2011 APCDE

: Vascular Imaging

Arterial-Cardiac Interaction
Concepts and Its Implication

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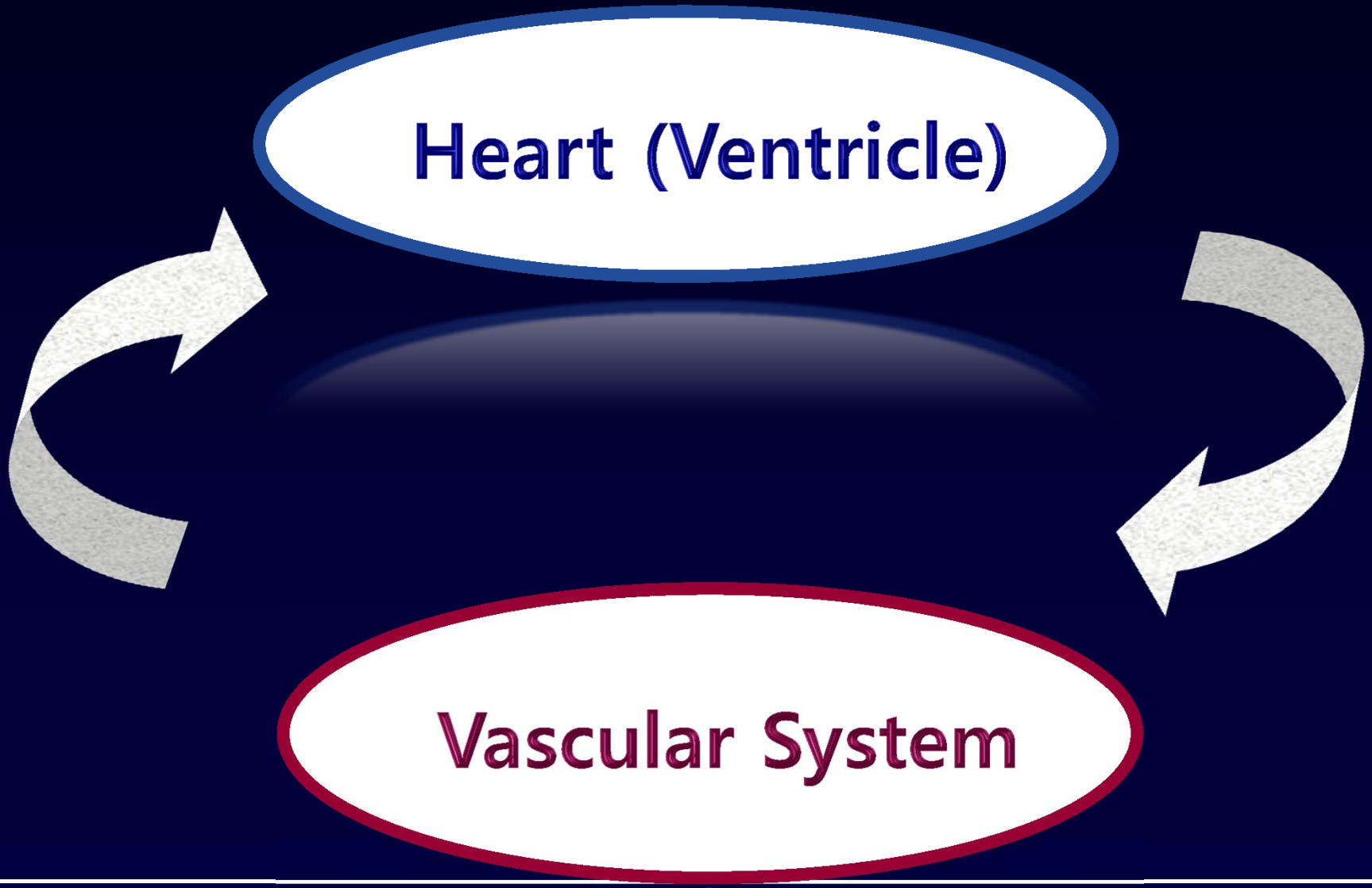
Circulation: Continuous closed system



Ventricular-vascular coupling

(Ventricular-vascular Interaction; Arterial-cardiac interaction)

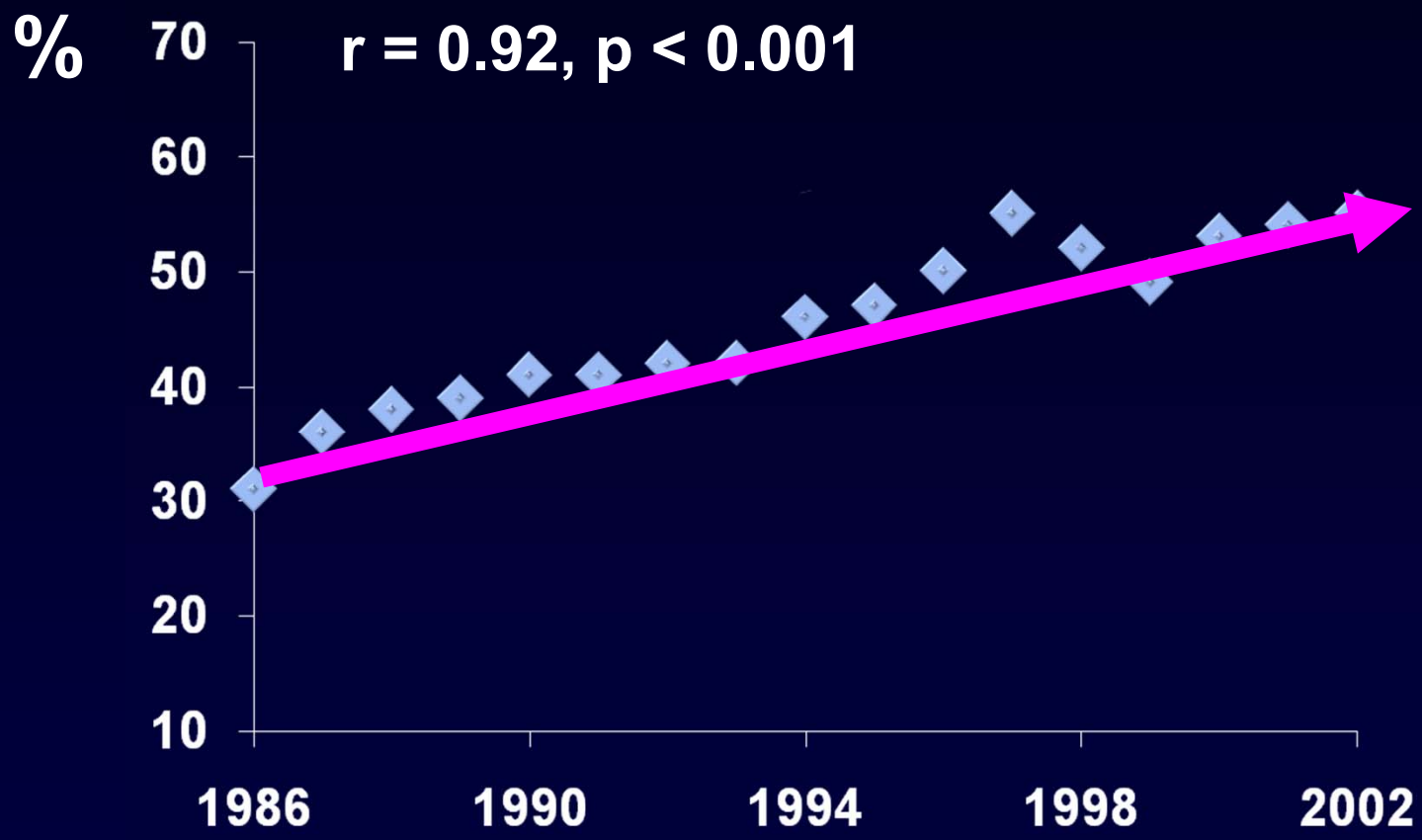
the Interaction of Heart and Systemic Vasculature

a Central Determinant of net CV Performance

David A. Kass, Heart failure review, 2002;7:51-62.

Why are the concepts of ventricular-vascular interaction important?

Prevalence of HF with preserved EF



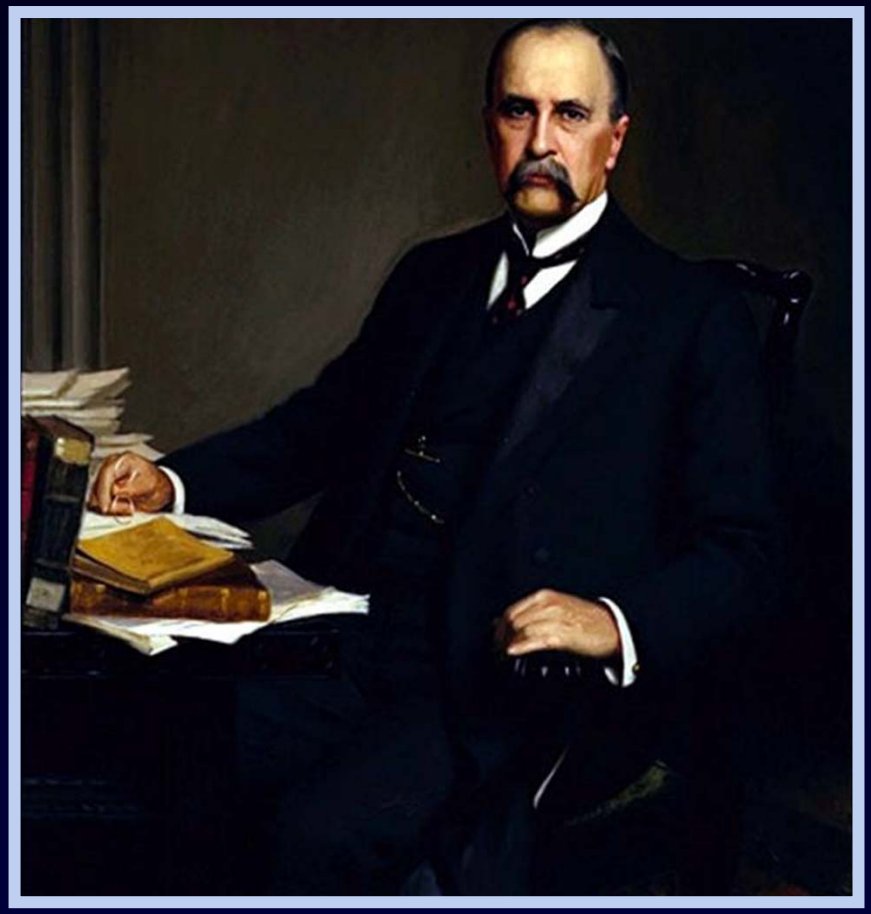
Owan TE et al. NEJM 2006;355:251-9.

Table 1. Characteristics of Patients with Heart Failure and Preserved [illegible] Ejection Fraction.*

Characteristic	Reduced Ejection Fraction (N=2429)	Preserved Ejection Fraction (N=2167)	P Value	Adjusted P Value†
Age (yr)	71.7±12.1	74.4±14.4	<0.001	NA
Male sex (% of patients)	65.4	44.3	<0.001	<0.001
Body-mass index‡	28.6±7.0	29.7±7.8	0.002	0.17
Obesity (% of pati				0.002
Serum creatinin				0.30
Hemoglobin o				<0.001
Hypertension (				<0.001
Coronary artery				<0.001
Atrial fibrillatio				<0.001
Diabetes (% of				0.61
Substantial val				0.05
Ejection fractio				NA

Aging
Female gender
Hypertension
Obesity

Owan TE et al. NEJM 2006;355:251-9.

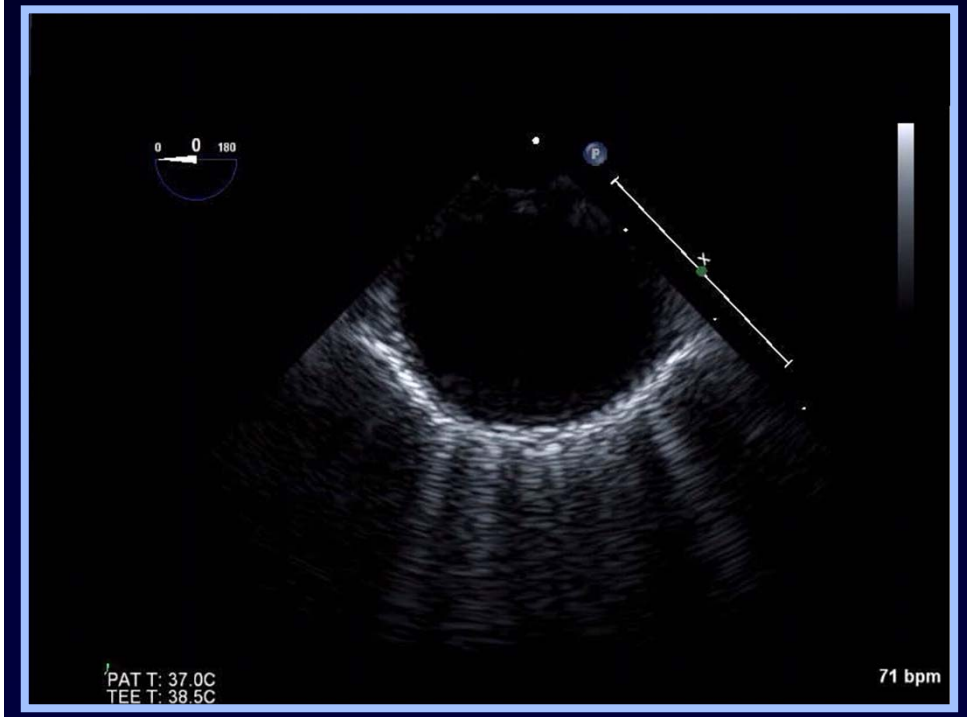


“ Man is as old as his arteries”

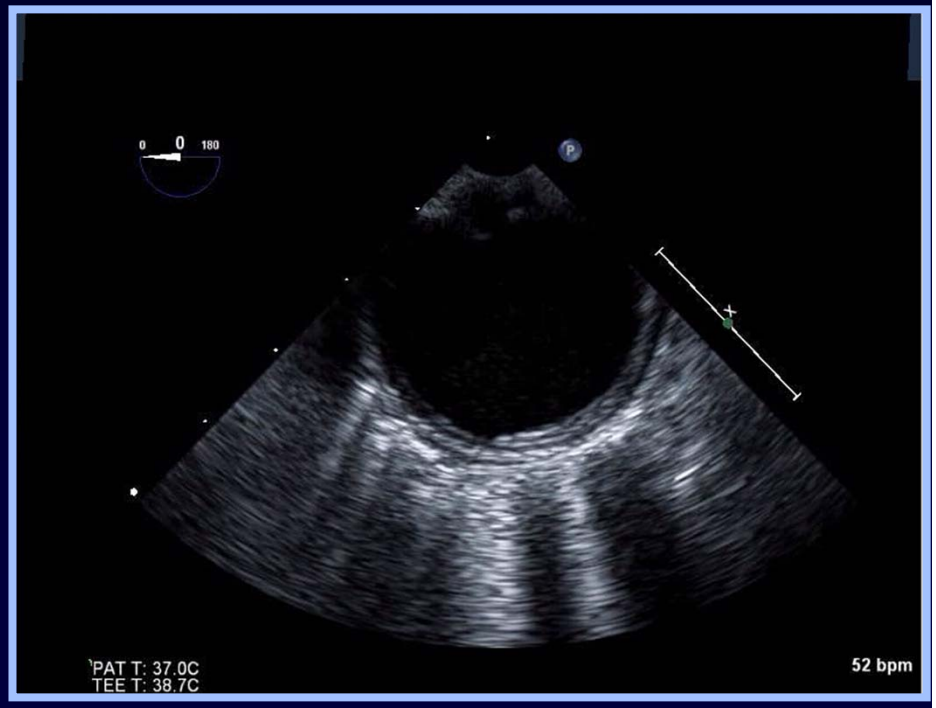
Sir William Osler (1849- 1919)

The “Father of modern medicine”

Young
Compliant Aorta



Old
Stiff Aorta

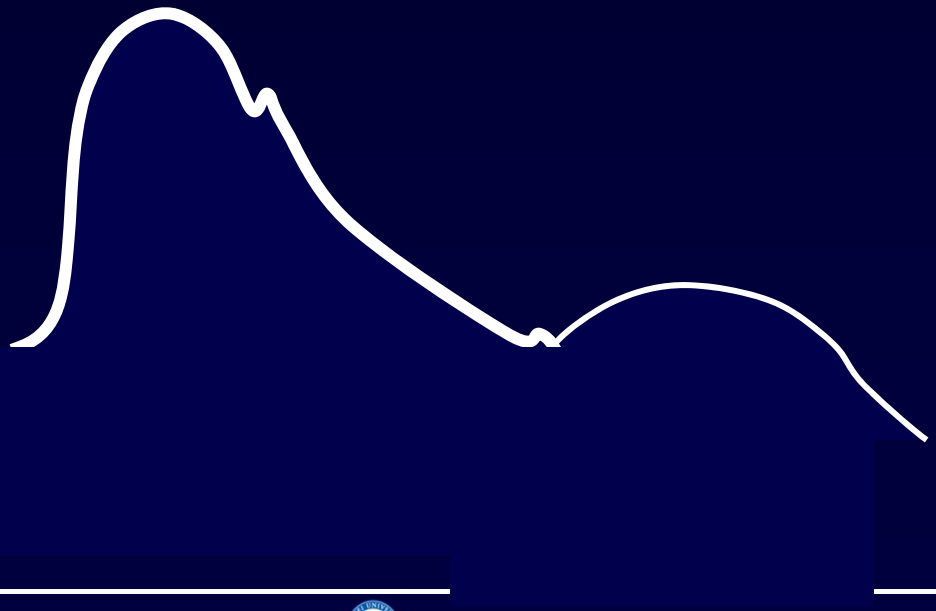


Young normal aorta

Old stiff aorta

Young normal aorta

Resistance artery

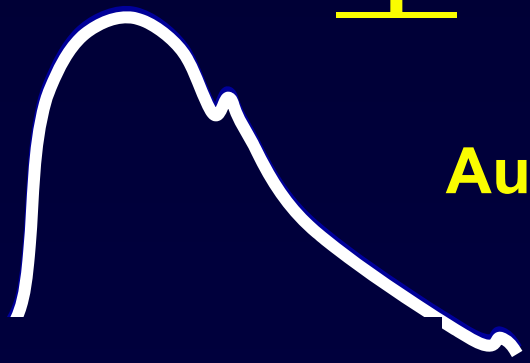


Old stiff aorta

PWV ↑

Resistance artery

Augmentation Pressure



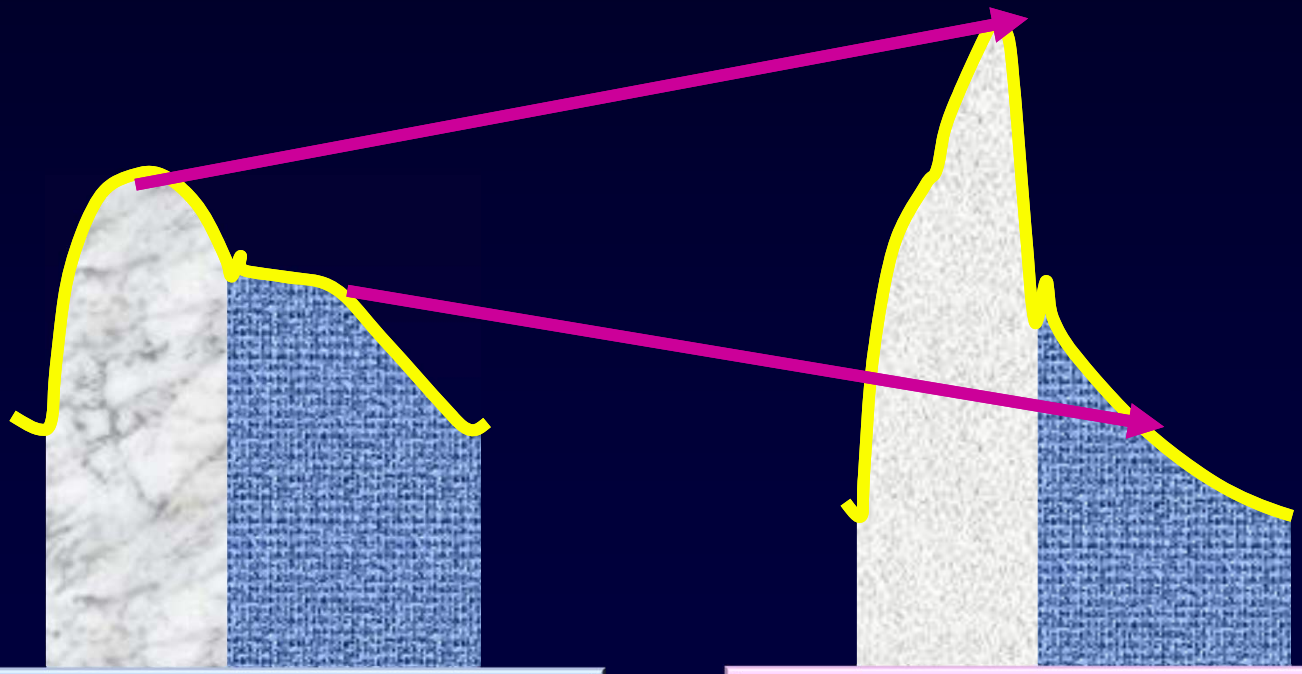
Augmentation Index ↑

Pressure during systole is

a major determinant of myocardial O_2 requirement

Pressure during diastole is

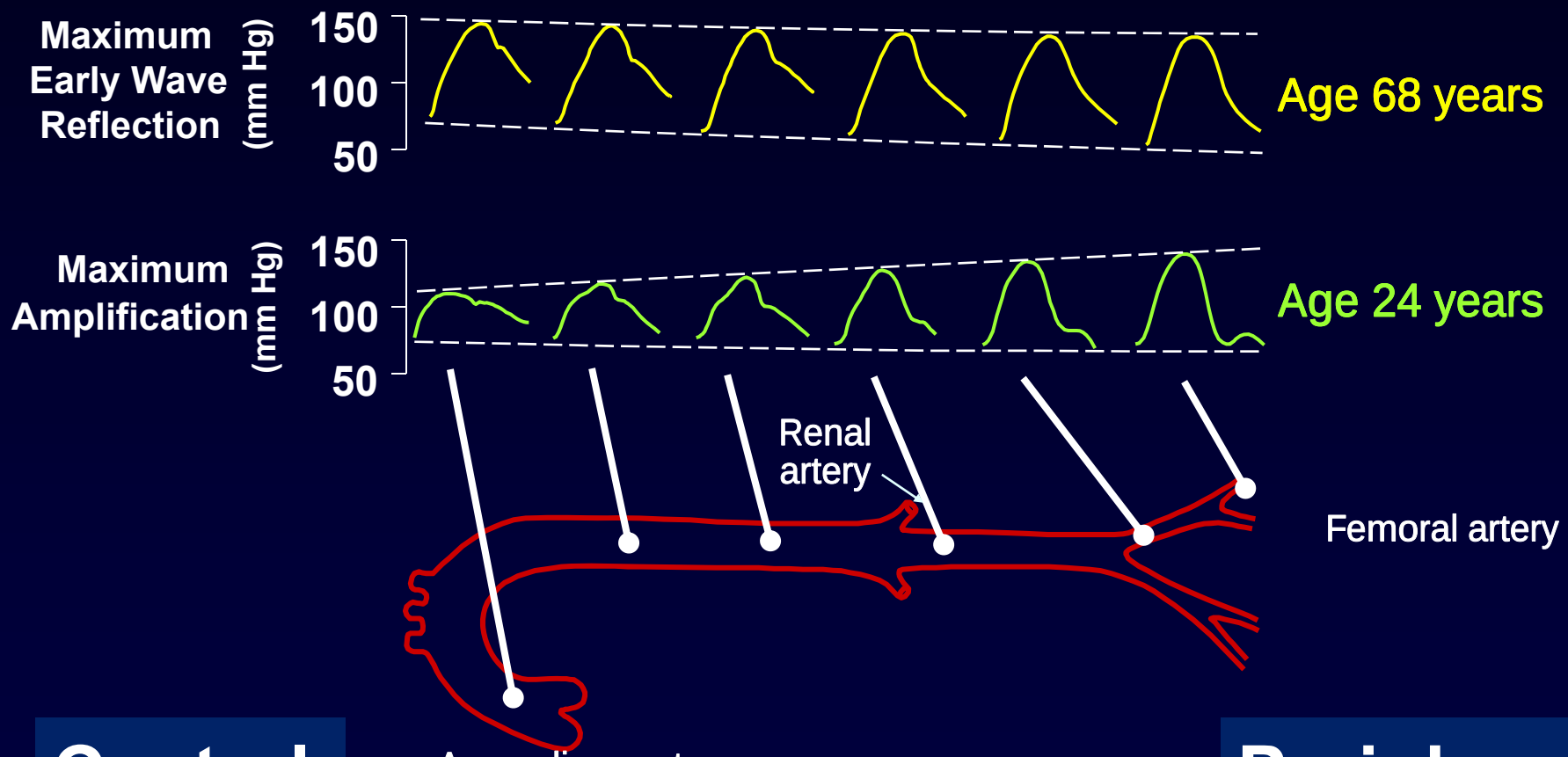
a major determinant of coronary blood flow



Efficient arterial system

Inefficient arterial system

Blood Pressure Curves



Lesson 1

Human aging

↓

Vascular stiffening

- Augmentation index ↑
- PWV ↑
- Central SBP ↑ DBP ↓
- Central PP ↑
- PP amplification ↓ (Peripheral PP/Central PP)

Influence of Vascular Stiffening on LV function

Arterial stiffness and LV function

Impact of Arterial Stiffening on Left Ventricular Structure

Mary J. Roman, Antonello Ganau, Pier Sergio Saba, Riccardo Pini,

pressures and the elastic modulus
of increases in wall thicknesses, β and the arterial compliance index
inversely related to chamber diameter and directly related to left ventricular relative wall thickness, the ratio of wall
thickness to chamber radius. Younger and older hypertensive subjects had comparable left ventricular mass, despite

CARDIOVASCULAR MEDICINE

Relation of arterial stiffness to diastolic dysfunction in hypertensive heart disease

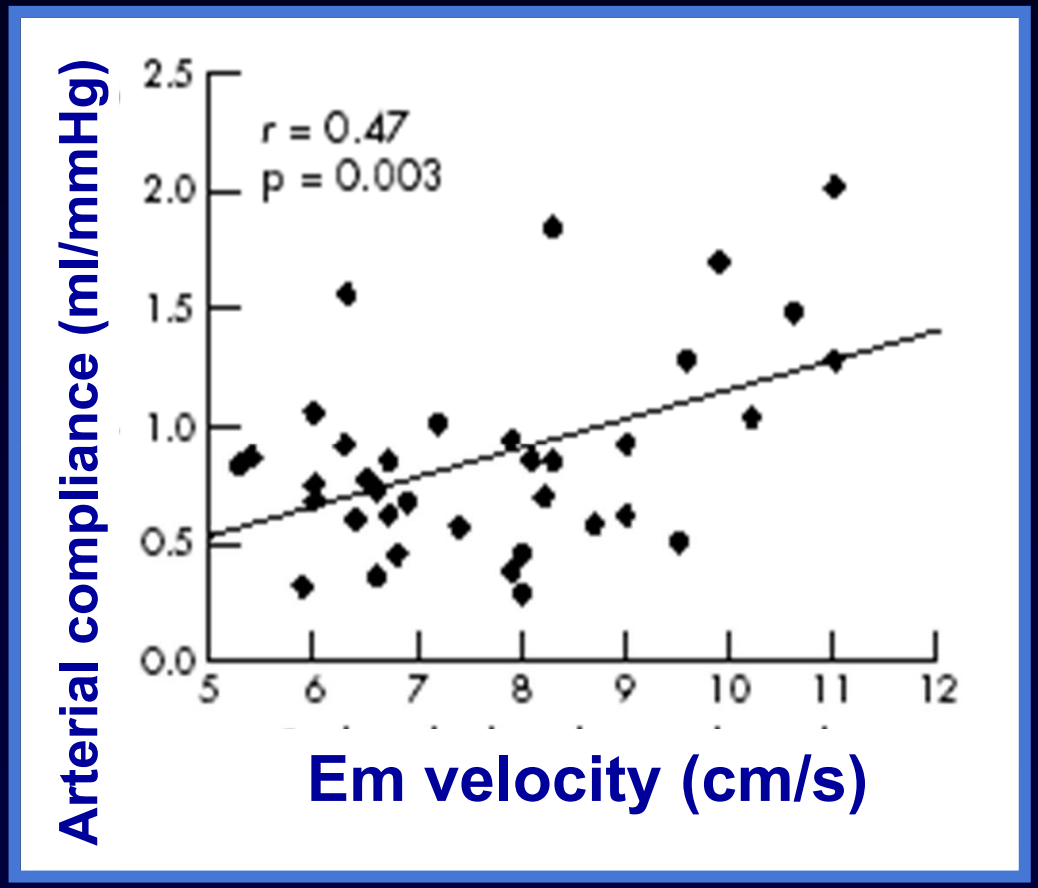
P M Mottram, B A Haluska, R Leano, S Carlier, C Case, T H Marwick

Heart 2005;91:1551–1556. doi: 10.1136/hrt.2004.04680

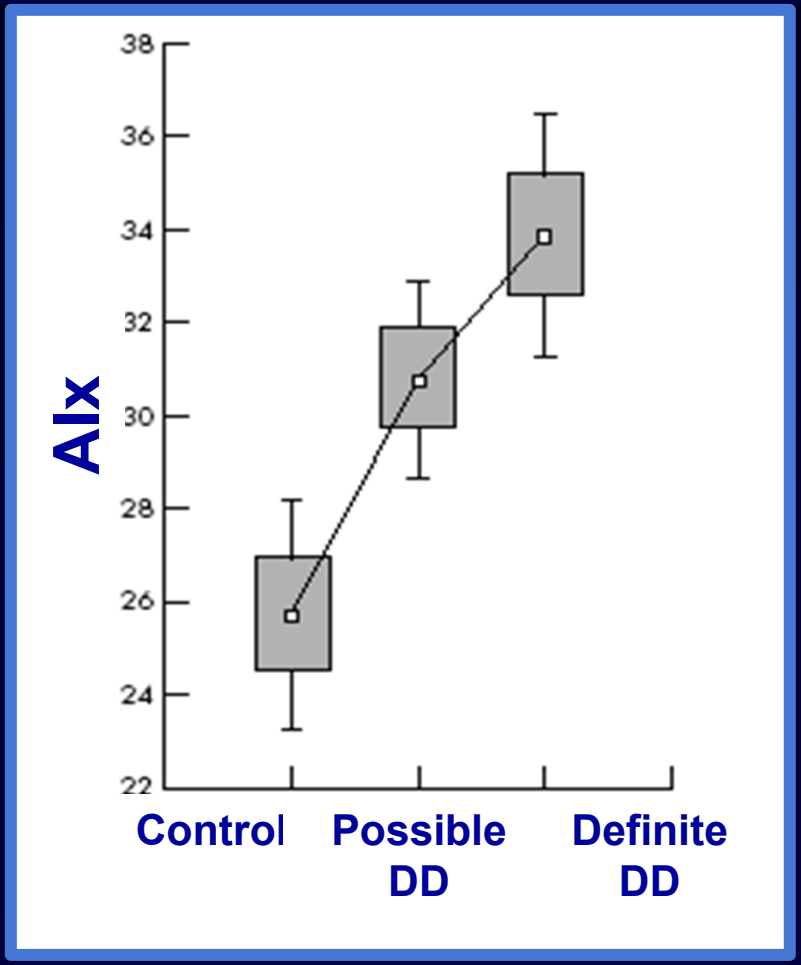
Relation of Arterial Stiffness to Left Ventricular Diastolic Function and Cardiovascular Risk Prediction in Patients ≥65 Years of Age

Walter P. Abhayaratna, MBBS[a], Marion E. Barnes, MS[a], Michael F. O'Rourke, MD, DSc[c], Bernard J. Gersh, MD, ChB, DPhil[a], James B. Seward, MD[a], Yoko Miyasaka, MD, PhD[a], Kent R. Bailey, PhD[b], and Teresa S.M. Tsang, MD[a,*]

Aortic stiffness & LV diastolic function

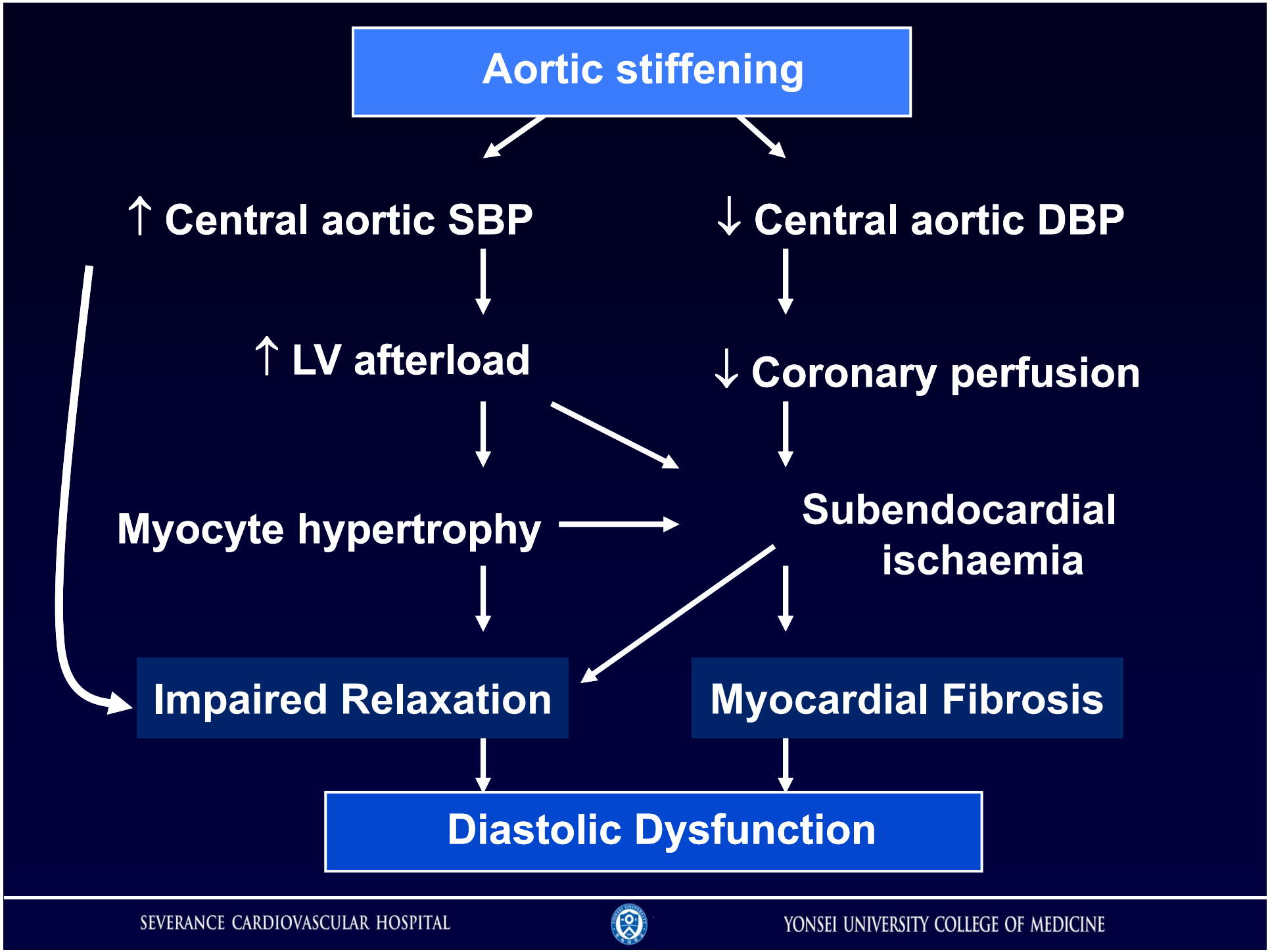


70 hypertensives with DOE



Mottram PM, Marwick TH et al. Heart 2005

Weber T et al. Heart 2006


Aortic stiffening
↑ Central aortic SBP
↓ Central aortic DBP
↑ LV afterload
↓ Coronary perfusion
Myocyte hypertrophy
Subendocardial ischaemia
Impaired Relaxation
Myocardial Fibrosis
Diastolic Dysfunction

Sex Differences in Central Hemodynamics and Their Relationship to Left Ventricular Diastolic Function

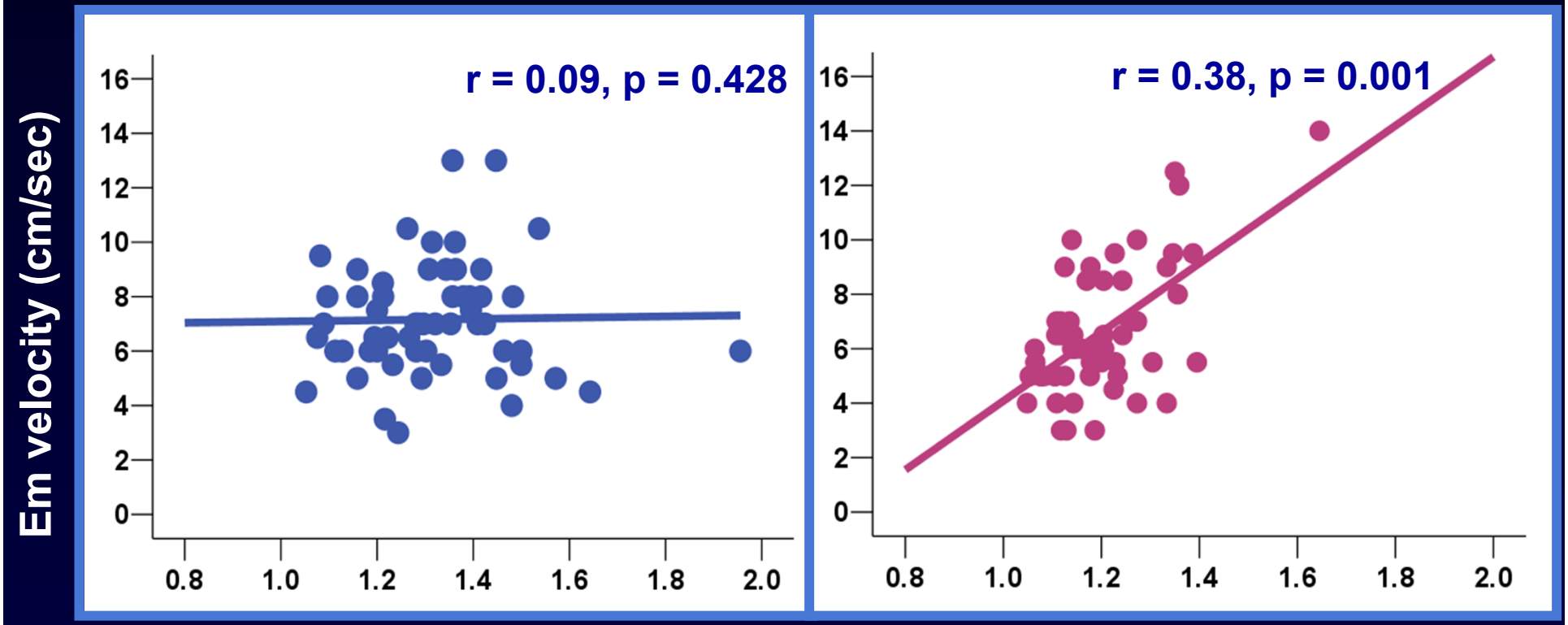
Chi Young Shim, MD, PHD,* Sungha Park, MD, PHD,* Donghoon Choi, MD, PHD,* Woo-In Yang, MD,* In-Jeong Cho, MD,* Eui-Young Choi, MD, PHD,* Namsik Chung, MD, PHD,* Jong-Won Ha, MD, PHD*†

Seoul, Republic of Korea

J Am Coll Cardiol 2011; 57:1226-33.

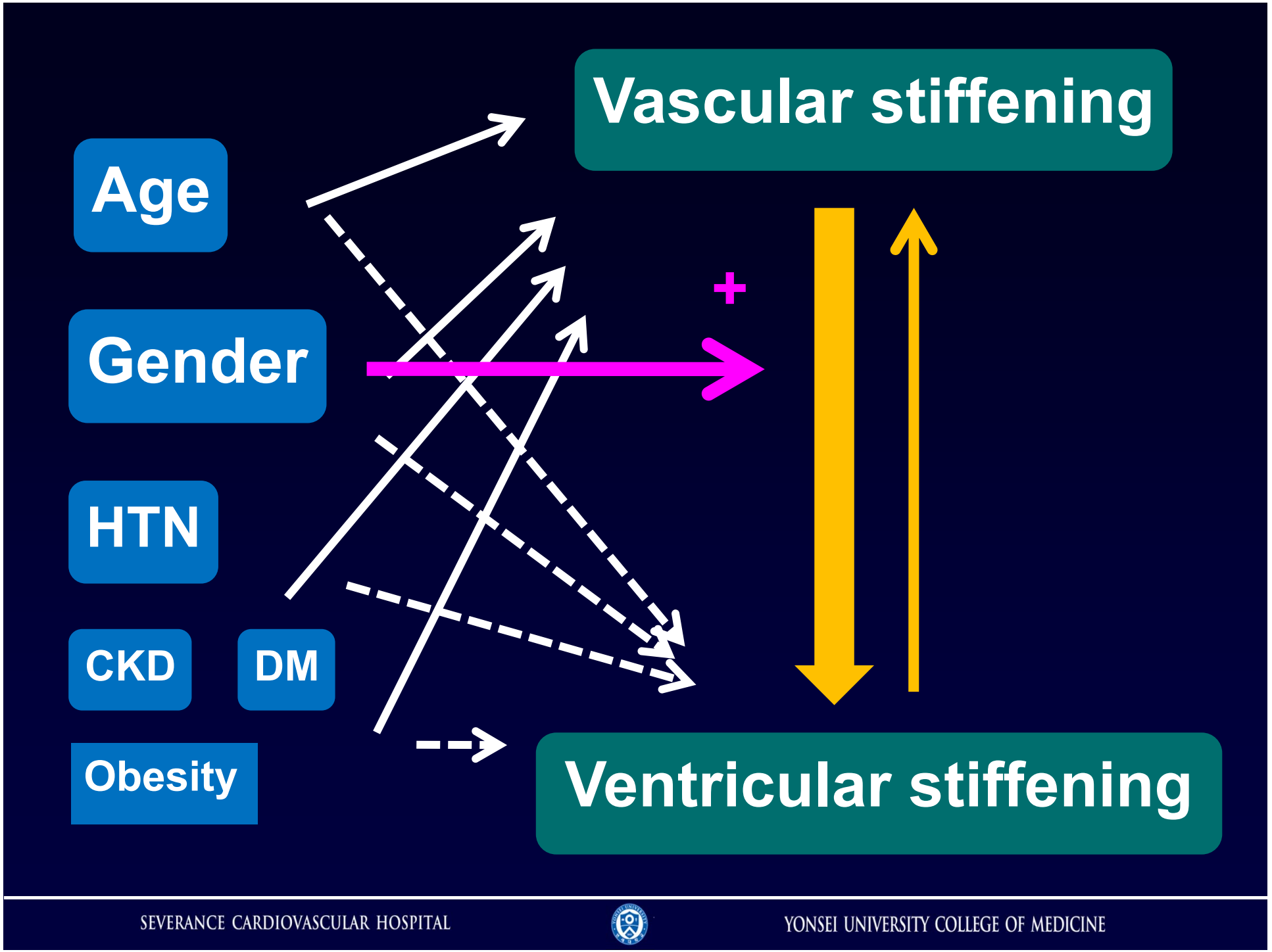
	Men (n=79)	Women (n=79)	P- value
Peripheral PP	51 ± 11	53 ± 13	0.401
Central PP	40 ± 9	45 ± 12	0.005
AIx, %	25.1 ± 9.8	34.7 ± 10.0	<0.001
PP amplification	1.31 ± 0.16	1.19 ± 0.10	<0.001

PP amplification and Em velocity



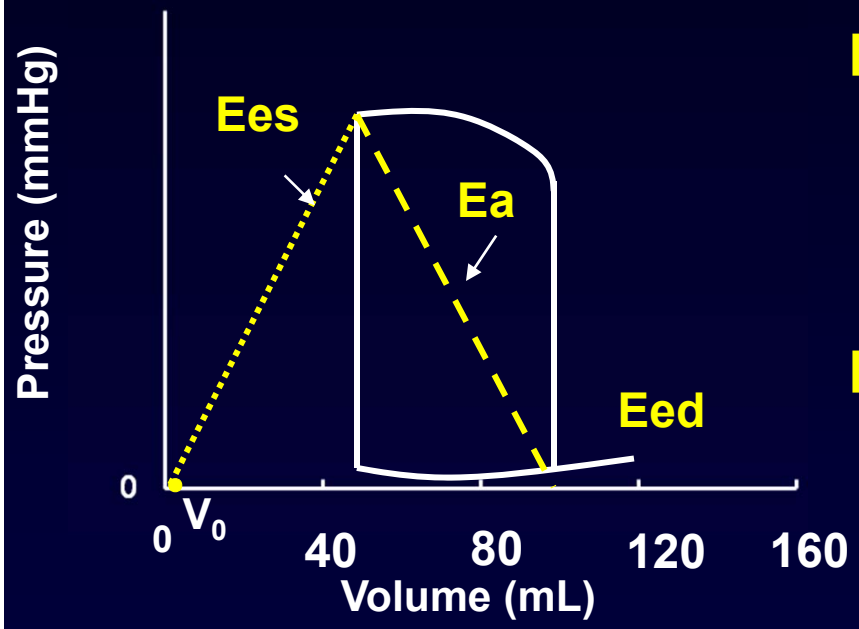
Lesson 2

- LV diastolic function is closely related to cardiac afterload, and this load dependence is enhanced in heart failure.
- Women have higher pulsatile arterial loading compared with men.
- Our observations suggest that women may display greater load-related diastolic dysfunction.


Vascular stiffening
Age
Gender
HTN
CKD
DM
Obesity
+
Ventricular stiffening

How can we evaluate & interpret ventricular-vascular coupling ?

Pressure-volume relations



Ees : Ventricular systolic elastance (ESP/ESV)

➔ **Chamber systolic stiffness**

Ea : Effective arterial elastance (ESP/SV)

➔ **Vascular stiffness**

The ratio of Ea/Ees

: Ventricular – vascular coupling index !

Step 1: Measure BP, LV volume

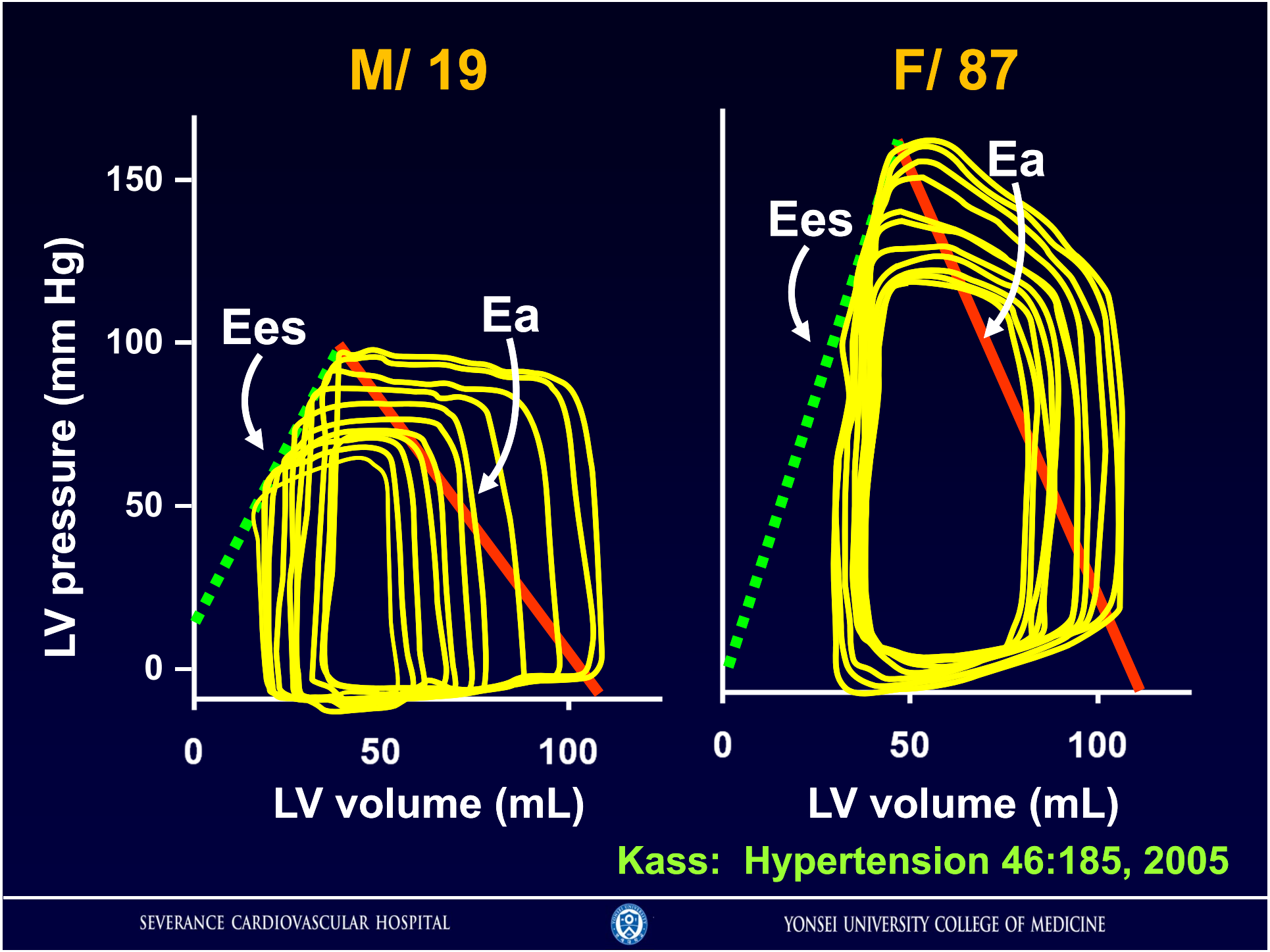
- End systolic pressure (ESP) = (2 X SBP + DBP) / 3
- Stroke volume (SV) = EDV - ESV

Step 2: Calculate Ea, Ees

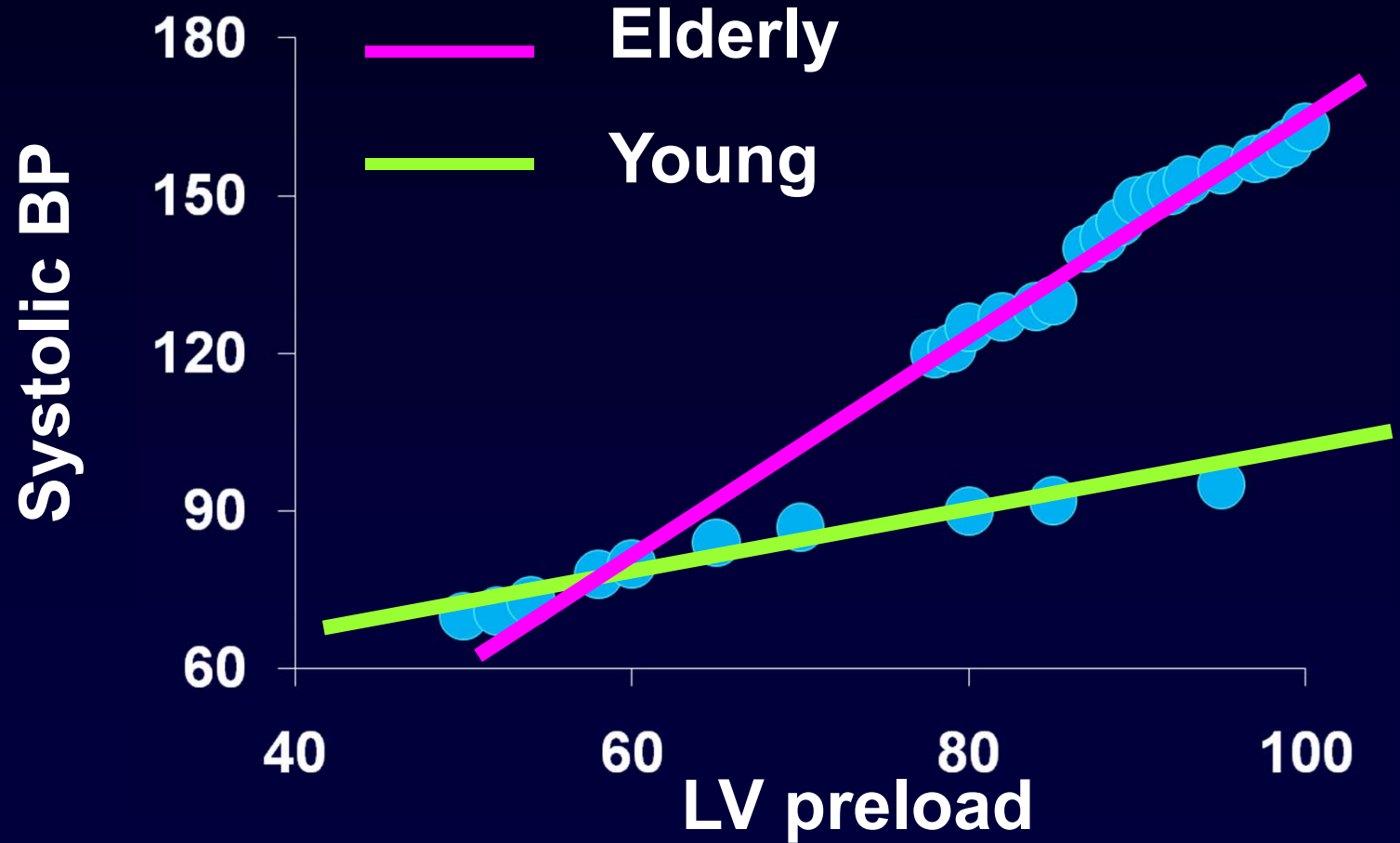
- Arterial elastance (Ea) = ESP/SV
- LV systolic elastance (Ees) = ESP/ESV

Step 3: Calculate VV coupling index

- Ea/ Ees = ~~ESP/SV~~ // ~~ESP/ESV~~ = ESV / SV


M/ 19
F/ 87
LV pressure (mm Hg)
150
100
50
0
Ees
Ea
0
50
100
LV volume (mL)
Ees
Ea
0
50
100
LV volume (mL)
Kass: Hypertension 46:185, 2005

Enhanced systolic pressure sensitivity to altered cardiac preload



Chen CH etal. J Am Coll Cardiol 1998

Age and Gender Affect Ventricular-Vascular Coupling During Aerobic Exercise

Samer S. Najjar, MD,* Steven P. Schulman, MD,† Gary Gerstenblith, MD, FACC,† Jerome L. Fleg, MD, FACC,* David A. Kass, MD,† Frances O'Connor, MPH,* Lewis C. Becker, MD,† Edward G. Lakatta, MD*

Baltimore, Maryland

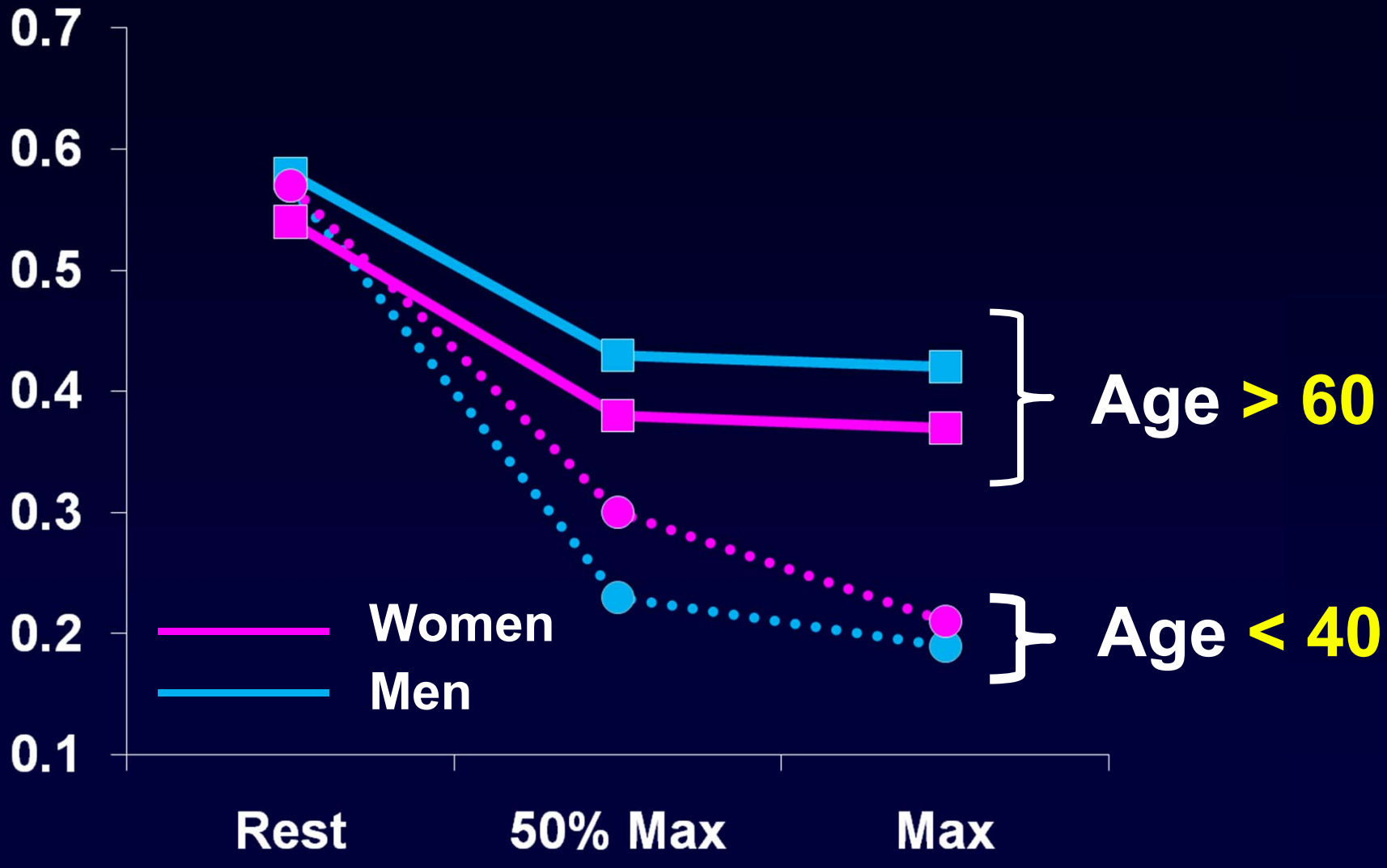
J Am Coll Cardiol 2004;44:611-7.

Gender-Related Difference in Arterial Elastance During Exercise in Patients With Hypertension

Sungha Park, Jong-Won Ha, Chi Young Shim, Eui-Young Choi, Jin-Mi Kim, Jeong-Ah Ahn, Se-Wha Lee, Se-Joong Rim, Namsik Chung

Hypertension 2008; 51:1163-9.

Ventricular-Vascular Coupling Index



J Am Coll Cardiol 2004;44:611-7.

Clinical relevance of ventricular-vascular stiffening

- **High basal Ees blunts contractile reserve**

  Limited further increase coupled to positive inotropy

- **High Ees and Ea augment systolic pressure sensitivity to cardiac loading**

  Aggravates hypertensive response during exertion

Kawaguchi M et al. Circulation 2003; 107:714-20.

Clinical relevance of ventricular-vascular stiffening

- Enhanced sensitivity of BP to circulating volume and diuretics

  may trigger rapid-onset pulmonary edema

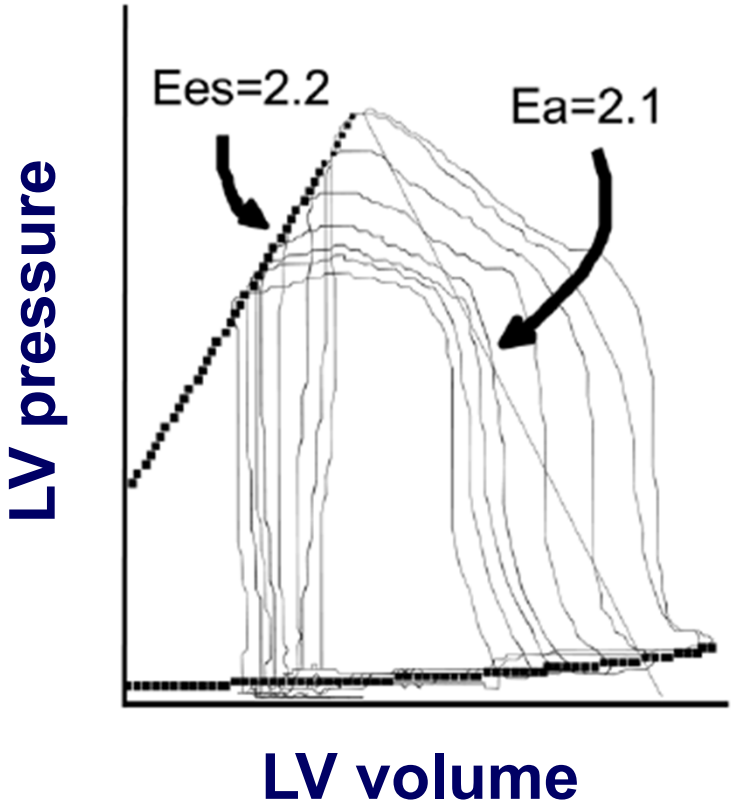
- Increased cardiac energy expenditure

Kawaguchi M et al. Circulation 2003; 107:714-20.

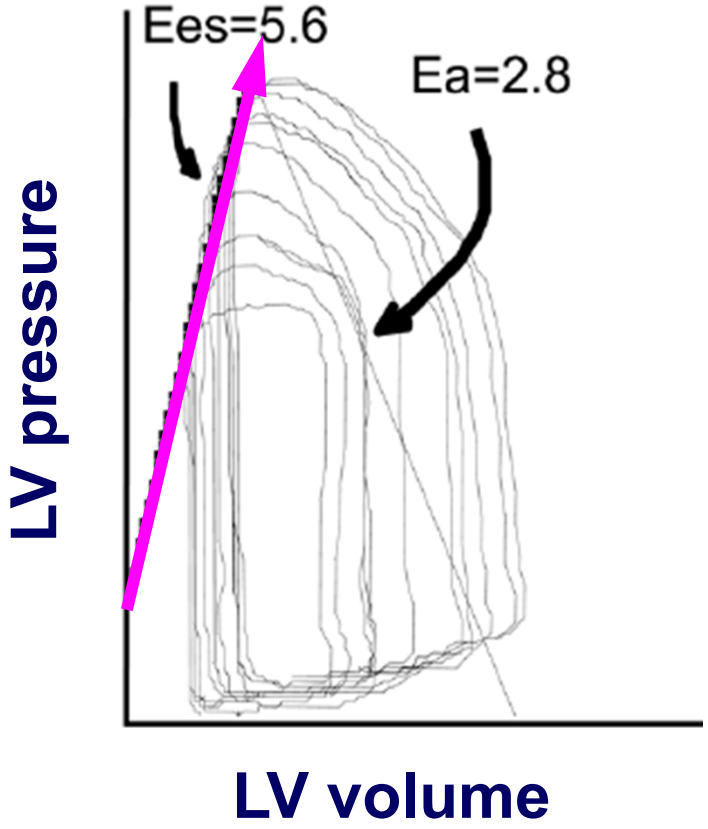
Lesson 3:

Rest	Ea	NL	↑↑
	Ees	NL	↑↑
	Coupling Index	NL	NL
Exercise	Ea	↑	↑↑↑
	Ees	↑↑↑	↑
	Coupling Index	↓↓	↓ or ↔

Control

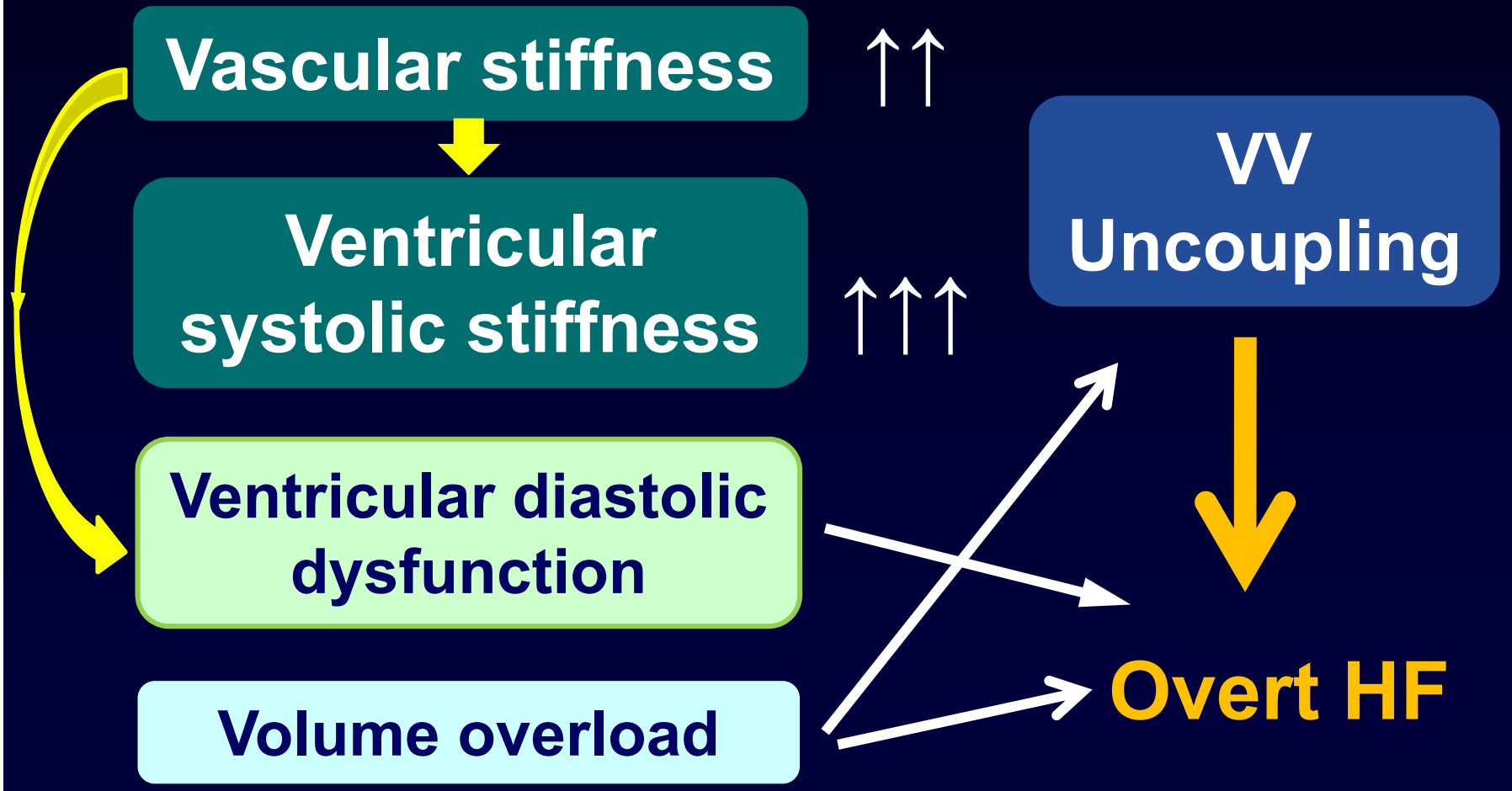


HF with preserved EF



Kawaguchi M et al. Circulation 2003; 107:714-20.

Lesson 4: HF with preserved EF



Take Home Message

- **"Ventricular-vascular coupling"** is a key determinant of CV performance.
- **Age-related vascular stiffening** can seriously affect this coupling.
- This **"coupling disease"** is common in patients with **HF with preserved EF.**

Thank You For Your Attention !