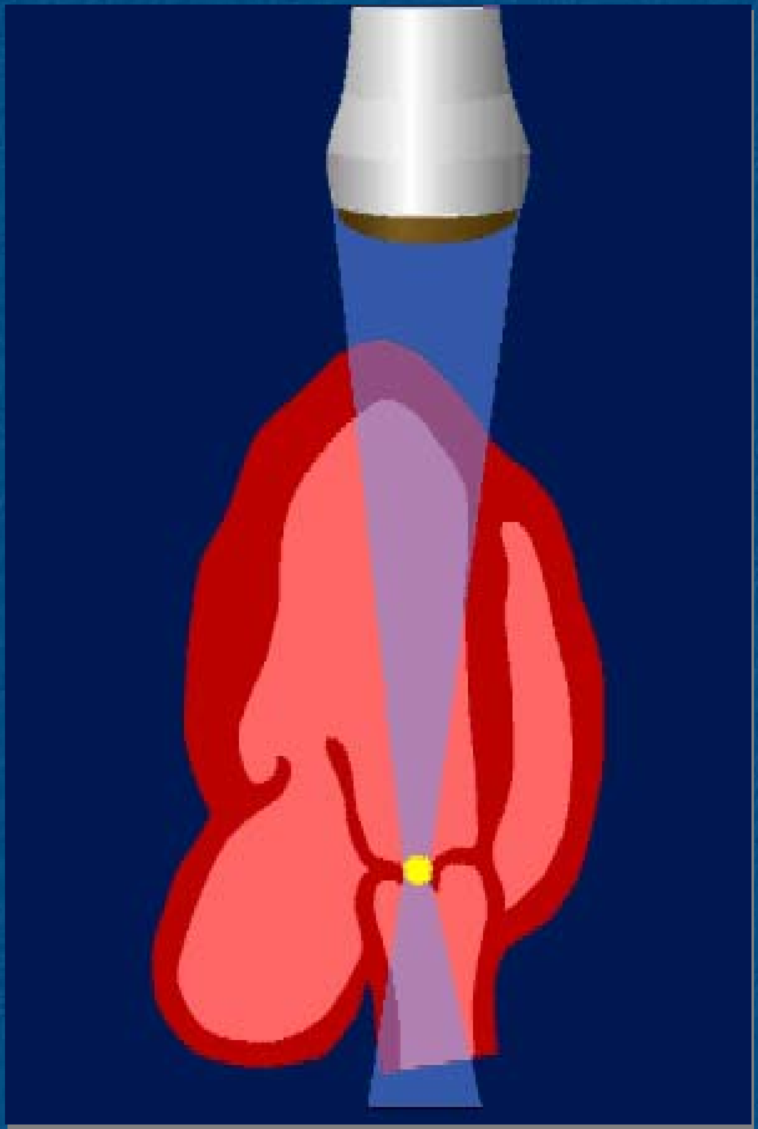
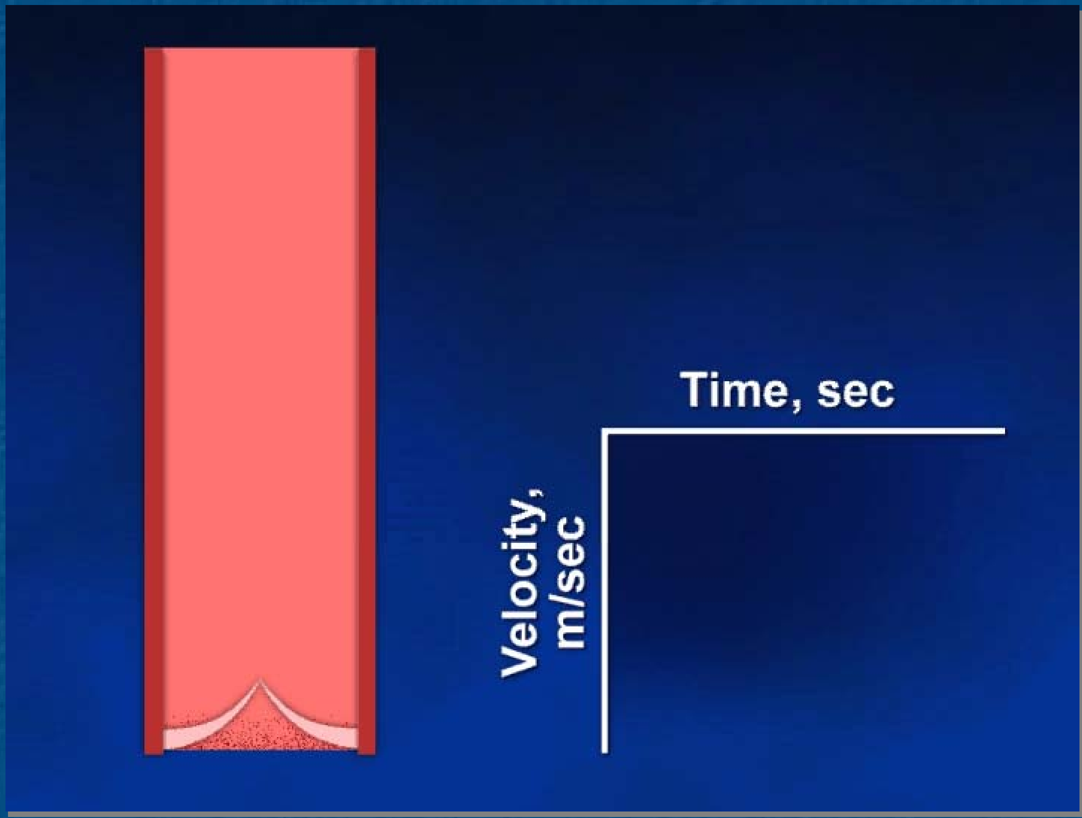
Two different TR signals



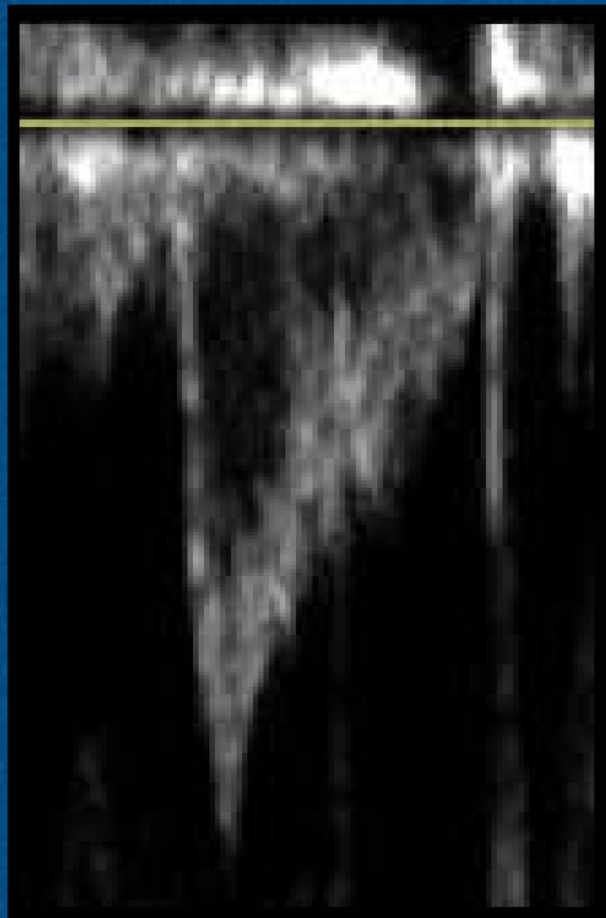
Elevated RAP or decreased RA compliance

LVOT PW Doppler





Two different LVOT signals



Non-compliant or stiff aorta

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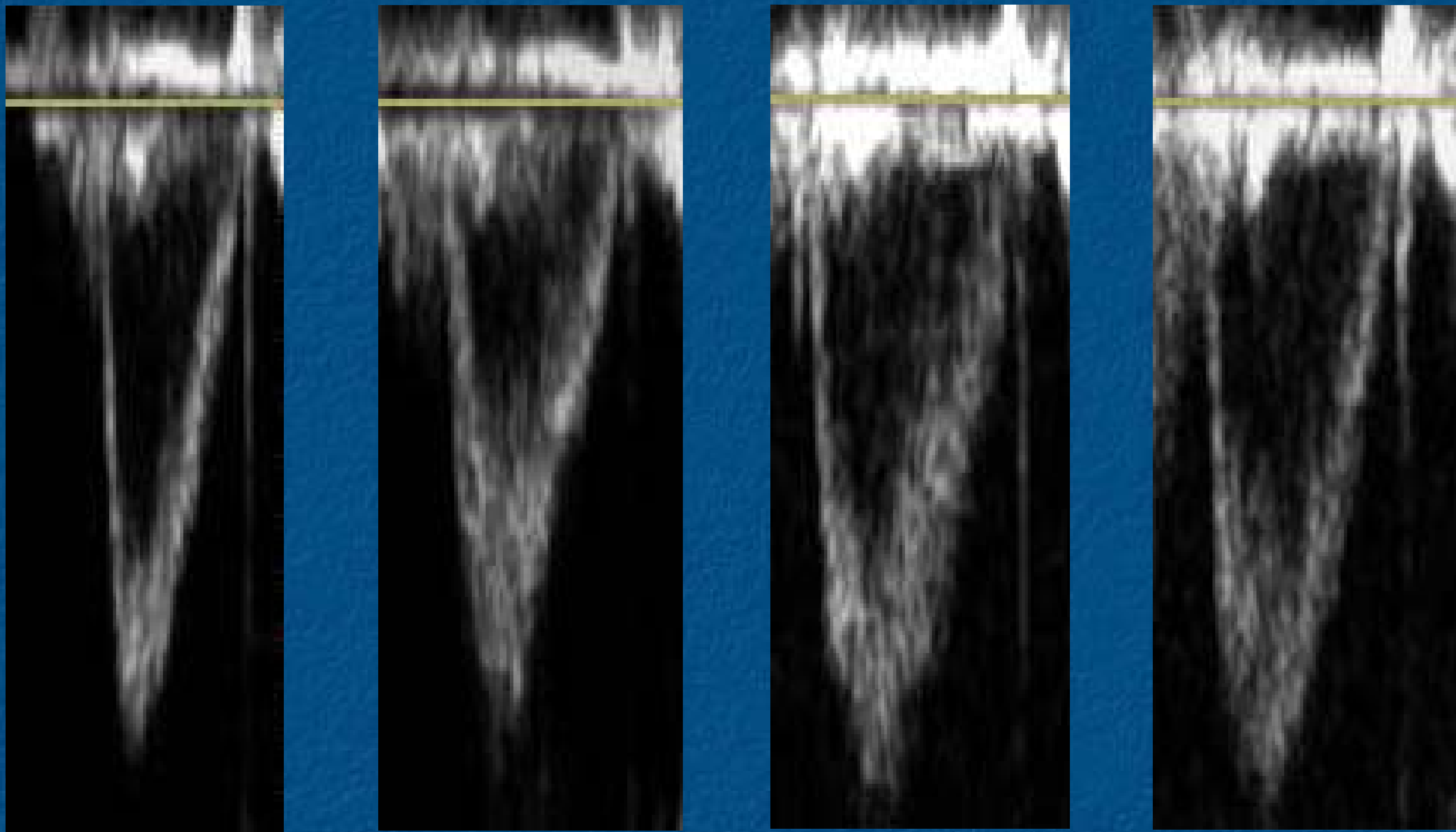
20 year-old man



Rest 25W 50W 75W

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M/ 20

At Rest

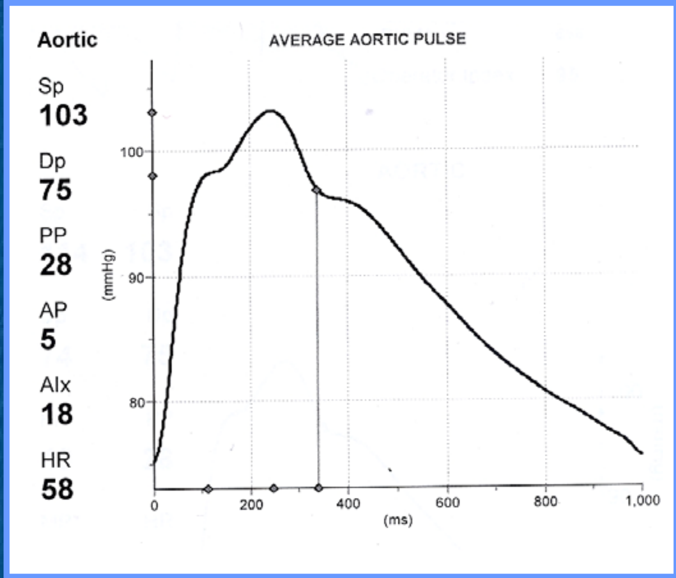
SBP/ DBP 103/ 75 mmHg

PP 28 mmHg

HR = 58 bpm

Aortic AIx 18 %

Aortic AIx (HR 75) 10 %



Peak Exercise (100 W)

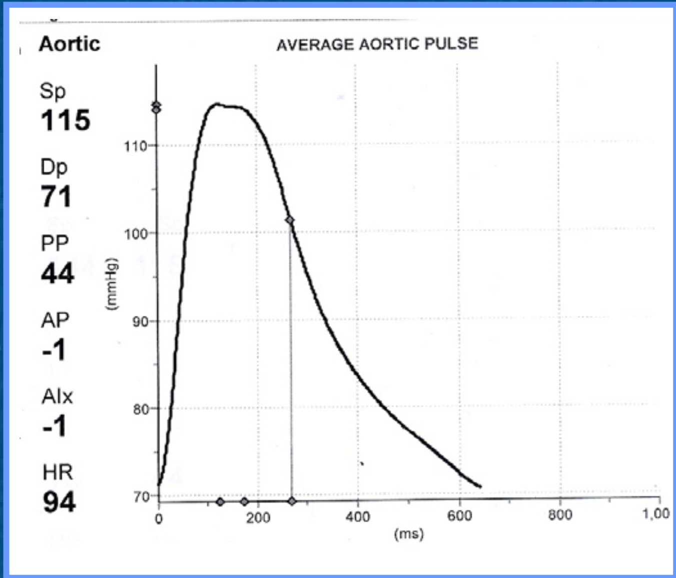
SBP/ DBP 115/ 71 mmHg

PP 44 mmHg

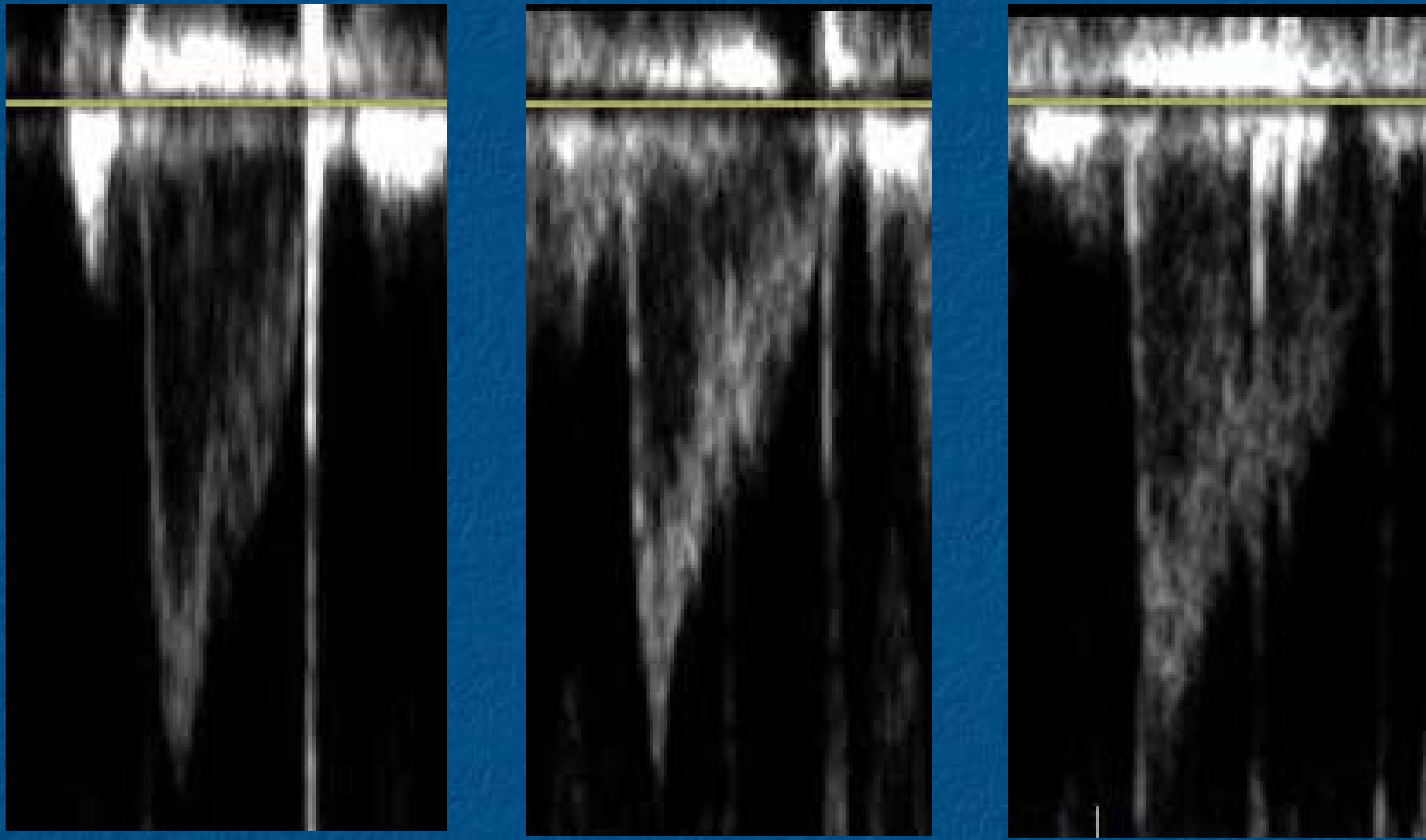
HR = 94 bpm

Aortic AIx -1 %

Aortic AIx (HR 75) 8 %



74 year-old man



Rest 25 W 50 W

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M/ 74

At Rest

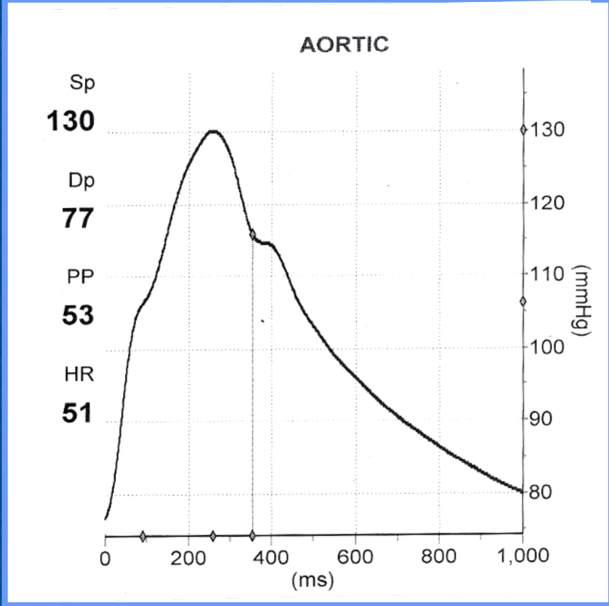
SBP/ DBP 130/ 77 mmHg

PP 53 mmHg

HR = 51 bpm

Aortic AIx 45 %

Aortic AIx (HR 75) 33 %



Peak Exercise (50 W)

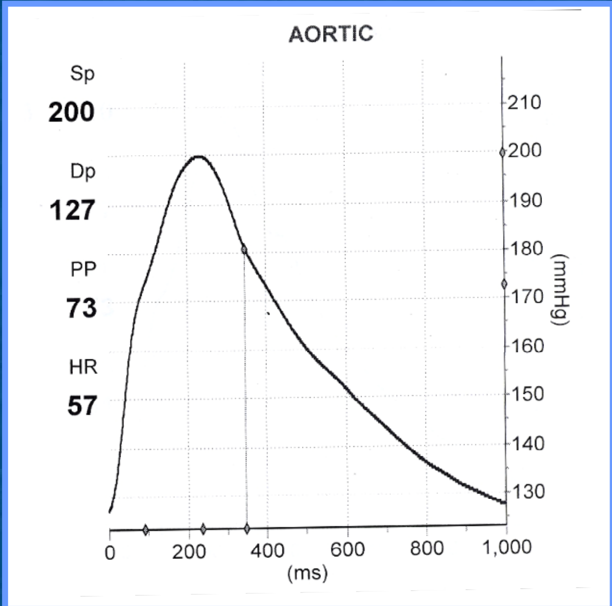
SBP/ DBP 200/ 127 mmHg

PP 73 mmHg

HR = 57 bpm

Aortic AIx 37 %

Aortic AIx (HR 75) 28 %



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Hypothesis #2

LVOT flow deceleration would be correlated with central PP and parameters of arterial stiffness

Methods

- **Subjects**

175 subjects (65 males, 57 ± 11 Yo, HTN 65.7 %)

2D and Doppler echo

Radial artery tonometry

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Exclusion criteria

Valvular heart disease

Peripheral vascular disease

Symptomatic cerebrovascular disease

History of significant CAD or inducible ischemia

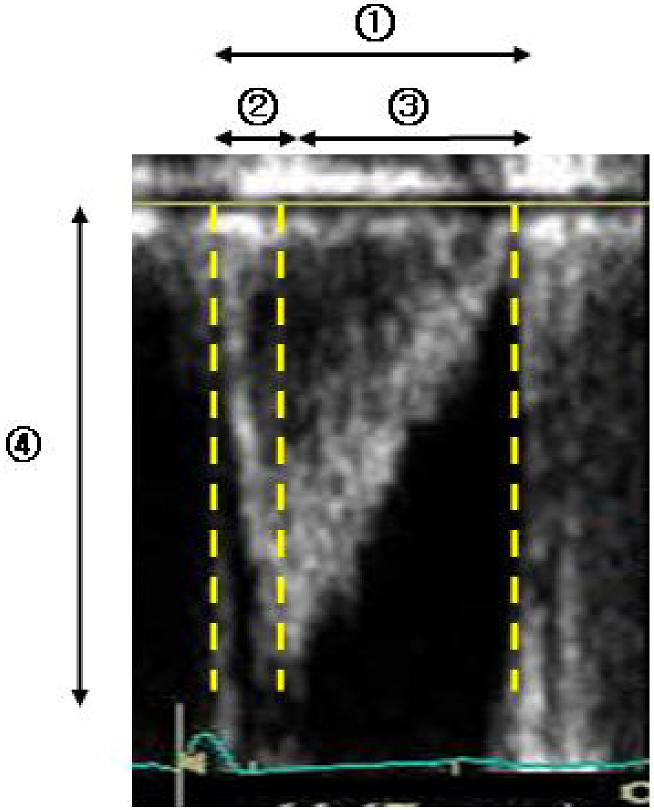
Significant systemic disease

Atrial fibrillation or significant arrhythmia

Severe hypertension (> 180/ 110 mmHg)

Renal insufficiency (Cr > 1.4 mg/dL)

The Parameters of LVOT Doppler



① LVOT Ejection time

② LVOT Acceleration time (Time to peak velocity)

③ LVOT Deceleration time

④ Peak aortic flow velocity

Acceleration time/ Ejection time = ② / ①

Deceleration time/ Ejection time = ③ / ①

Deceleration time/ Acceleration time = ③ / ②

Shim CY et al. ASE 2008

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Methods -2

● Assessment of central blood pressure and arterial transfer function

Simultaneously

with 2D and Doppler echo

(Supine position)

Radial artery tonometry

(SphygmoCor®, AtCor Medical)

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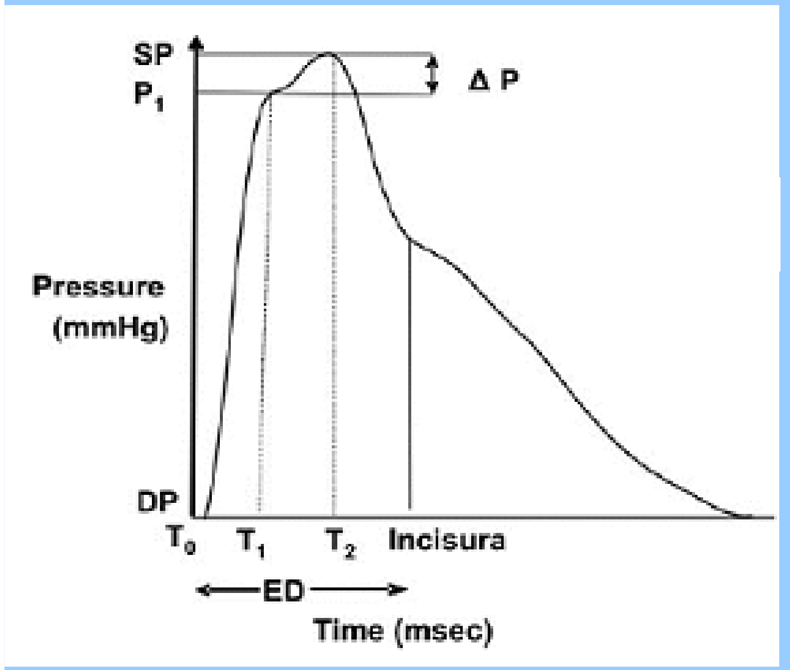
Methods -3



- Central Systolic BP
- Central Diastolic BP
- Central PP (pulse pressure)
- Augmentation pressure (ΔP)
- Augmentation index

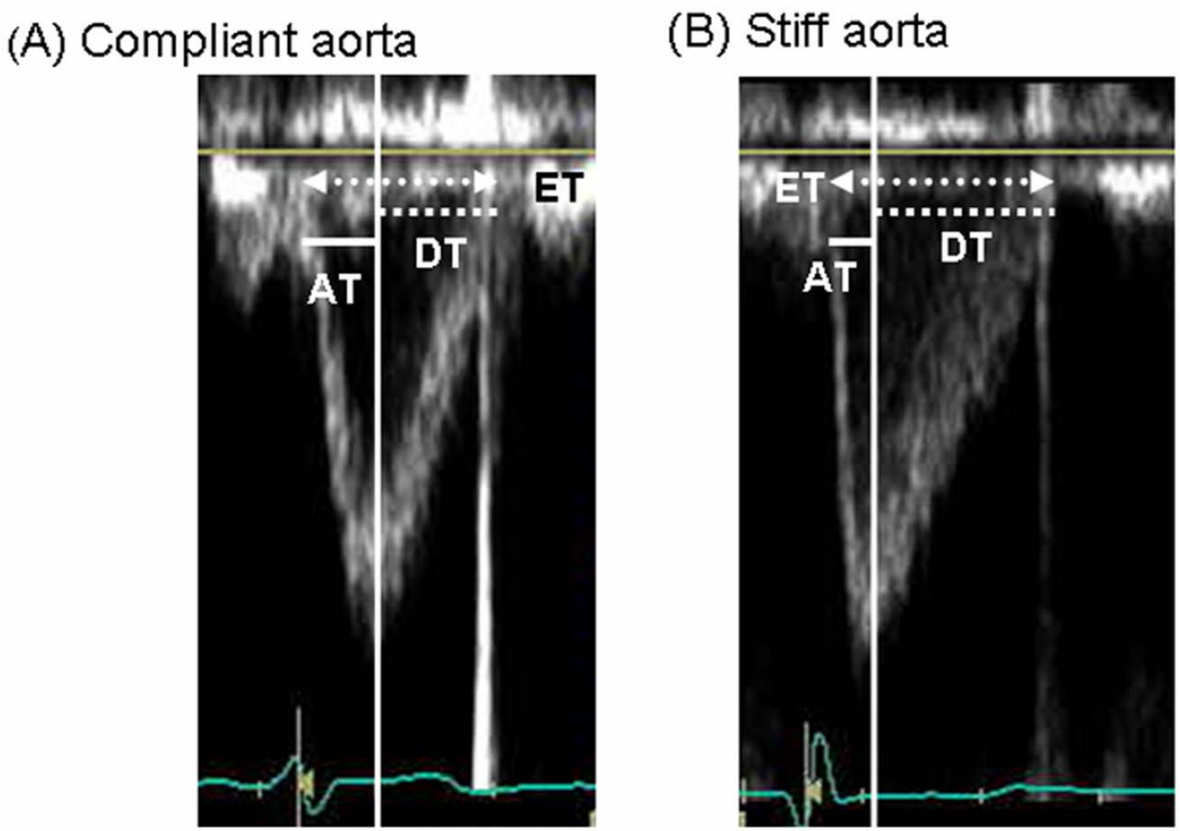
Augmentation index

= (Δ P/PP) x 100

Demographic characteristics

	N= 175
Age, years	57 ± 12
Male gender, n (%)	65 (37.1)
Height, cm	162 ± 9
Weight, Kg	66 ± 10
Body mass index, kg/m^2	25.2 ± 3.1
HTN, n (%)	115 (65.7)
Diabetes mellitus, n (%)	13 (7.4)
Dyslipidemia, n (%)	73 (41.7)
Smoking, n (%)	48 (27.4)

LVOT Doppler pattern



	(A) Compliant aorta	(B) Stiff aorta
LVOT DT	160 msec	303 msec
Central PP	34 mmHg	74 mmHg

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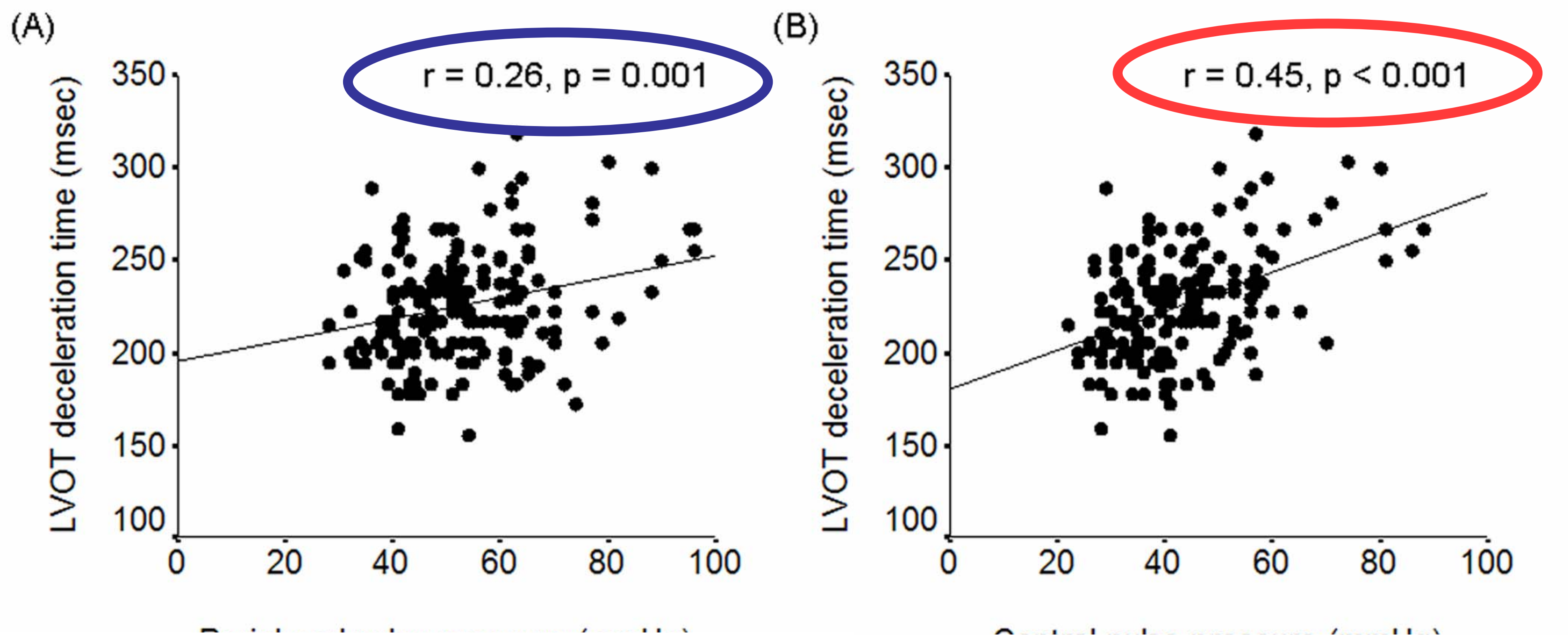
LVOT deceleration time and PP



Peripheral PP (mmHg) **Central PP (mmHg)**

Simple correlation

	Deceleration time	
	r	p-value*
Age	0.37	<0.001
Female gender	0.29	<0.001
Height	-0.35	<0.001
LVEF	0.19	0.018
LV mass index	0.01	0.911
LA volume index	0.33	<0.001
LVOT diameter	-0.16	0.034

	Deceleration time	
Peripheral		
SBP	0.11	0.160
DBP	-0.14	0.076
PP	0.26	0.001
Heart rate	-0.52	<0.001
Central		
SBP	0.22	0.004
DBP	-0.15	0.047
PP	0.45	<0.001
AP	0.49	<0.001
PP amplification	-0.37	<0.001
AIx	0.42	<0.001
AIx@75	0.25	0.001

Multiple regression analysis

	β	T	p-value*
LVOT deceleration time (R^2 = 0.456)			
Age	0.11	1.47	0.144
Female gender	0.06	0.58	0.564
Height	-0.11	-0.90	0.369
LVEF	0.08	1.32	0.189
LA volume index	0.07	1.11	0.267
LVOT diameter	0.07	0.98	0.327
Peripheral DBP	-0.07	-1.18	0.240
Heart rate	-0.39	-6.18	<0.001
Central PP	0.29	4.35	<0.001

Implications

- DT of the LVOT flow velocity is

  a surrogate Doppler echocardiographic parameter for central PP

- Prolonged LVOT DT would be a useful parameter to detect reduced compliance of a central artery

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Limitations

1. At rest
2. Immediately (< 1 min) after peak exercise

Not technically feasible during exercise

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Deceleration time of the left ventricular outflow tract flow velocity reflects central arterial stiffness **during exercise**

160 subjects (64 males, 57 ± 11 Yo)

Diastolic stress echocardiogram

with supine bicycle ergometry

Radial artery tonometry

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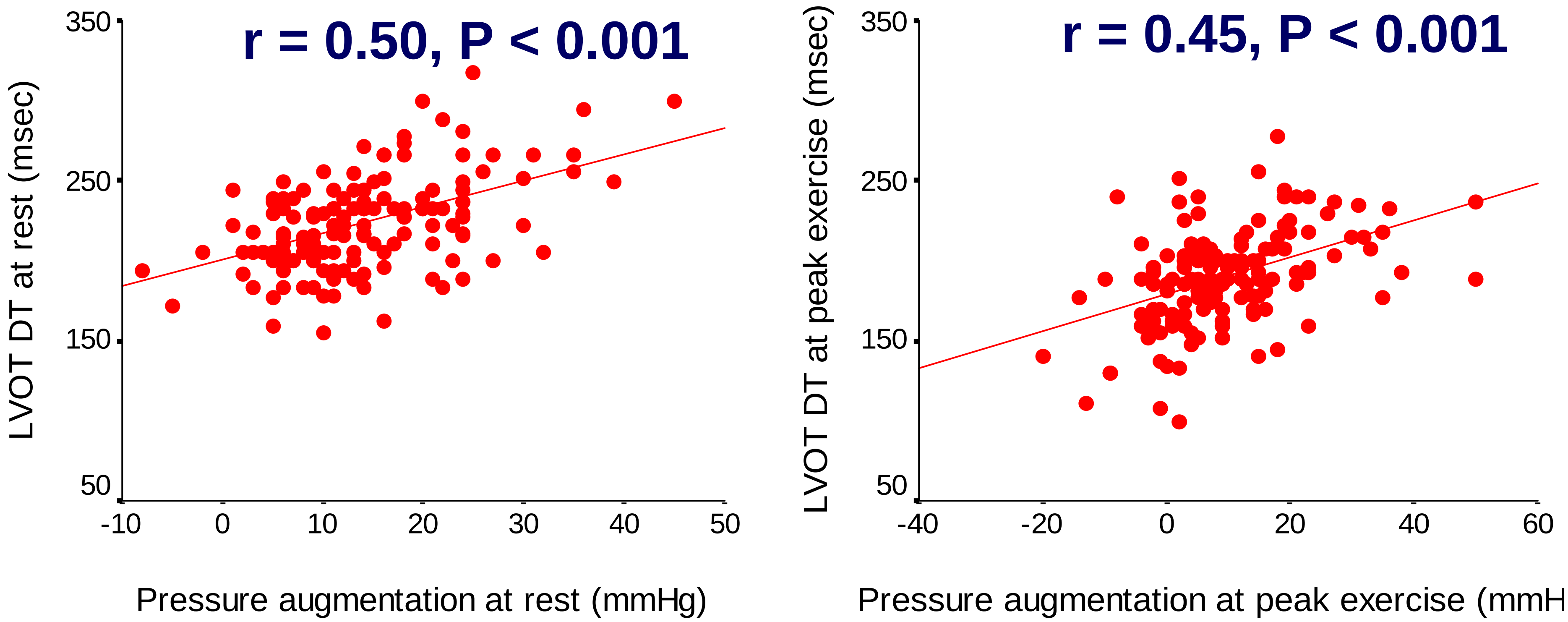
LVOT DT & Pressure augmentation



At rest

At peak Ex

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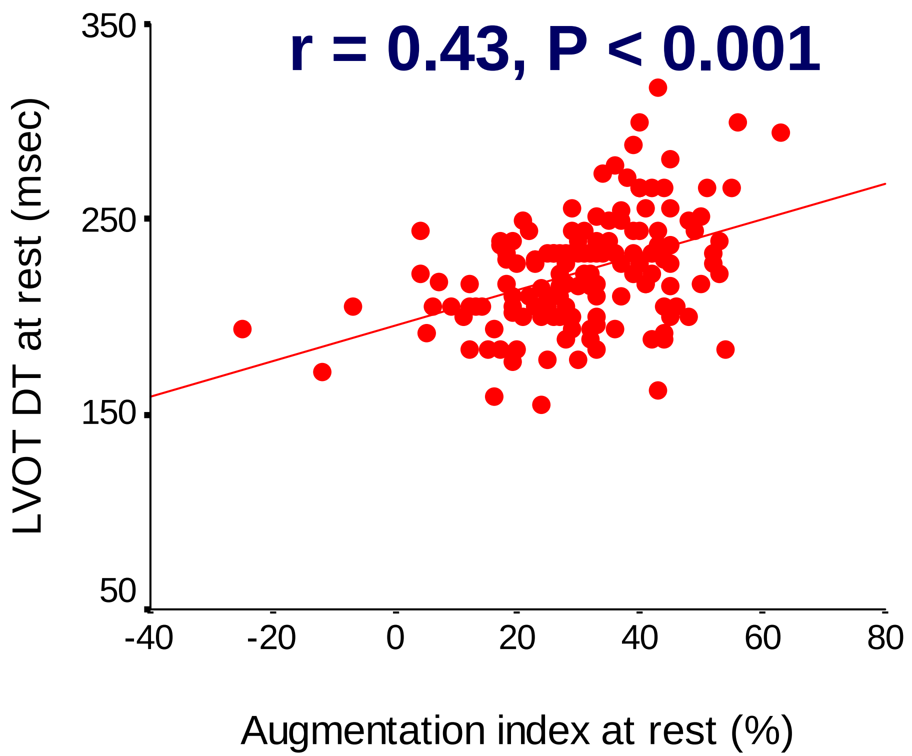
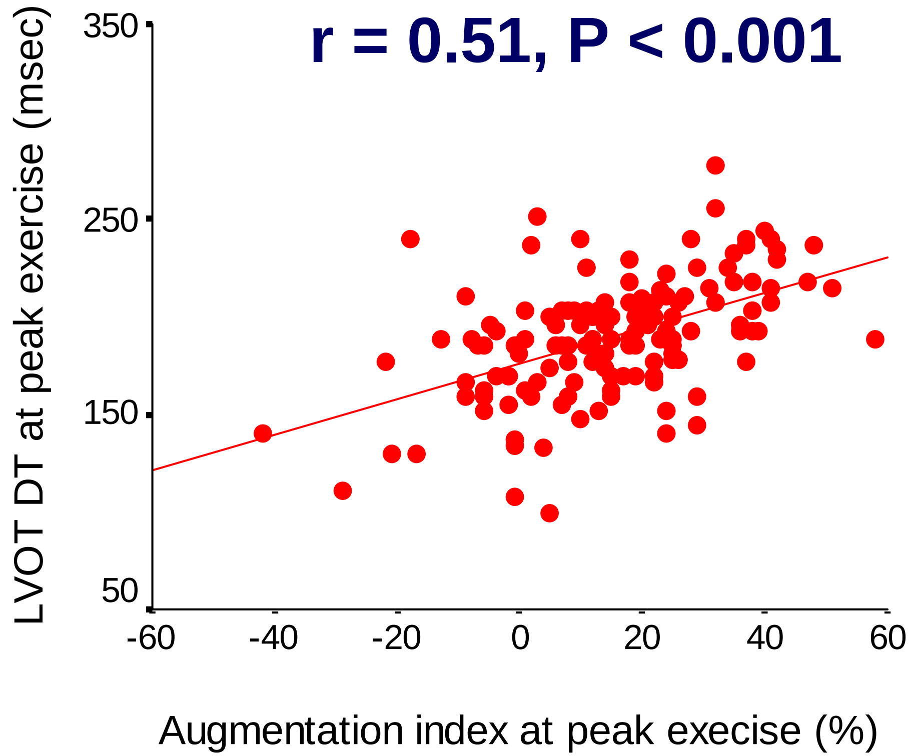
LVOT DT & Augmentation index





At rest

At peak Ex

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Implications

- DT of the LVOT flow velocity is a surrogate Doppler echocardiographic parameter reflecting central arterial stiffness **not only at rest but also during exercise**
- With a Doppler assessment of LVOT flow, **central arterial stiffness and its dynamic changes with exercise** can be assessed

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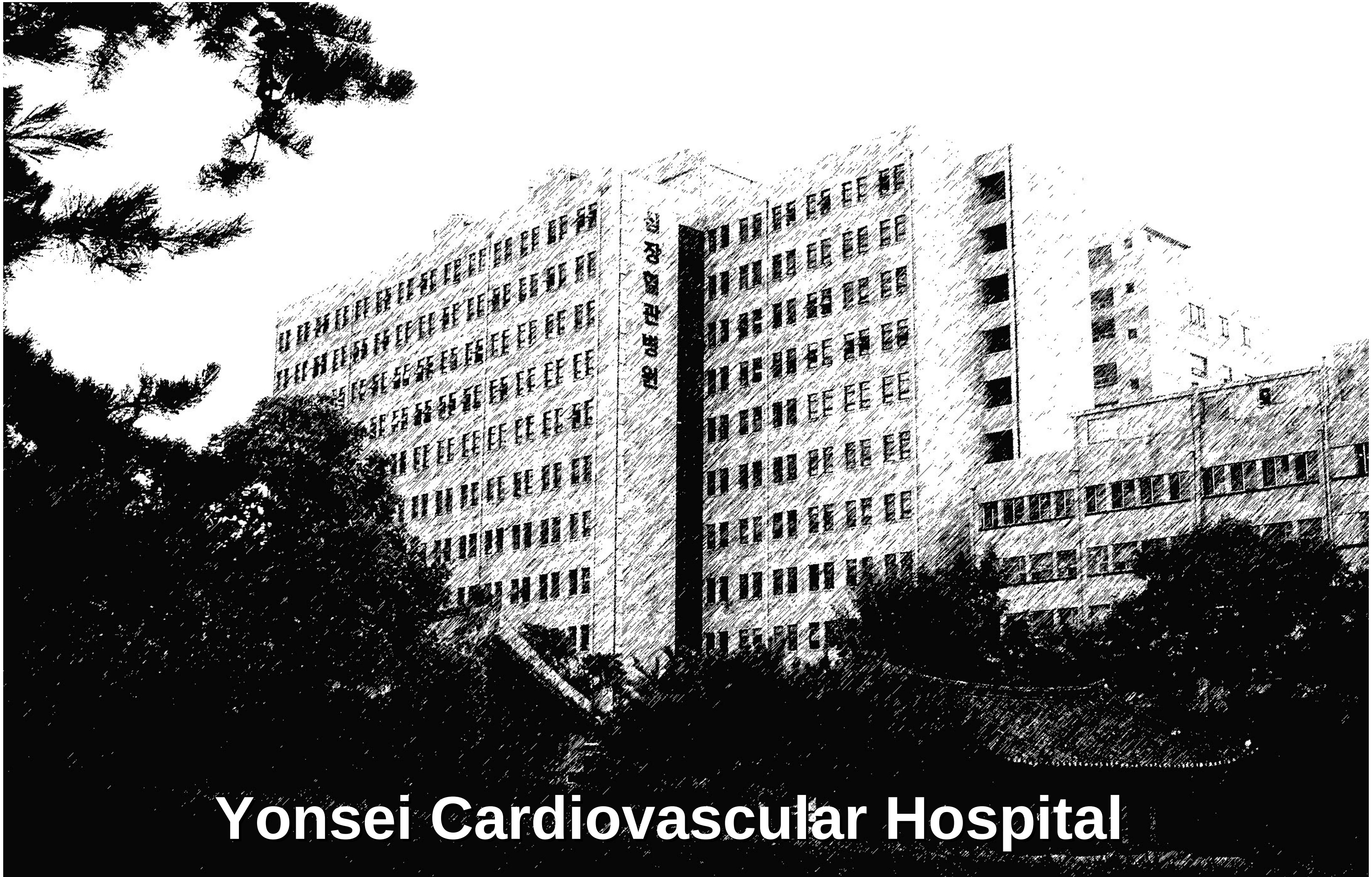
Conclusion

- Assessment of arterial stiffness during exercise is important
- LVOT Doppler pattern may provide dynamic arterial stiffness during exercise



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