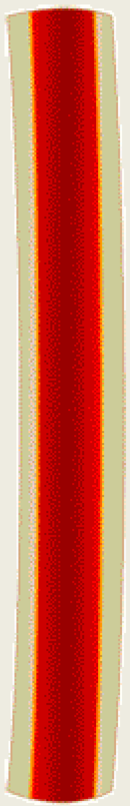
Arteryal Sertlik ve Nabız Dalga Hızı

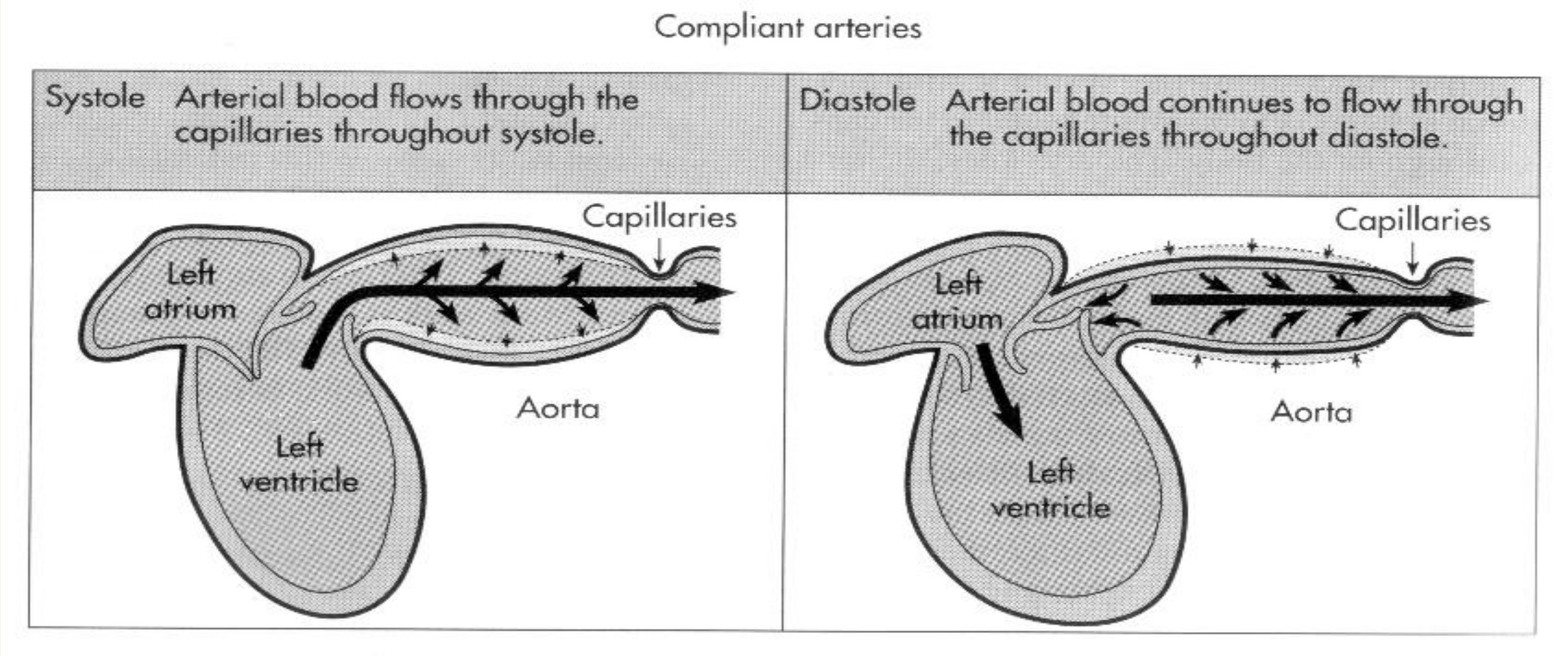
Dr. Barış Afşar
Konya Numune Hastanesi

- **Kompliyans:** Birim basınç değişimine karşın hacimde meydana gelen değişim (cm/mmHg veya cm^2/mmHg)
- **Distensibility:** Esneyebilme. Kompliyans ile aynı manada kullanılıyor
- **Katılık (Sertlik):** Elastik bir maddenin kendisine uygulanan saptırma gücüne karşı olan direnci. Fizyolojik olarak kompliyansın tersi



Elastik

Katı



Normal çalışan kalp sistolde kanı pompalar. Bu sırada aort esnek olduğu için genişler ve enerjiyi depolar. Depolanan bu enerji diyastol sırasında kanın perifere gitmesi için kullanılır ve böylece kan akımı sürekli olur.

- Sistolik Ejeksiyon ile birlikte 2 olay meydana gelir:

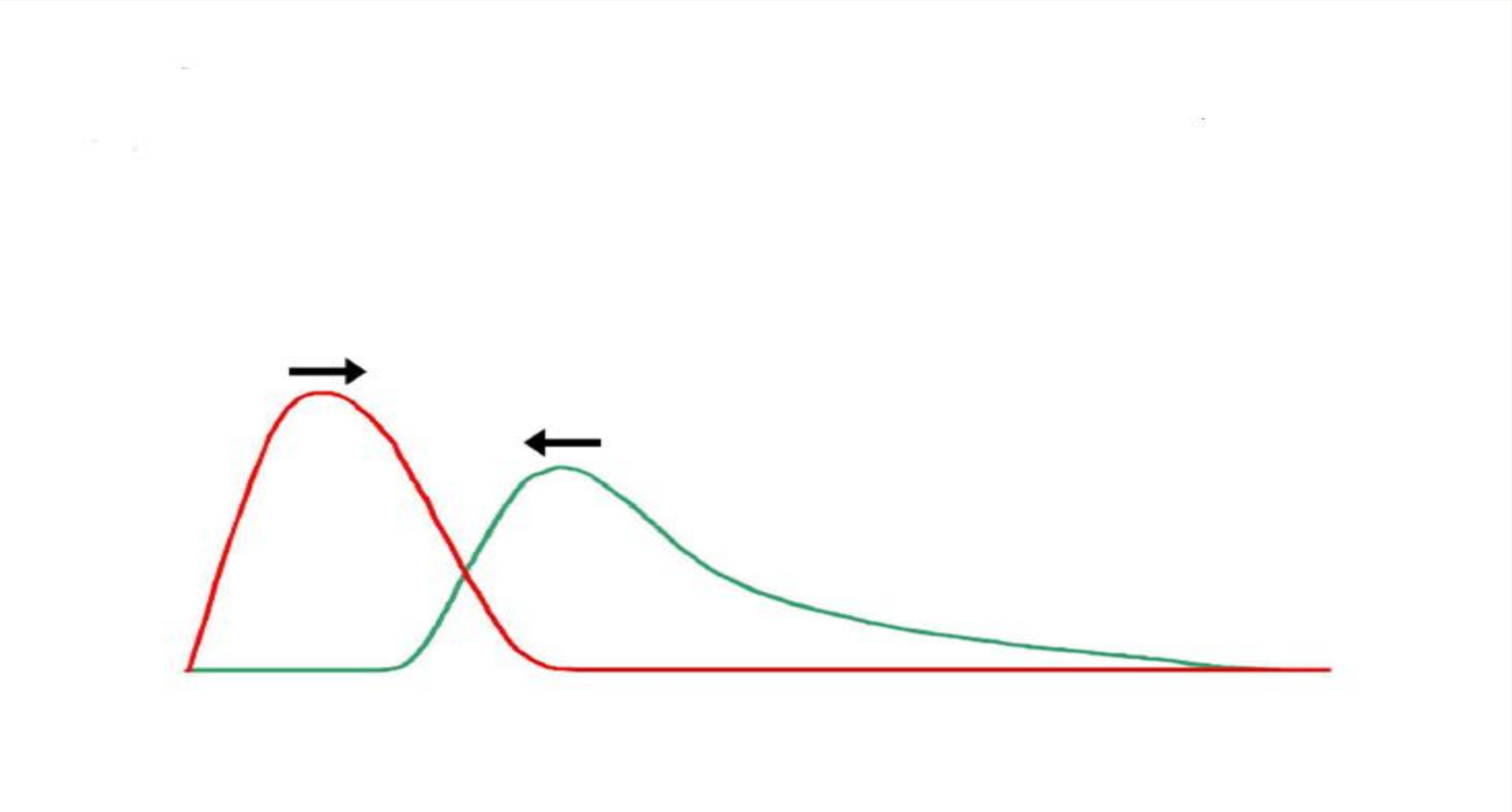
Kan ileri doğru atılır (20cm/sn)

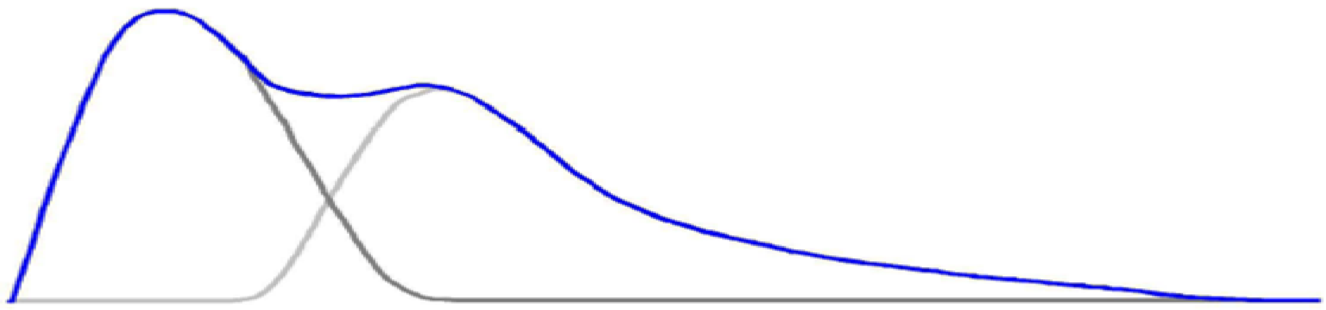
Basınç dalgası oluşur (5m/sn)

Arteryal Sertlik ve Nabız Dalga Hızı

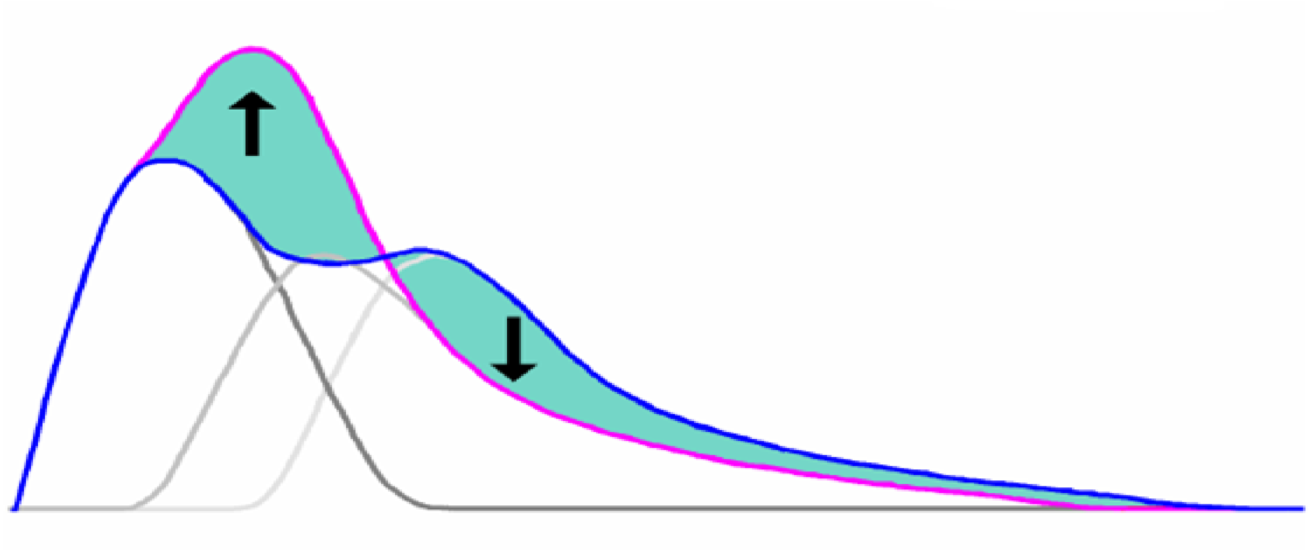
- Oluşan basınç dalgası arter yal ağacın dallanma noktalarında yansımalara uğrar.
- Basınç dalgasındaki bu yansımalarda da arteryal sertlikten etkilenir

Yansıyan dalga ilk dalganın üstüne biner





Sistolik basınç ve nabız basıncı artar

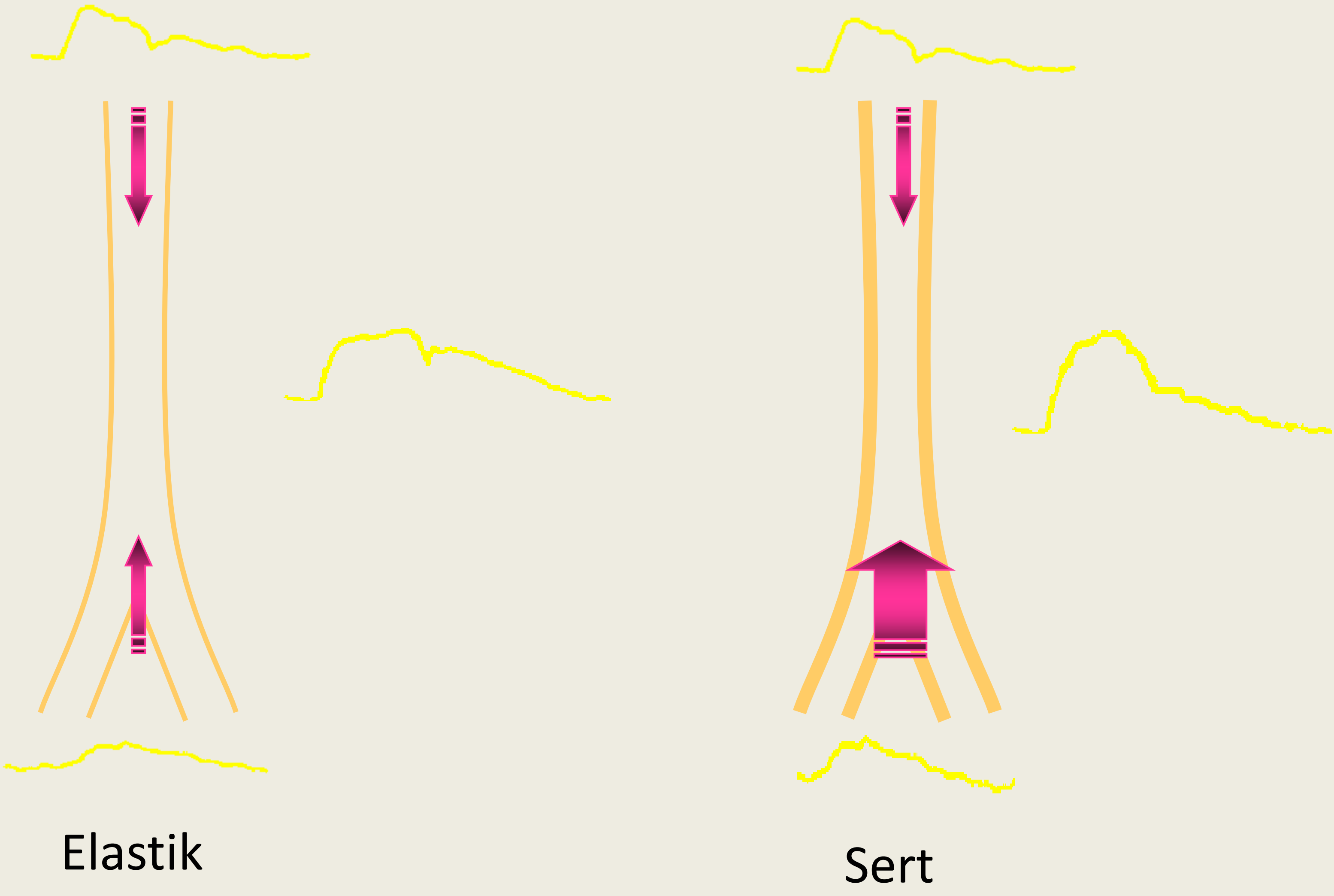


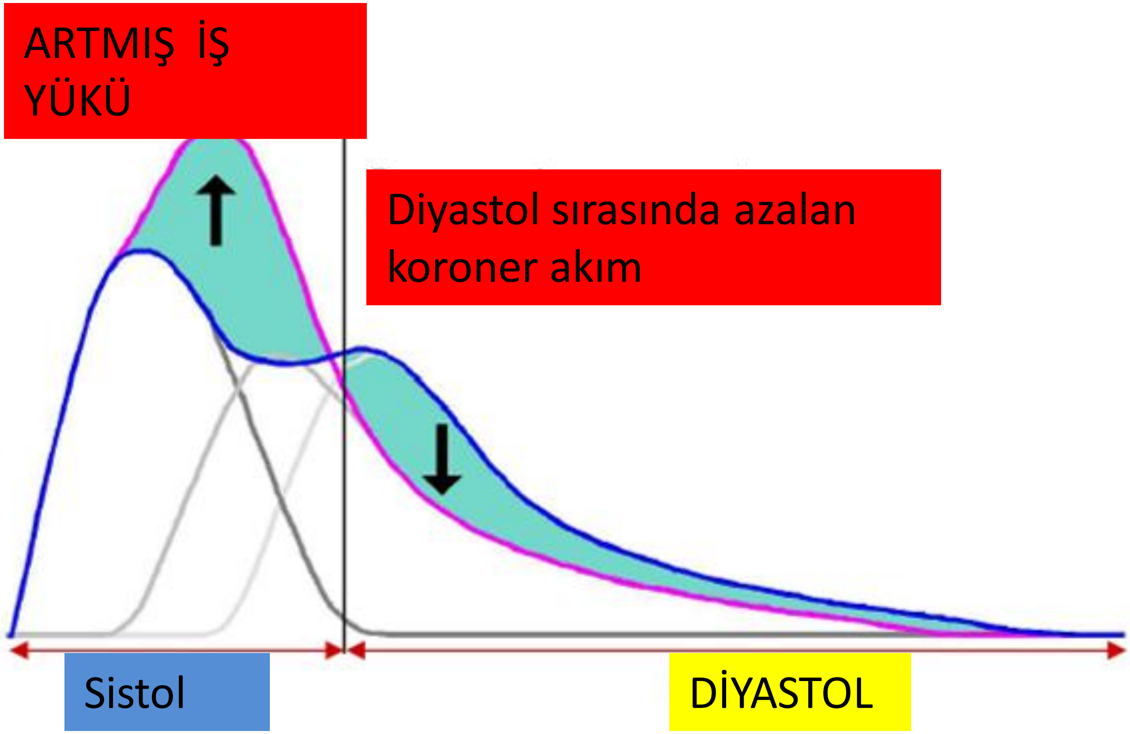
Arteryal Sertlik Artarsa

Yansıyan basınç dalgası daha hızlı hareket ederek daha erken döner. Bunun sonucunda:

- Santral sistolik kan basıncı artarken diastolik basınç düşer ve santral nabız basıncı artar.
- Sol ventrikül kütlesi ve yükü artar. Böylece kalbin iş yükü artar.
- Diyastol sırasında koroner perfüzyon düşer.

Dalga Yansıması



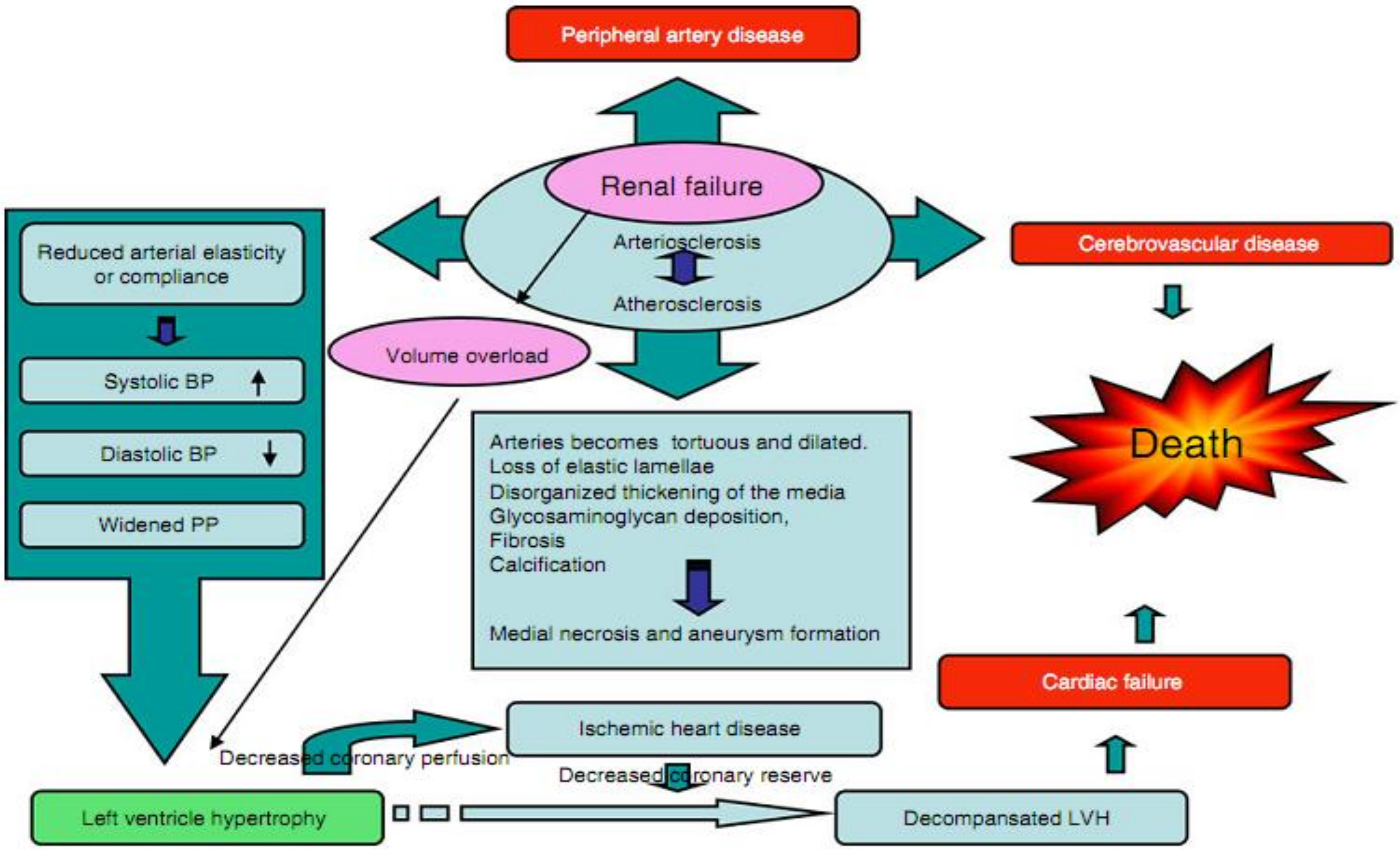

ARTMIŞ İŞ YÜKÜ
Diyastol sırasında azalan koroner akım
Sistol
DİYASTOL

Int Urol Nephrol (2010) 42:741–752
DOI 10.1007/s11255-009-9675-1

NEPHROLOGY - REVIEW

Arterial stiffness in dialysis patients: where are we now?

Mehmet Kanbay · Baris Afsar ·
Paul Gusbeth-Tatomir · Adrian Covic



Nabız Dalga Hızını Etkileyen Faktörler

Arterin Kendine Ait Özellikleri ve Yapısal Değişiklikler

- Arterin yapısı, elastin/kollojen oranı ve elastikiyeti.

\- Elastin oranı arttıkça esneklik artar ve nabız dalga hızı düşer, kollojen oranı arttıkça esneklik azalır nabız dalga hızı yükselir.

\- Glikozaminoglikanların depolanması ve glikasyon son ürünlerinin damar duvarında artışı, damar yapısını bozarak nabız dalga hızını artırır.

- Bramwell and Hill denklemi : dV/ dP (arter ne kadar elastik ise nabız dalga hızı o kadar yavaş olur)
- Young (Elastisite modülü): Arter ne kadar sert ise değeri artar ve nabız dalga hızı o kadar büyür.

Nabız Dalga Hızını Etkileyen Faktörler

Arter duvarındaki gerilim, arter çapı ve arter duvarının kalınlığı ile doğru orantılıdır (Laplace Kanunu):

Arter ne kadar genişleyebilirse (ne kadar esnek ise) teorik olarak onu eski haline getirmeye yarayan kuvvet (gerilim kuvveti) o kadar yüksek olmalıdır.

Nabız Dalga Hızını Etkileyen Faktörler

- **Yaş**
- **Kan basıncı**

- Kolesterol
- Kan şekeri
- Sigara
- Cinsiyet
- Ateroskleroz ve Arterioskleroz
- Genetik Faktörler
- İnflamasyon

Expert consensus document on arterial stiffness: methodological issues and clinical applications

Stephane Laurent[1*], John Cockcroft[2], Luc Van Bortel[3], Pierre Boutouyrie[1], Cristina Giannattasio[4], Daniel Hayoz[5], Bruno Pannier[6], Charalambos Vlachopoulos[7], Ian Wilkinson[8], and Harry Struijker-Boudier[9] on behalf of the European Network for Non-invasive Investigation of Large Arteries

Table 6 Clinical conditions associated with increased arterial stiffness and/or wave reflections

Ageing	CV risk factors	CV diseases
Other physiological conditions	Obesity	Coronary heart disease
Low birth weight	Smoking	Congestive heart failure
Menopausal status	Hypertension	Fatal stroke
Lack of physical activity	Hypercholesterolaemia	Primarily non-CV diseases
Genetic background	Impaired glucose tolerance	ESRD
Parental history of hypertension	Metabolic syndrome	Moderate chronic kidney disease
Parental history of diabetes	Type 1 diabetes	Rheumatoid arthritis
Parental history of myocardial infarction	Type 2 diabetes	Systemic vasculitis
Genetic polymorphisms	Hyperhomocyteinaemia	Systemic lupus erythematosus
	High CRP level	

Arteryal Sertlik Nasıl Ölçülür?

Arteryal katılığı ölçerken birçok parametre göz önüne alınmalı:

A- Ölçüm Yeri:

- **Sistemik:** Aortik NDH (Aortik NDH'nı ölçmek için karotis-femoral NDH transfer fonksiyonu kullanılıyor)
- **Bölgesel:** (Brakial NDH)
- **Lokal:** (Radyal NDH) Lokal yöntemin avantajı direkt olarak ölçüm aletinin ölçüm yapacak damarın üstüne koyulabilmesidir. Dezavantajı santral hemodinamikleri anlamak için transfer fonksiyonuna daha fazla ihtiyaç var.

Arteryal Sertlik Nasıl Ölçülür?

B- Ölçüm Yöntemi:

- Hız
- Basınç
- Şekil değişikliği

Arteryal Sertlik Ölçülür?

C- Ölçülen Parametre:

- Nabız Dalga Hızı
- Arttırma İndeksi (Augmentaston index)
- Arteryal Kompliyans
- Ambulatuar Arteryal Sertlik İndeksi
- X ray Kalsifikasyon Skorlaması

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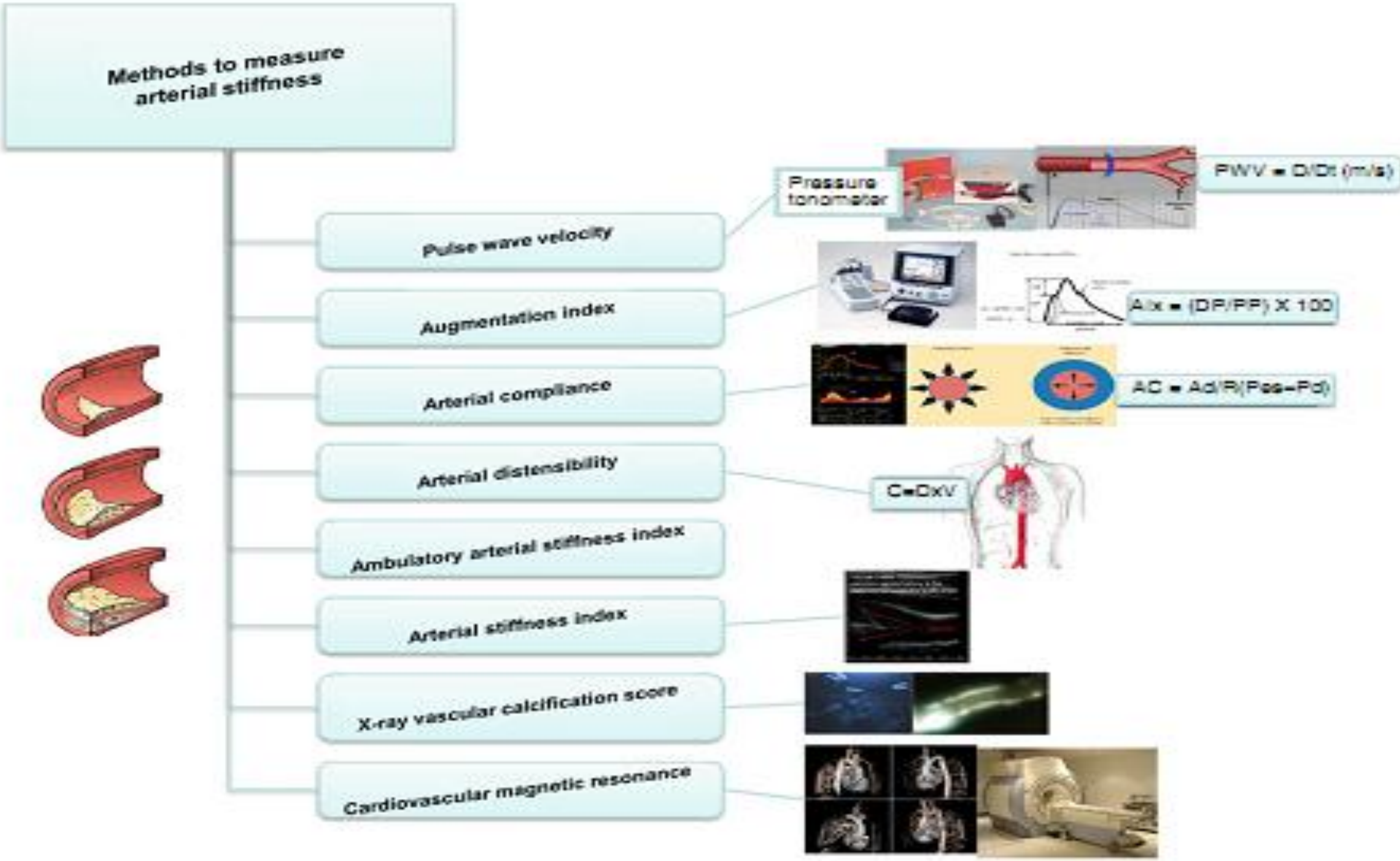
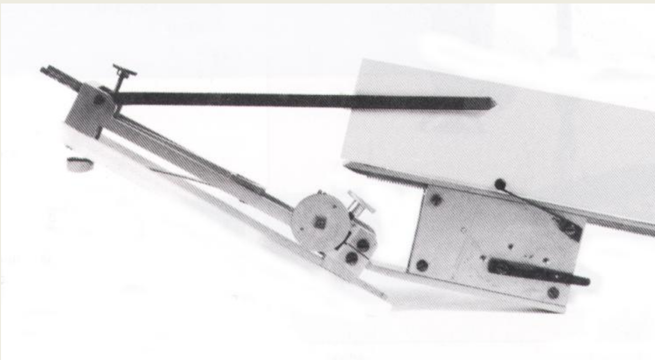
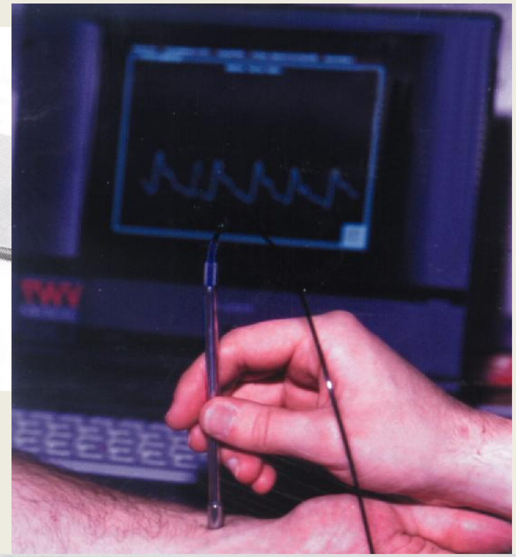
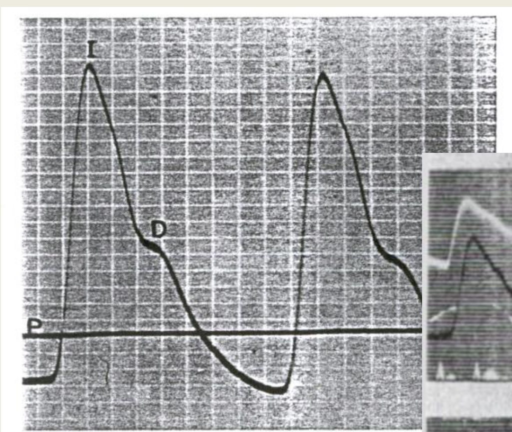


Fig. 2 Methods of measuring arterial stiffness



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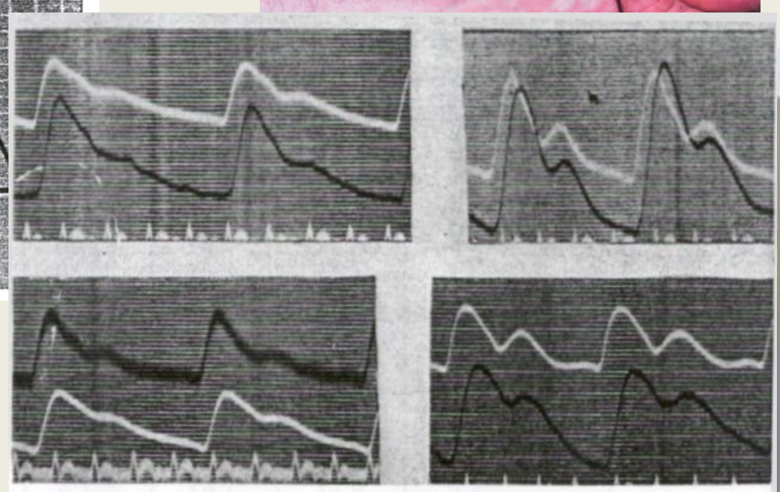



CardioVascular Profiling Instrument
START CUFF

- Bu yöntemler içinde altın standart olan yöntem:

Aortik Nabız Dalga Hızı Ölçümüdür

- Aort Nabız Dalga Hızı Ölçümü:

- Klinikte en sık kullanılan
- Kolay
- Tekrarlanabilir
- Güvenilir
- En iyi prognostik

Metottur

Stiffness of Capacitive and Conduit Arteries

Prognostic Significance for End-Stage Renal Disease Patients

Bruno Pannier, Alain P. Guérin, Sylvain J. Marchais, Michel E. Safar, Gérard M. London

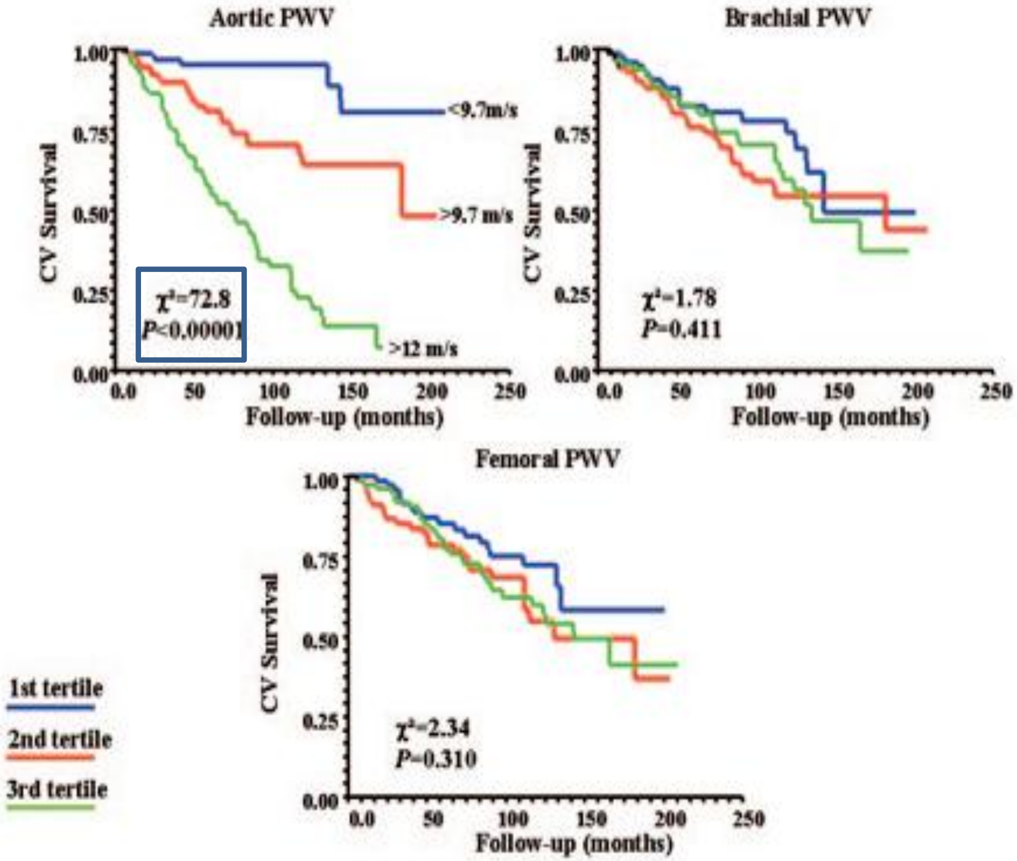


Figure 2. Probability of cardiovascular survival of ESRD patients according to the levels of aortic, brachial, and femoral PWVs.

Stiffness of Capacitive and Conduit Arteries
Prognostic Significance for End-Stage Renal Disease Patients

Bruno Pannier, Alain P. Guérin, Sylvain J. Marchais, Michel E. Safar, Gérard M. London

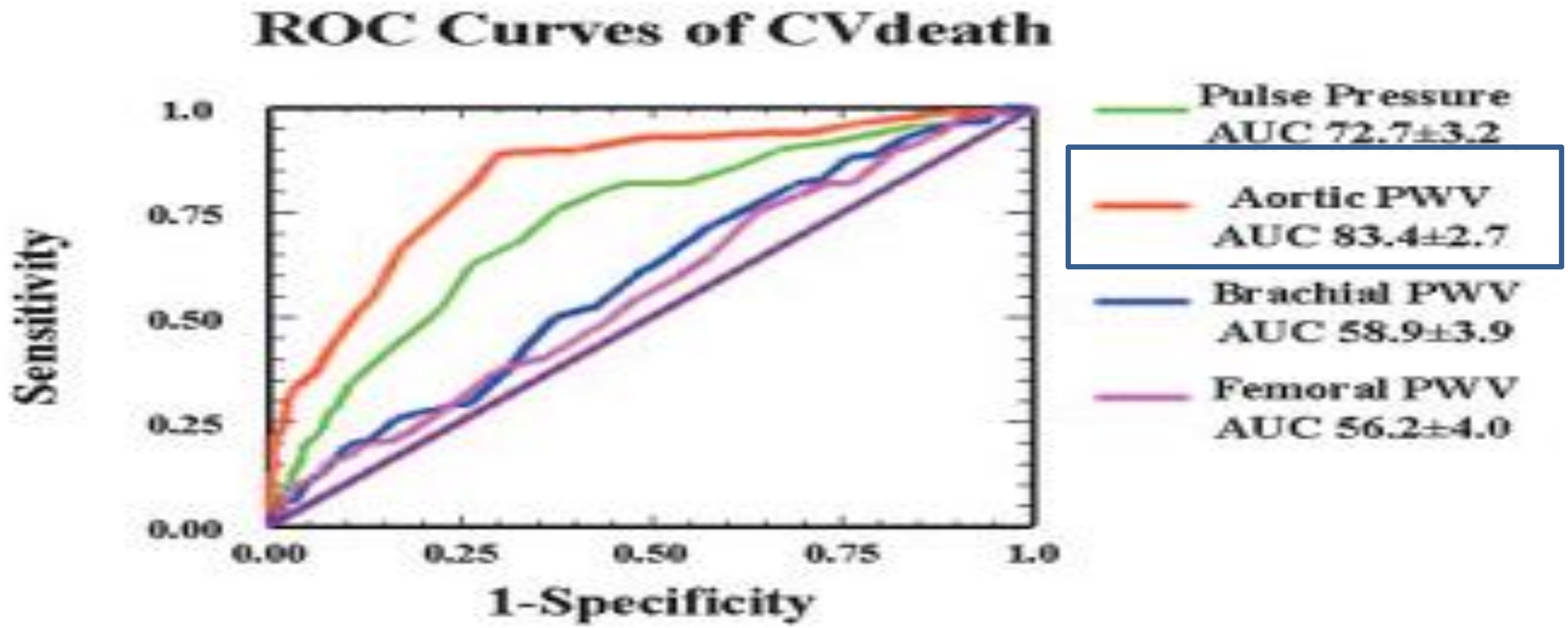
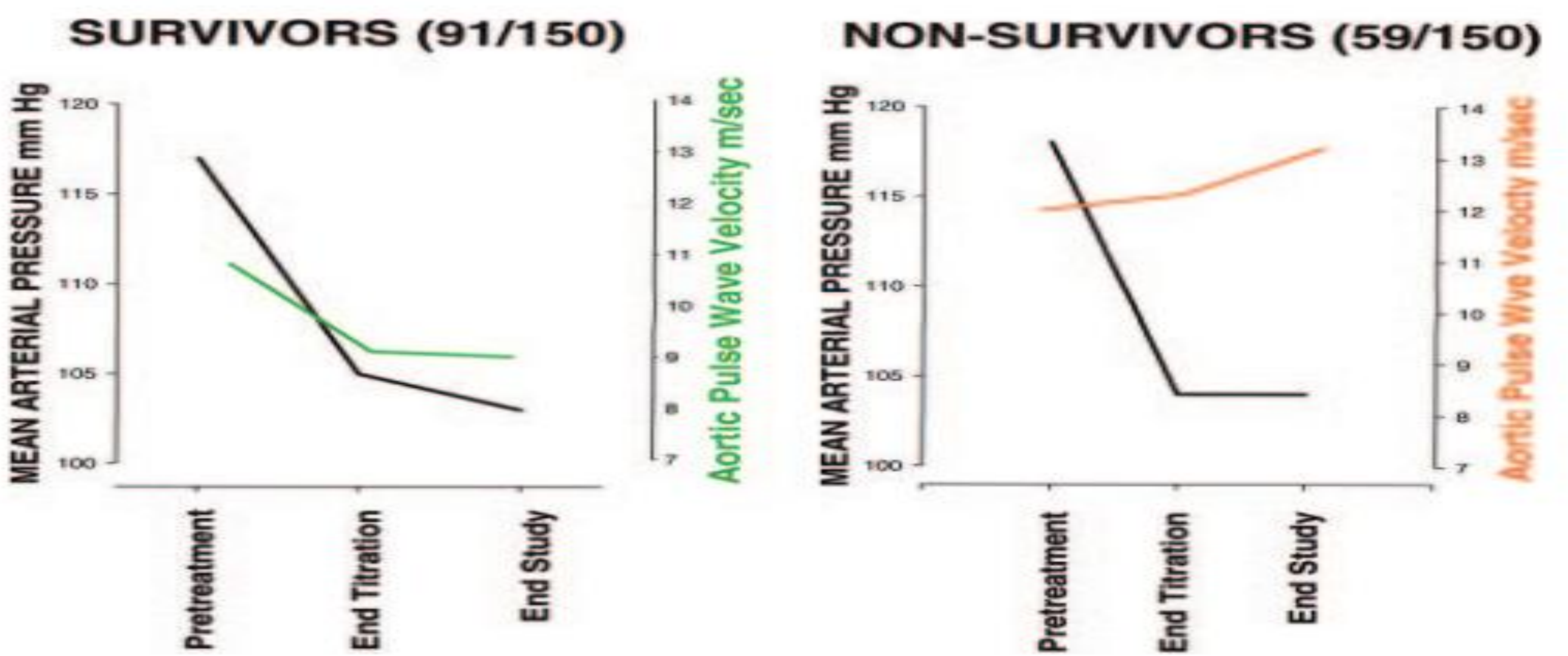


Figure 3. Receiver operating characteristics curves for pulse pressure, aortic PWV, brachial PWV, and femoral PWV in ESRD patients.

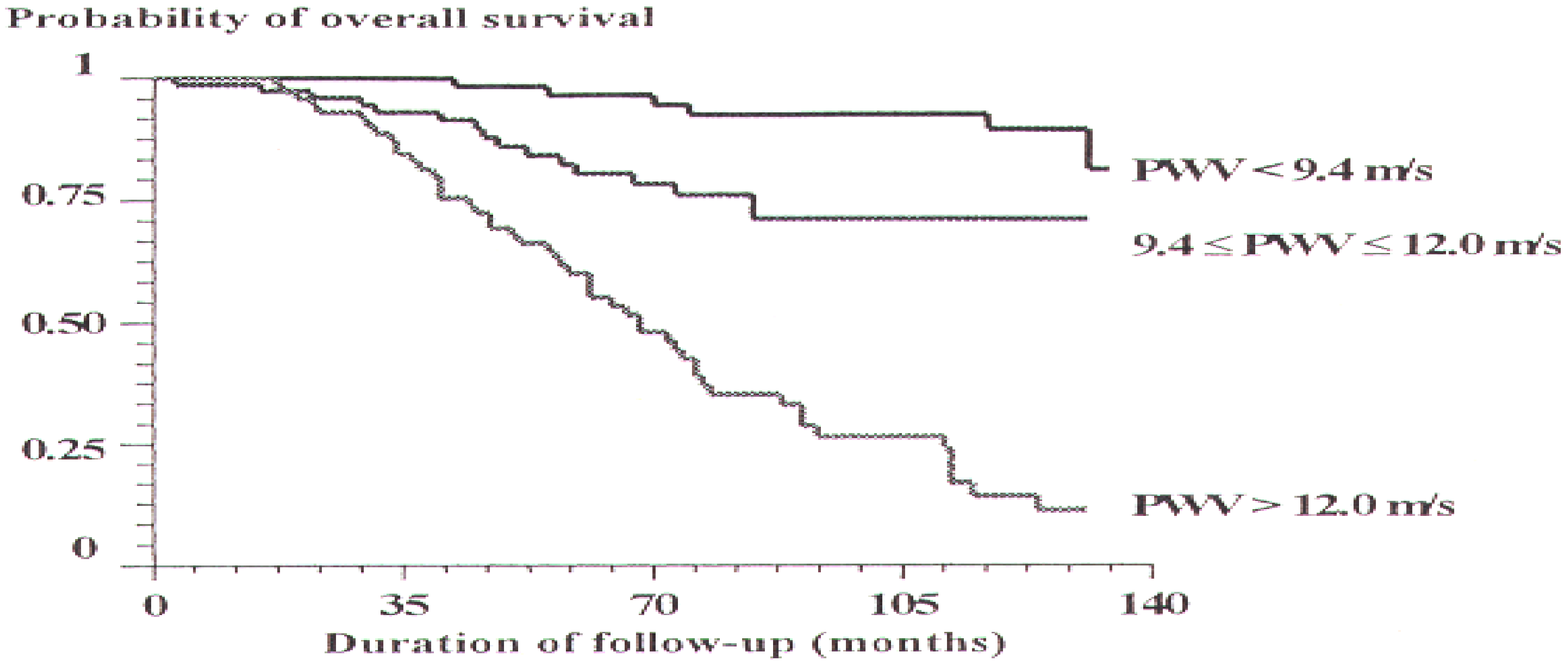
Impact of Aortic Stiffness Attenuation on Survival of Patients in End-Stage Renal Failure

Alain P. Guerin, MD; Jacques Blacher, MD, PhD; Bruno Pannier, MD; Sylvain J. Marchais, MD; Michel E. Safar, MD; Gérard M. London, MD



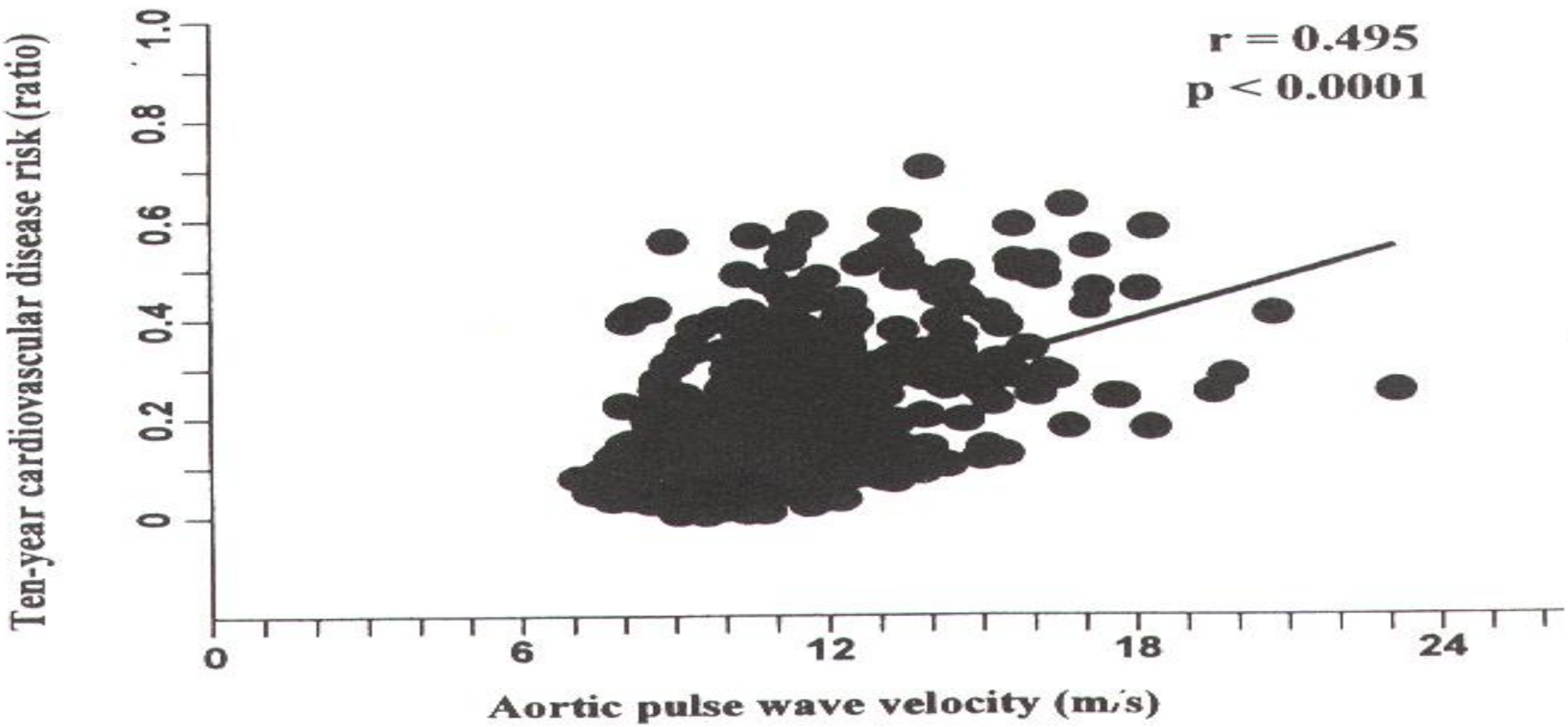
Impact of Aortic Stiffness on Survival in End-Stage Renal Disease

Jacques Blacher, MD; Alain P. Guerin, MD; Bruno Pannier, MD; Sylvain J. Marchais, MD; Michel E. Safar, MD; Gérard M. London, MD



Aortic Pulse Wave Velocity as a Marker of Cardiovascular Risk in Hypertensive Patients

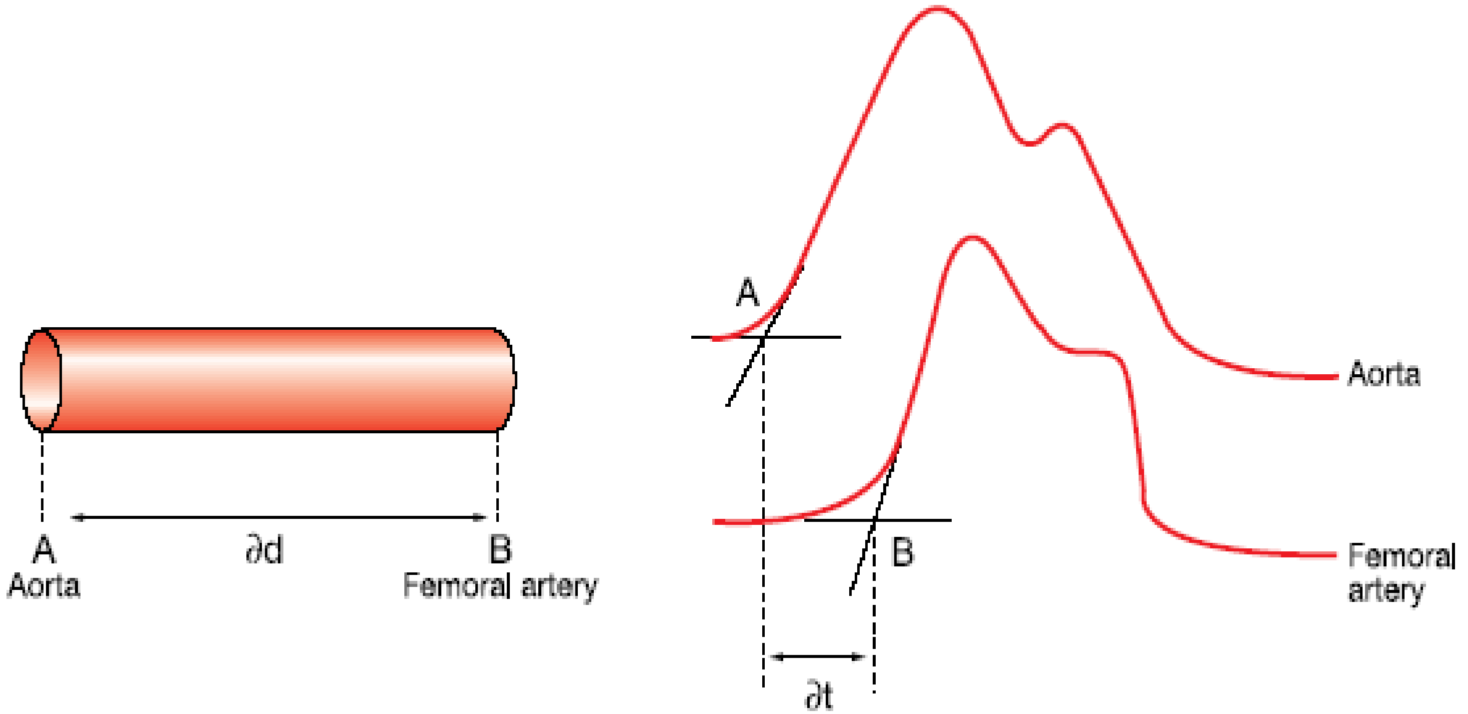
Jacques Blacher, Roland Asmar, Saliha Djane, Gérard M. London, Michel E. Safar



Nabız Dalga Hızı Ölçümü

- Aplanasyon Tonometrisi (Sphygmo Cor, Comlior)
- Pletismografi
- Infrared Sensörler (Pulsemetrik)
- Osilometrik Yöntemler (Arteriograph, Mobil-o-Graph
- Doppler USG, MR (genişleme, şekil değişikliğini ölçer)

NABIZ DALGA HIZI

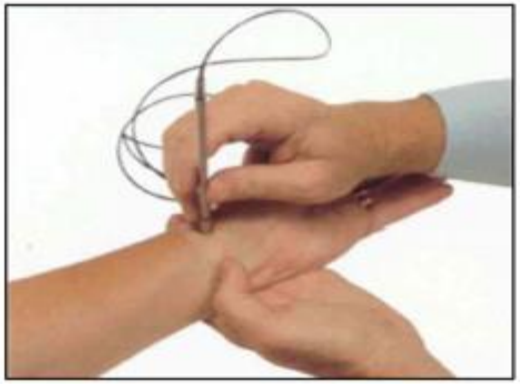


PWV = Distance (D) / Time delay (ΔT) m/sec

Usually measured over 10 heart beats.

NABIZ DALGA HIZI ANALİZİ

- Applanation tonometry
- Infra-red sensor – digit volume pulse



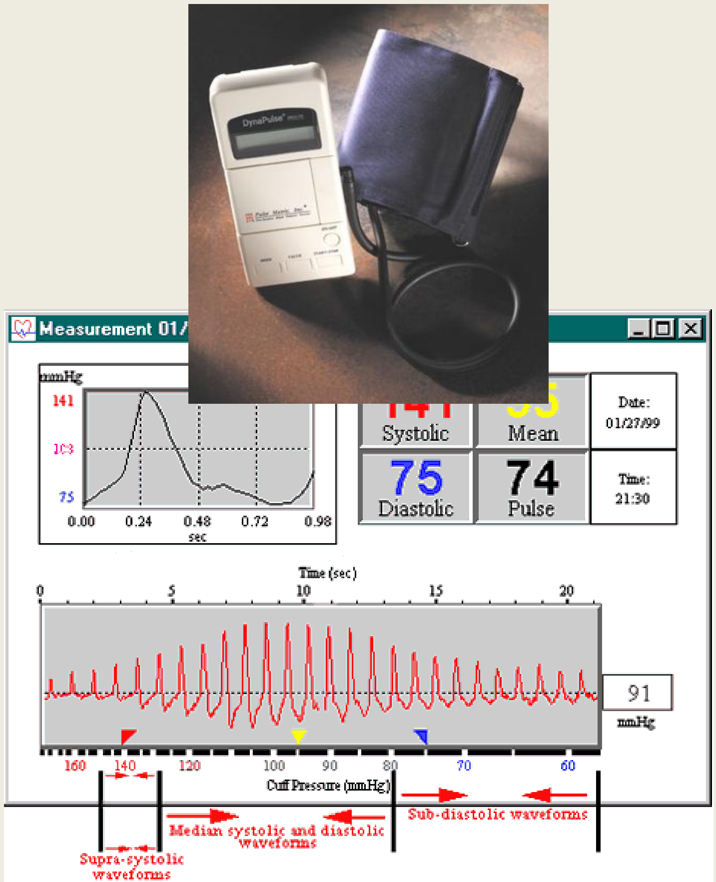
Aplanasyon Tonometrisi

- Perifer arterdeki basınç dalgalarının transfer fonksiyonu kullanılarak santral basınç ve santral basınç dalgaları hakkında bilgi sağlanmasıdır.
- Periferik arterdeki basınç dalgaları bu arterlerin üstüne konulan sensörler sayesinde algılanır.
- Bu algılanan basınç dalgaları otomatik olarak (software) ölçülmesi istenen parametreleri (NDH, AiX) ölçer.

Transfer Fonksiyonu

- Arteryal ağaç boyunca damarlar histolojik, hücresel ve moleküler olarak değişiklik gösterir.Bu durum nabız dalga hızlarının değişik arter bölümlerinde farklı olmasına neden olur.
- Örneğin NDH çıkan aortada 4–5m/s, abdominal aortada 5–6m/s ve iliak ve femoral arterlerde 8–9m/s civarındadır.
- Bu nedenle perifer damarlardan ölçülen NDH santral NDH'nı öngörebilmesi için bu fizyolojik faktörler göz önüne alınmalıdır.
- Transfer fonksiyonu bu fizyolojik prensibin software tarafından kabaca hesaplanması yoluyla sonuçların düzenlenmesi işlemidir.

PulseMetric



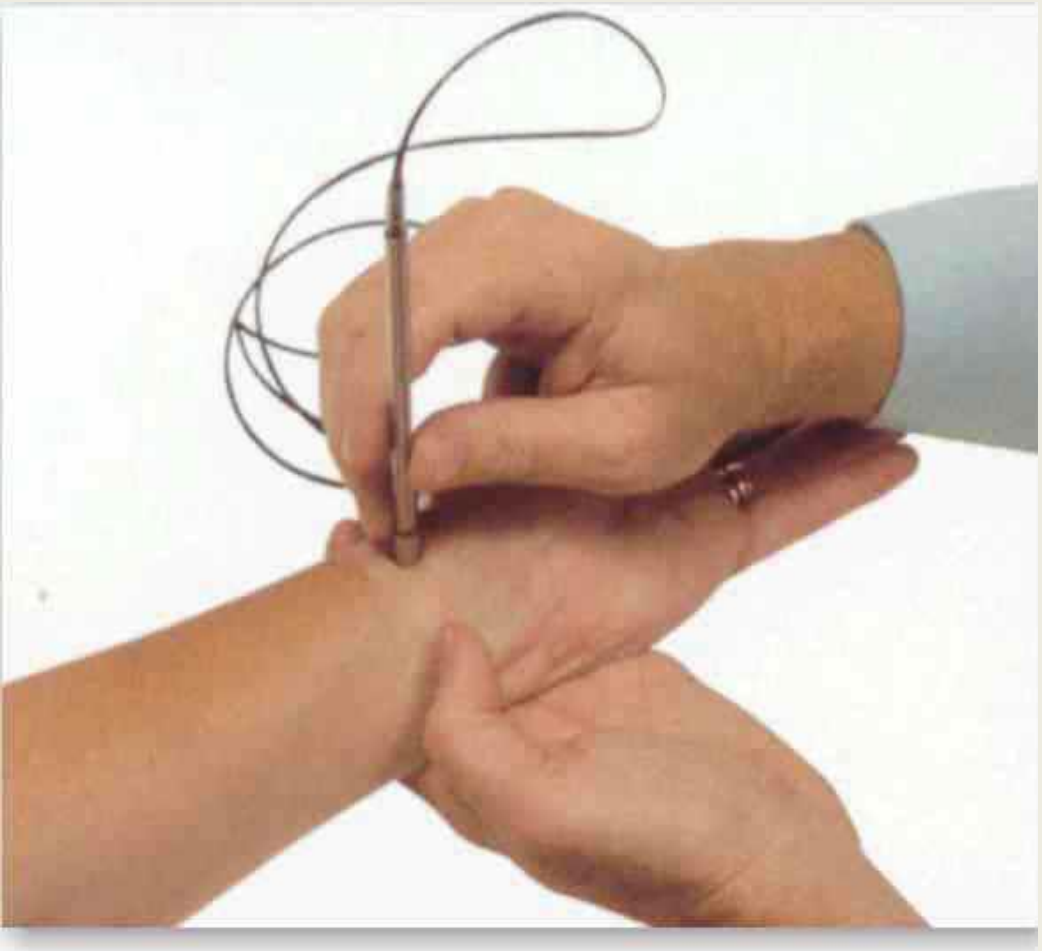
CARDIAC PARAMETERS		[Normal Range(Male)*]
LV Ejection Time (sec)	0.373	[0.207 - 0.388]
LV dP/dt Max (mmHg/s)	1,200	[847 - 1506]
LV Contractility (1/s)	15.95	[12.39 - 19.08]
Cardiac Output (L/min)	4.41	[3.59 - 7.9]
Cardiac Index (L/min/m^2)	2.47	[1.95 - 3.74]
Stroke Volume (mL)	74.2	[57.7 - 100.7]
Stroke Vol Index (mL/m^2)	41.6	[31.8 - 48]
SYSTEMIC VASCULAR PARAMETERS		
SV Compliance (mL/mmHg)	1.43	[1.02 - 2]
SV Resistance (dynes/sec/cm^5)	1598	[871 - 1902]
BRACHIAL ARTERY PARAMETERS		
BA Compliance (mL/mmHg)	0.069	[0.056 - 0.132]
BA Distensibility (%/mmHg)	5.44	[4.38 - 9.28]

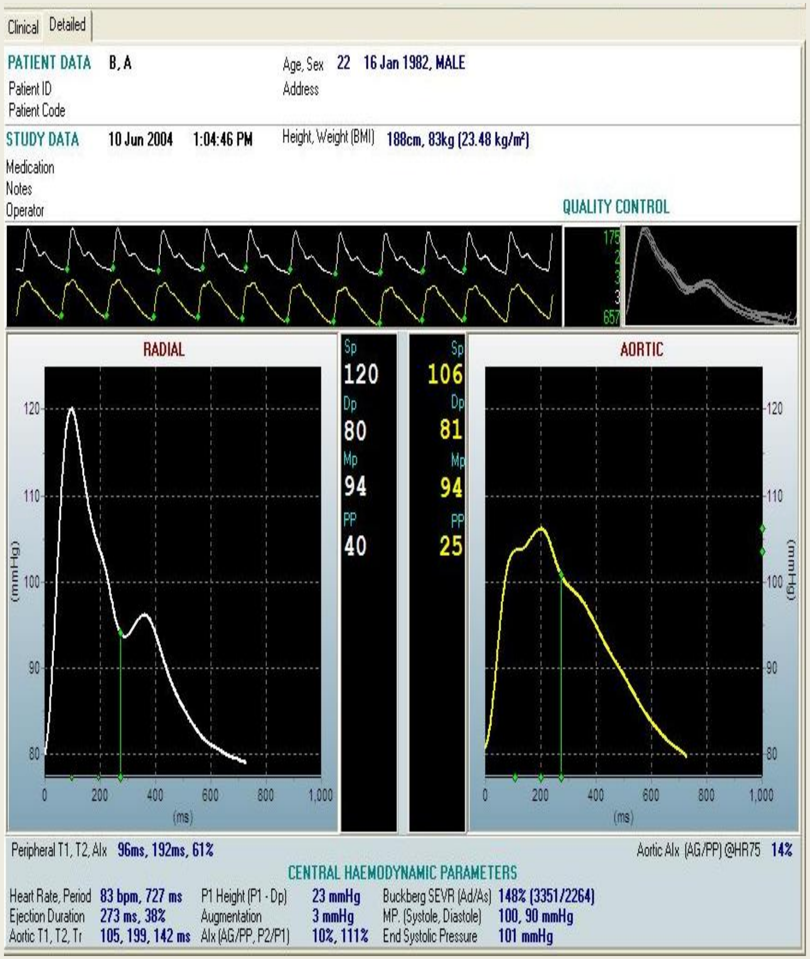
Brachial Artery Distensibility, SVR, CO, LV dP/dt

Uses Oscillometric BP cuff

Sphygmo Cor aleti

Sphygmocor



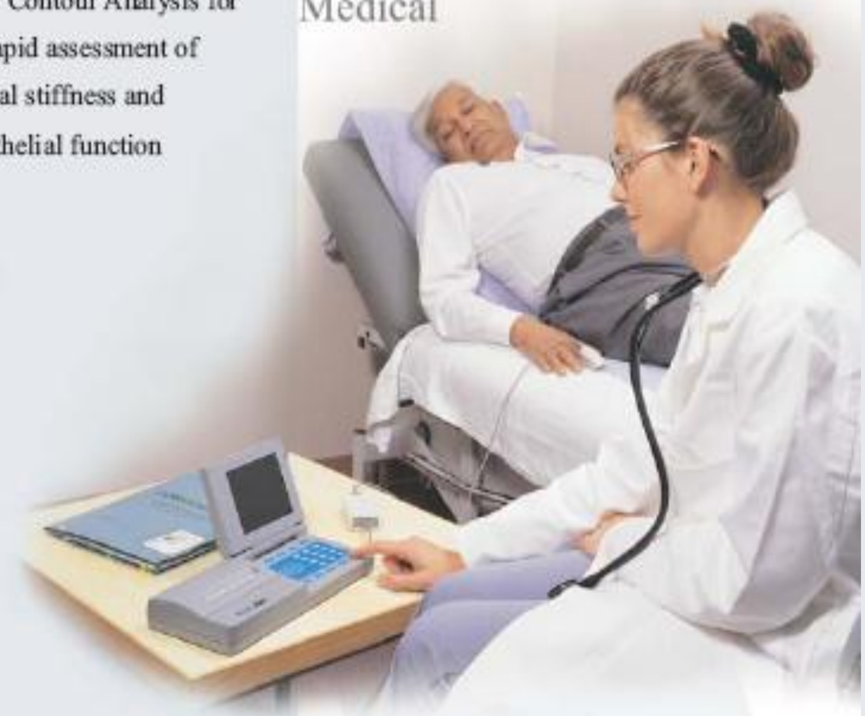


Pulse Wave Velocity & Augmentation Index
Uses Arterial tonometer (radial)

PulseTrace PCA

Micro Medical

Pulse Contour Analysis for the rapid assessment of arterial stiffness and endothelial function



Also Available with PWV option

PulseTrace measures Arterial Stiffness (SI), which has been shown to be an independent predictor of cardiovascular risk that can be used to:

- *Assess cardiovascular health, non-invasively*
- *Identify patients at risk of heart attack and stroke*
- *Monitor the progress of vascular disease*
- *Monitor effect of specific drugs*

PulseTrace measures Vascular Tone (RI) providing:

- *A simple and non-invasive test of endothelial function, an early marker of developing arterial disease.*

PulseTrace PCA

Micro Medical

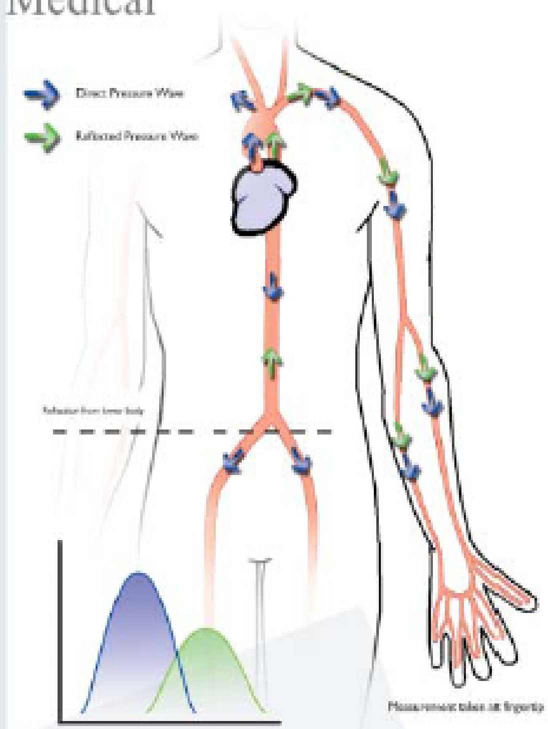
Arterial Stiffness & Pulse Contour Analysis

The new Micro Medical PulseTrace provides the clinical information that can aid early detection and treatment of arterial disease. PulseTrace is a powerful non-invasive device that measures two vascular disease parameters: large artery wall stiffness (SI) and vascular tone (RI).

PulseTrace uses pressure wave transmission and reflection theory to evaluate the speed with which the pressure pulse travels through the large arteries, and to estimate vascular tone (determined by the diameter of the small to medium arteries). This theory explains why the pressure pulse waveform changes as it travels through the arterial system[1].

The speed with which the pressure pulse travels up and down through the arteries is directly related to their stiffness[2] (blood pressure, vessel diameter and blood density are other factors). Measuring the time it takes for the pressure waves to travel through the arterial system provides a simple but accurate way of measuring arterial stiffness[3].

PulseTrace uses the fact that the pressure waveform in the radial artery is related to the volume waveform in the finger[4]. It is this very important observation that makes the Micro Medical PulseTrace such a powerful non-invasive tool for the assessment of vascular disease.



Wave Transmission & Reflection Theory

The first part of the volume waveform in the finger is the result of pulse transmission along a direct path from the aortic root to the finger. The second part is formed by the pulse transmitted from the aortic root to the lower body where it is reflected back along the aorta and subclavian artery to the finger.

The time delay between the first and second peak is determined by the transit time of the pressure pulse from the root of the subclavian artery to the apparent sight of reflection and back to the subclavian artery. Assuming this distance is proportional to the subject's height, the transit time of the pressure pulse in the aorta and large arteries can be used to calculate a stiffness index (see diagram above).

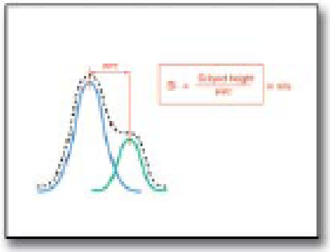
The height of the second peak relates to the amount of pressure wave reflection. This in turn relates mainly to the tone of small arteries. When the second peak is absent then the point of inflection in the down-slope of the waveform is used.

PulseTrace PCA

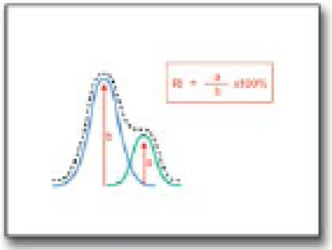
Micro Medical

The Digital Volume Pulse (DVP)

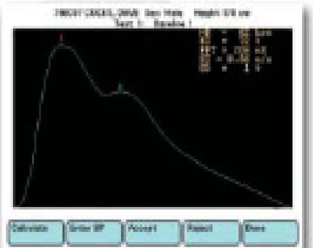
The DVP waveform is directly related to pressure waveform in the radial artery[4] and provides an accurate and noninvasive method to obtain information on the pressure pulse waveform. The Micro Medical PulseTrace uses a high fidelity photoplethysmograph transducer with signal conditioning circuit to obtain an extremely accurate and noise free signal of the DVP waveform. This technique follows the changes in the amount of infra red light passing through the finger, which is inversely proportional to the number of red blood cells (volume of blood) in the finger at any given moment. To maximise the flow of blood, a special temperature controlled heated probe has been developed to optimise signals. This overcomes problems with photoplethysmography in subjects with poorly perfused fingers.



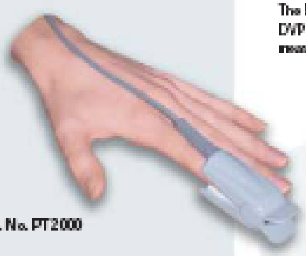
The Stiffness Index SI is an estimate of pulse wave velocity in large arteries and is obtained from the subjects height divided by the time between the first and second peak of the DVP. It is a measure of large artery stiffness.



The Reflection Index RI is the height of the second peak of the DVP expressed as a percentage of the waveform peak and is a measure of the tone of the small/medium arteries.



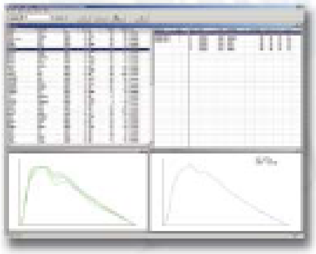
PulseTrace Cat. No. PT2000



After less than 2 seconds the PulseTrace displays the average waveform based on the number of pulses selected by the user together with the computed SI and RI.

Features

- *Minimum user training or special skills needed to obtain clinically valid results*
- *Well tolerated by the subject*
- *Fast sequential measurements*
- *Self contained and portable*
- *Temperature controlled heating pads in both the top and bottom of the sensor*
- *High resolution printer and colour display*
- *Complete with all accessories in a sturdy case*
- *User defined test protocols*
- *Ectopic beats and artefact rejection*
- *PC software for uploading and managing results*
- *Future Proof - can be upgraded via software downloads*



The PulseTrace utilities software, PC Upload, included with all PulseTrace systems is an Access database that allows you to upload and store your results and waveforms on your PC.

Specifications

Measurements	Averages the digital volume pulse waveforms over a user-defined period (1-60 seconds). Rejects waveforms with low amplitude, artefact or noise and rejects ectopic waveforms. Waveform is visible in real time during sampling period. Calculation time < 2 seconds for a typical recording of 10sec. The points used in the calculations are marked as follows: first peak, systolic inflection point if present and second peak or inflection point. Manual selection of the second peak or inflection point is available. Calculates and displays: • Total number of waveforms identified • Total number of waveforms used and their standard deviation • Time from systolic inflection point (if present) or first peak to second peak or inflection point (PPT) • Stiffness Index (SI) defined as the subjects height divided by PPT (only displayed if subjects height has been entered) • Reflection Index (RI) defined as the height of the second peak or inflection point divided by the height of the waveform peak • Heart Rate
Tests/examination	Up to 12 complete tests per examination session
Storage	200 examinations including the waveform can be stored
Transducer	Precision photoplethysmographic finger probe with temperature controlled heating pads fitted internally to both the top and bottom of the sensor
Printer	320 dot per line internal thermal printer
Display	1/4 VGA Colour LCD
Power Supply	Input 100-250V 50-60Hz. DC output 12V 500mA
Dimensions	337 x 140 x 45mm (when display closed). Transducer 20 x 20 x 60mm
Weight	Unit weight 1.1 kg. Packed weight with carry case and accessories 2.6kg
Standards	Type B device, CE approved (Directive 93/42/EEC)
Environment	Complies with directive EN60601-1-2 electromagnetic compatibility

Bibliography

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The PulseTrace is manufactured by Micro Medical Ltd and is offered as Catalogue No. PT2000

PULSE WAVE VELOCITY

The Complior® device

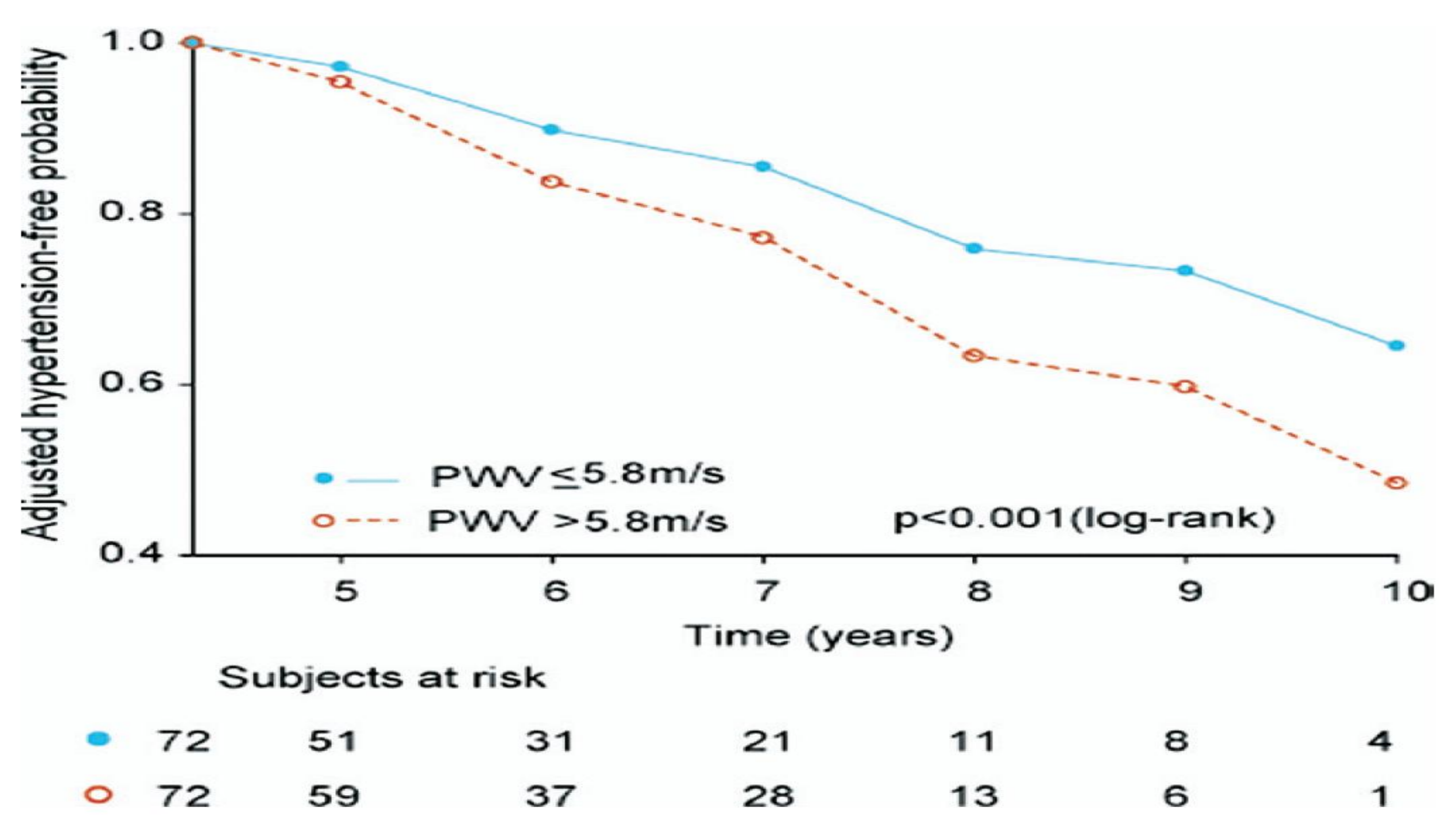
Expert consensus document on arterial stiffness: methodological issues and clinical applications

Stephane Laurent[1*], John Cockcroft[2], Luc Van Bortel[3], Pierre Boutouyrie[1], Cristina Giannattasio[4], Daniel Hayoz[5], Bruno Pannier[6], Charalambos Vlachopoulos[7], Ian Wilkinson[8], and Harry Struijker-Boudier[9] on behalf of the European Network for Non-invasive Investigation of Large Arteries

Measurement site	First author (year, country)	Events	Follow-up (years)	Type of patient (number)
Aortic PWV	Blacher (1999, Fr)	CV mortality	6.0	ESRD (241)
	Laurent (2001, Fr)	CV mortality	9.3	Hypertension (1980)
	Meaume (2001, Fr)	CV mortality	2.5	Elderly (>70) (141)
	Shoji (2001, Jp)	CV mortality	5.2	ESRD (265)
	Boutouyrie (2002, Fr)	CHD events	5.7	Hypertension (1045)
	Cruickshank (2002, GB)	All cause mortality	10.7	IGT (571)
	Laurent (2003, Fr)	Fatal strokes	7.9	Hypertension (1715)
	Sutton-Tyrrell (2005, USA)	CV mortality and events	4.6	Elderly (2488)
	Shokawa (2005, Jp)	CV mortality	10	General population (492)
	Willum-Hansen (2006, Dk)	CV mortality	9.4	General population (1678)
	Mattace-Raso (2006, Neth.)	CV mt, CHD	4.1	Elderly (2835)
Ascending aorta (invasive)	Stefanadis (2000, Gr)	Recurrent acute CHD	3	Acute CHD (54)
Carotid distensibility	Blacher (1998, Fr)	All cause mortality	2.1	ESRD (79)
	Barenbrock (2001, Ge)	CV events	7.9	ESRD (68)

Pulse Wave Velocity Is an Independent Predictor of the Longitudinal Increase in Systolic Blood Pressure and of Incident Hypertension in the Baltimore Longitudinal Study of Aging

Samer S. Najjar, MD*, Angelo Scuteri, MDPhD*,†, Veena Shetty, MPH*, Jeanette G. Wright, BA‡, Denis C. Muller, MS‡, Jerome L. Fleg, MDFACC§, Harold P. Spurgeon, PhD*, Luigi Ferrucci, MDPhD‡, and Edward G. Lakatta, MD*



Aortic Pulse Wave Velocity Is Associated With Measures of Subclinical Target Organ Damage

Thais Coutinho, MD,*† Stephen T. Turner, MD,*‡ Iftikhar J. Kullo, MD*†
Rochester, Minnesota

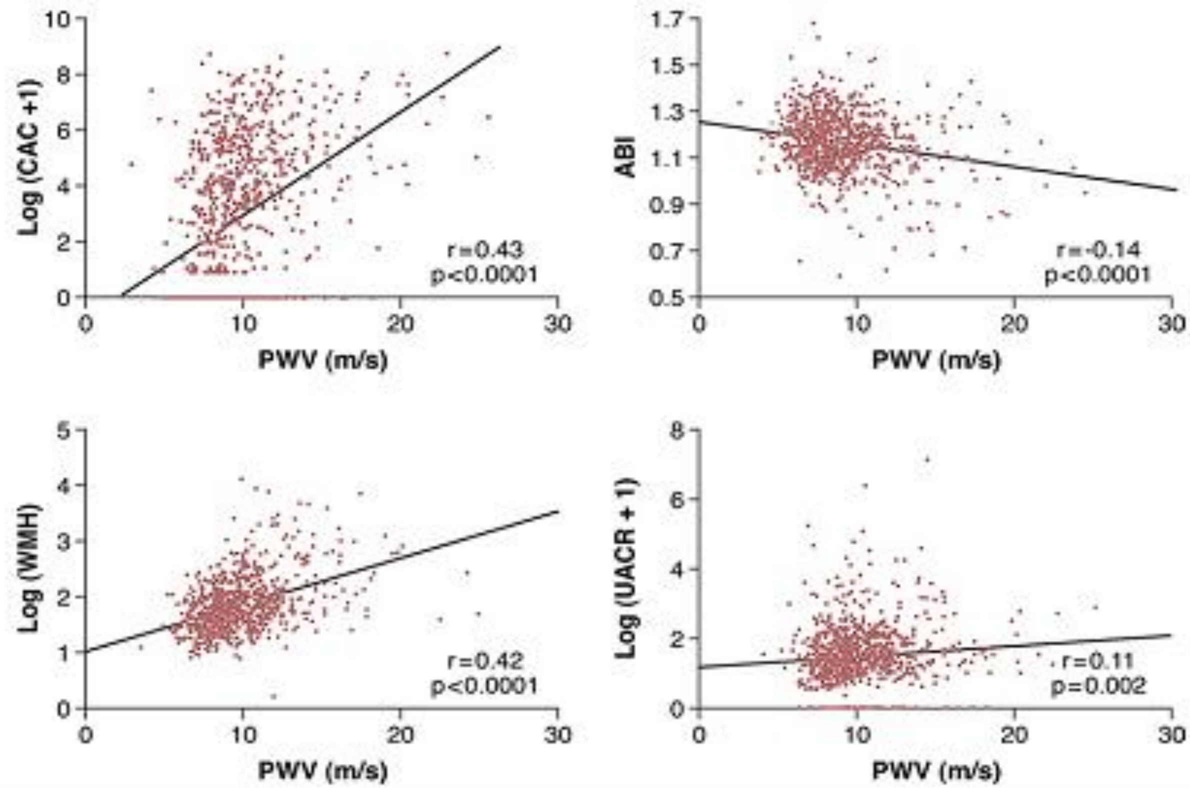
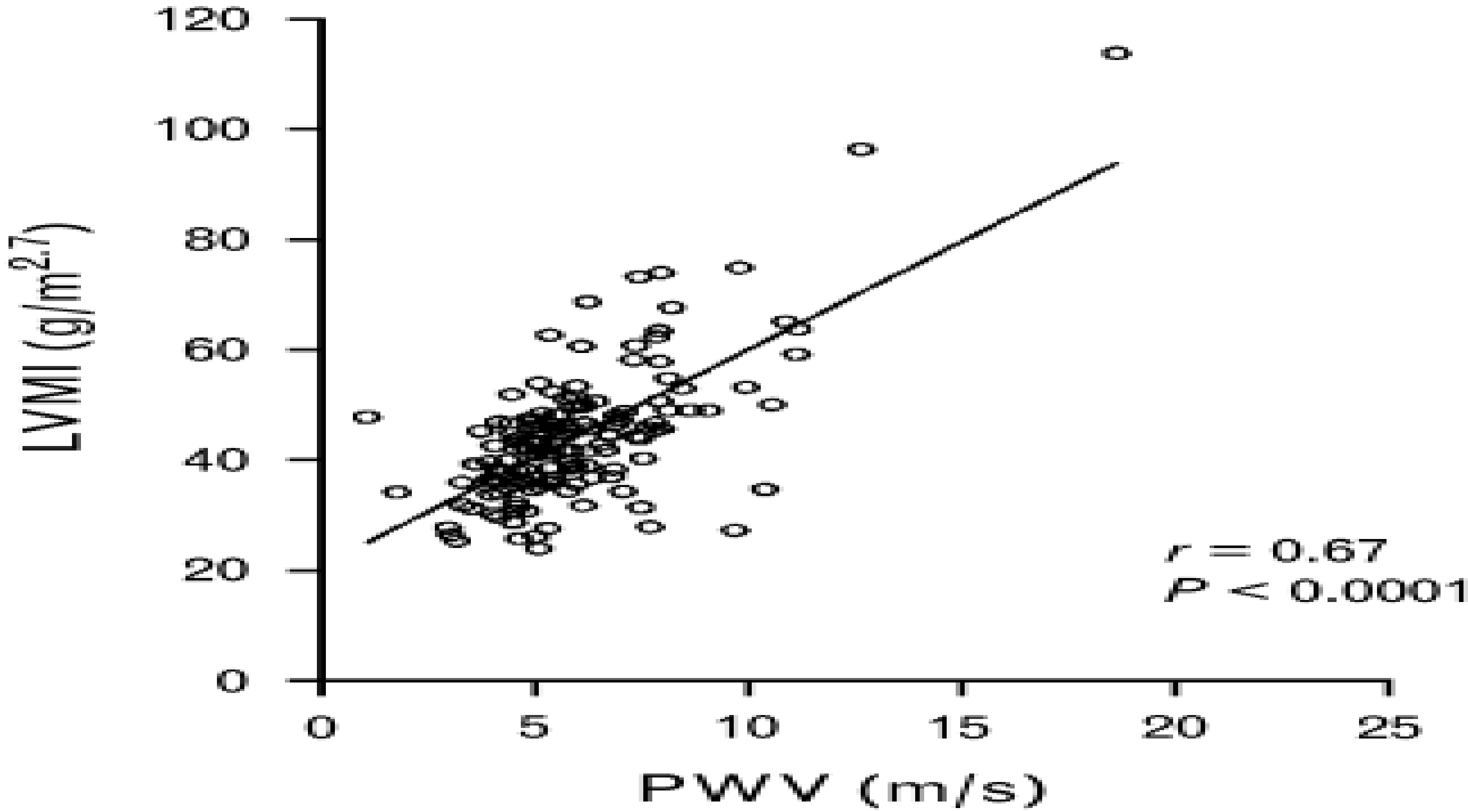


Figure 1. Correlations of aPWV With Coronary, Lower Extremity, Cerebral, and Renal Arteriosclerosis

Scatterplot depicting the unadjusted correlations of aortic pulse wave velocity (aPWV) with log (CAC + 1), ABI, log (WMH), and log (UACR + 1). ABI = ankle-brachial index; CAC = coronary artery calcification; UACR = urine albumin/creatinine ratio; WMH = brain white matter hyperintensity volume.

Gender-specific brachial artery blood pressure-independent relationship between pulse wave velocity and left ventricular mass index in a group of African ancestry

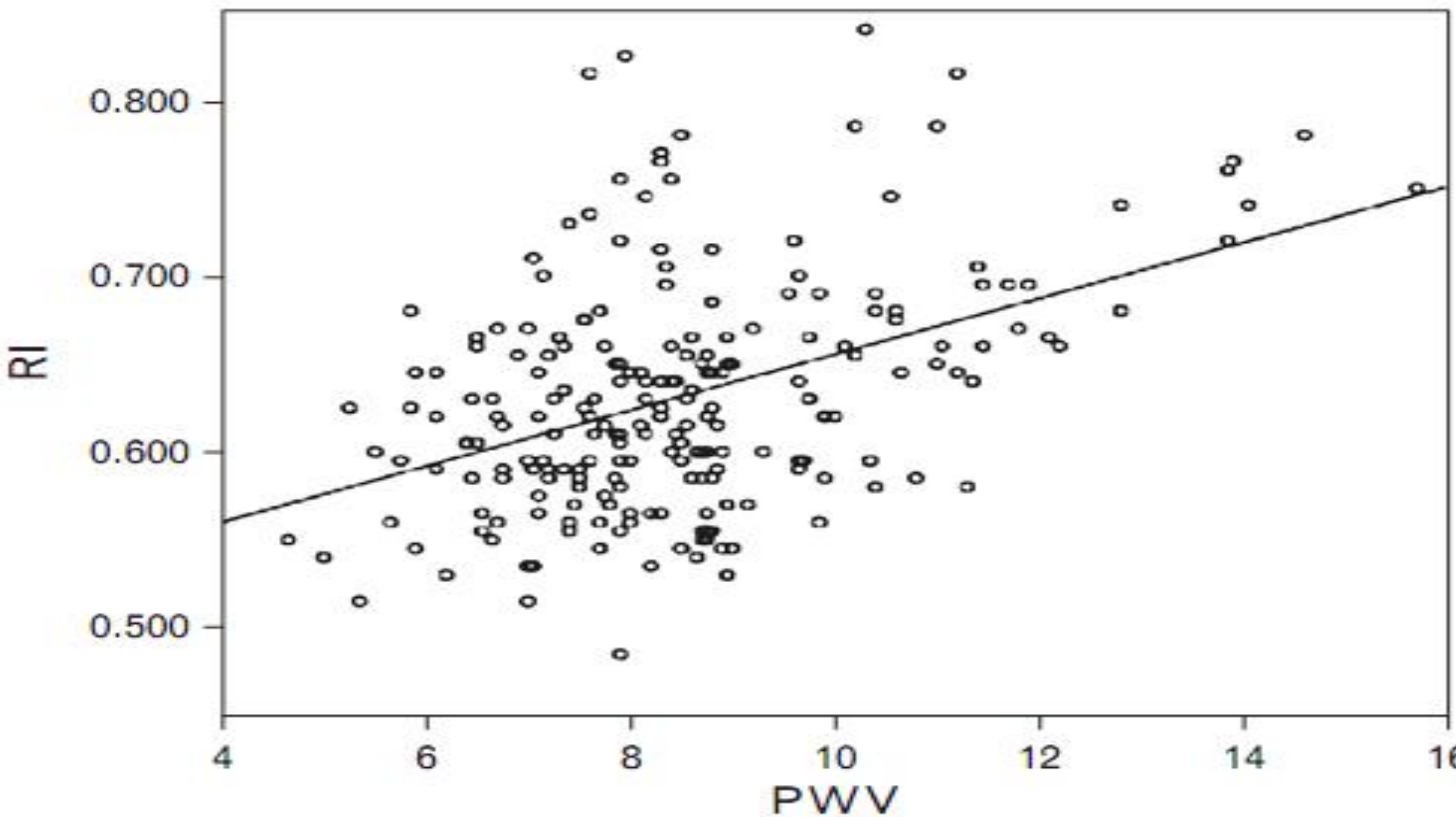
Elena Libhaber[a,b], Angela J. Woodiwiss[a], Carlos Libhaber[b], Muzi Maseko[a], Olebogeng H.I. Majane[a], Siyanda Makaula[a], Patrick Dessein[a], Mohammed R. Essop[b], Pinhas Sareli[a] and Gavin R. Norton[a]



Barenbrock et al. KI 1994;45:1397

Relationship between wave reflection and renal damage in hypertensive patients: a retrospective analysis

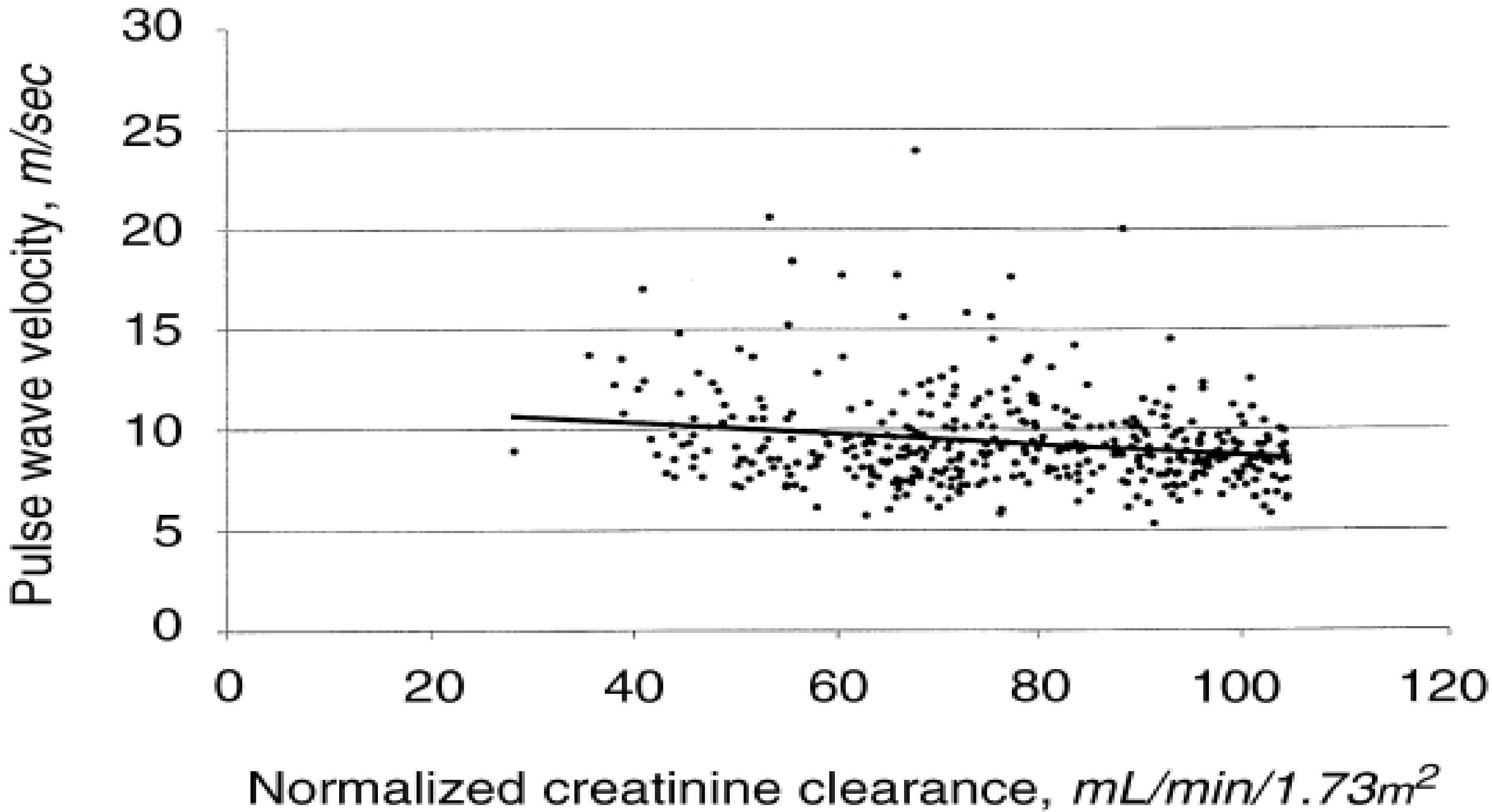
Francesco Stea[a,b], Melania Sgrò[b], Francesco Faita[a], Rosa M. Bruno[a,b], Giulia Cartoni[b], Sabina Armenia[b], Stefano Taddei[b], and Lorenzo Ghiadoni[b]



Kidney International, Vol. 59 (2001), pp. 1834–1841

Creatinine clearance, pulse wave velocity, carotid compliance and essential hypertension

JEAN-JACQUES MOURAD, BRUNO PANNIER, JACQUES BLACHER, ANNIE RUDNICHI, ATHANASE BENETOS, GÉRARD M. LONDON, and MICHEL E. SAFAR



Increased Aortic Pulse Wave Velocity Is Associated With Silent Cerebral Small-Vessel Disease in Hypertensive Patients

Léon H.G. Henskens, Abraham A. Kroon, Robert J. van Oostenbrugge, Ed H.B.M. Gronenschild, Monique M.J.J. Fuss-Lejeune, Paul A.M. Hofman, Jan Lodder, Peter W. de Leeuw

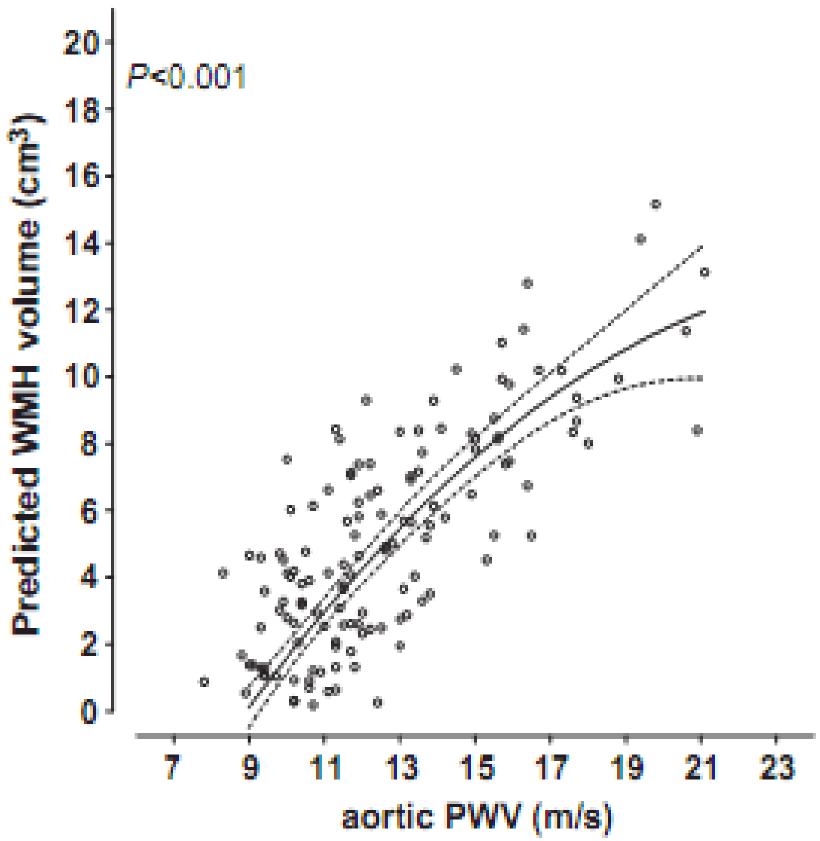


Figure 1. Plot illustrating the relationship between aortic PWV and WMHV for the total study population (n=167). The data points illustrate the predicted WMHV vs the aortic PWV, adjusted for age, sex, and BV. The *P* value indicates the significance level for the corresponding linear regression analysis (using log-transformed WMHV). Abbreviations as in Tables.

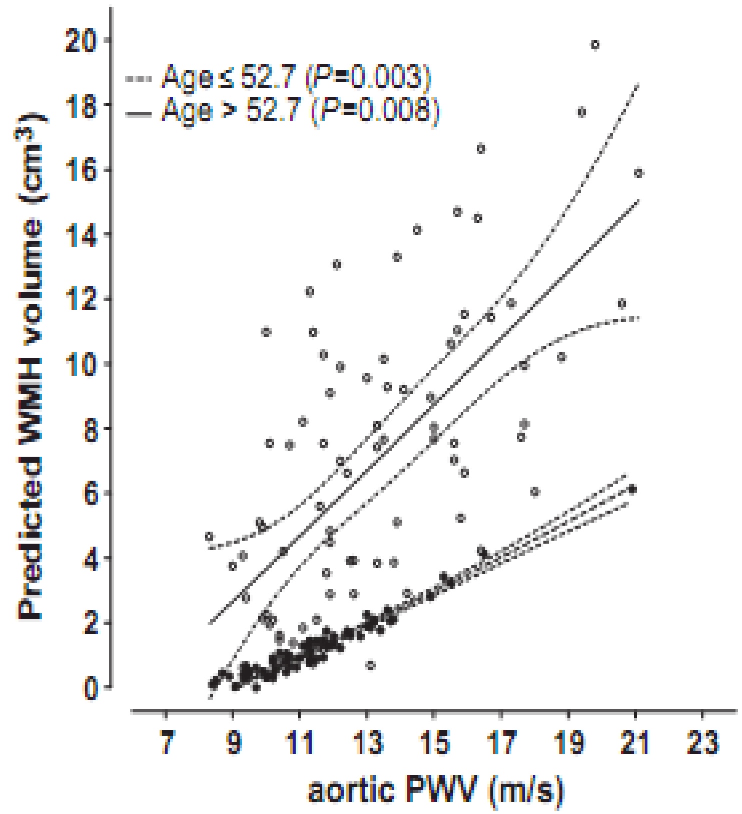


Figure 2. Plot illustrating the relationship between aortic PWV and WMHV for participants younger (n=83) and for participants older (n=84) than the median age of 52.7 years. The data points illustrate the predicted WMHV vs the aortic PWV, adjusted for age, sex, and BV, and for younger and older participants separately. *P* values indicate the significance levels for the corresponding linear regression analyses (using log-transformed WMHV). Abbreviations as in Tables.

Tedavi

- Arteryal Sertlikte Kullanılan Tedaviler
  - ADEi, ARBs
  - Nitratlar
  - Diuretikler
  - Statinler
  - Aspirin
  - Beta Blokerler
  - Kalsiyum Kanal Blokerleri

- Umut Vadeden Tedaviler:
    - Endopeptidaz inhibitorleri (Omiprilait)
    - Fosfodiesteraz inhibitorleri (Sildenafil)
    - Glikolizasyon son ürün çapraz bağlarını koparan ilaçlar.

Sonuç

- Santral hemodinamik parametreler, mortalite ve kardiyovasküler prognozu etkiler
- Damar katılığı arttıkça hemodinamik parametreler değişir, sistolik kan basıncı, nabız basıncı ve nabız dalga hızı artar.
- Bu sistol sırasında kalbin iş yükünü artırırken diyastol sırasında kalbin beslenmesini bozar

Sonuç

- NDH birçok yöntemle, birçok alet kullanarak ve birçok yerden ölçülebilir. Ama altın standart yöntem Aortik NDH’nı ölçmektir.
- Artmış NDH birçok istenmeyen klinik durumla birliktedir.
- NDH Kan basıncından bağımsız olarak azaltılmasının morbidite ve mortaliteyi azaltıp azaltmayacağını gösteren çalışmalara ihtiyaç vardır.

Teşekkürler…