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Arterial Stiffness

Short-term changes in indices of arterial stiffness and compliance in patients undergoing EVAR of AAA

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Arterial stiffness

"describes the reduced capability of an artery to expand and contract in response to pressure changes"

main parameters

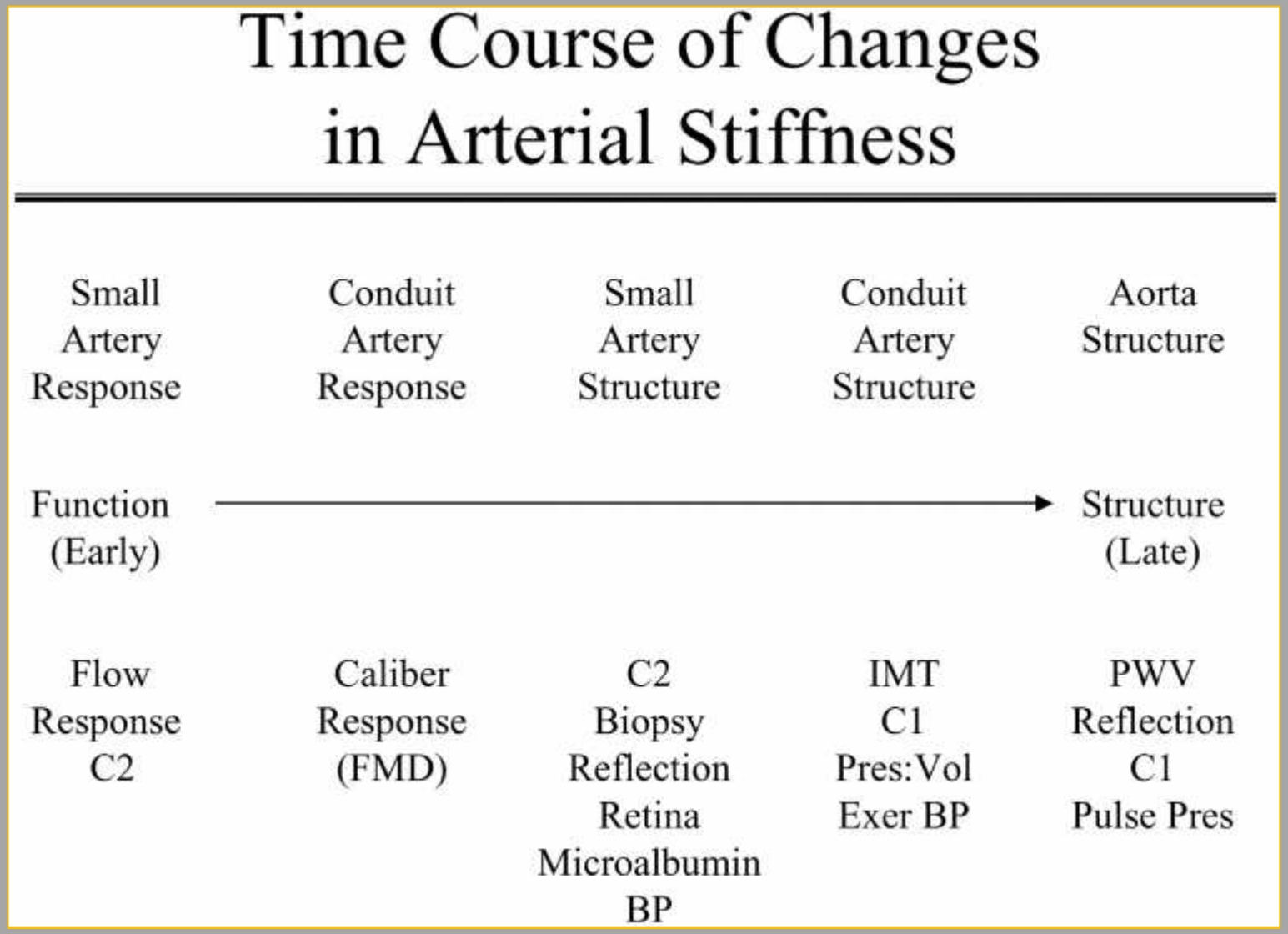
- ✓**Distensibility**
- ✓**Compliance**

$$\text{Distensibility} = \frac{2\,(Ds-Dd)/Dd}{SBP-DBP} \quad (N^{-1}.\,M^{2})$$

$$\text{Arterial Compliance} = \frac{(Ds-Dd)}{2\,(SBP-DBP)} \quad \pi\,Dd\,(N^{-1}.\,M^{4})$$

Marina Cecelja , Phil Chowienczyk
Role of arterial stiffness in cardiovascular disease
J R Soc Med Cardiovasc Dis 2012;1:11

Time Course of Changes in Arterial Stiffness



Flow response indicates response to acetylcholine; **reflection**, augmentation index; **retina**, retinal vasculature; **Pres: Vol**, pressure/volume relationship of a single artery; **Exer BP**, blood pressure rise in response to programmed exercise test;

Cohn J N et al. Hypertension 2005;46:217-220

Arterial stiffness

What is known

- ***European Guidelines for the diagnosis and treatment of hypertension*** ***suggest that aPWV>12m/s is a marker of target organ damage***
- Aortic stiffness expressed as ***aortic PWV*** **is** ***a strong predictor of future CV events and all-cause mortality*** (The predictive ability of arterial stiffness is higher in subjects with a higher baseline CV risk)
- Arterial stiffness, as measured by **carotid-femoral PWV**, ***is an independent predictor of cardiovascular morbidity and mortality*** in ***hypertensive patients, type 2 diabetes, end-stage renal disease and in elderly populations***
- Arterial stiffness has been ***correlated with long-term cardiovascular outcomes*** ***independent of traditional cardiovascular risk factors*** (e.g. hypertension, diabetes, obesity, dyslipidemia, smoking)

Hypertension 2010 Jun;55(6):e22;
Aortic pulse wave velocity may have prognostic value not just for hypertension but also for abdominal aortic aneurysms.
Paraskevas KI, Kyriakides ZS, Mikhailidis DP

Cecelja M, Chowienczyk P.
Dissociation of aortic pulse wave velocity with risk factors for cardiovascular disease other than hypertension: a systematic review.
Hypertension. 2009 Dec;54(6):1328-36.

Vlachopoulos C. et al.
Aortic Stiffness for Cardiovascular Risk Prediction
JACC Vol. 63, No. 7, February 25, 2014:647–9

Vlachopoulos et al.
Arterial Stiffness and Clinical Events
JACC Vol. 55, No. 13, 2010 March 30, 2010:1318–27

Abdominal Aortic Aneurysm (AAA)

- Aortic diameter >3cm (or >50% of normal range)
- A potential life threatening situation
  - Mainly asymptomatic
  - Serious complications (rupture, thromvosis, embolization)
- Well-established risk factors

  (Age – Male gender - FH – Smoking – Hypertension – Hyperlipidemia)
- Atherosclerosis and weakening of the aortic wall as a result of a change in arterial wall structural components are responsible for the pathogenesis of AAA. *These factors associated with AAA development also increase* ***arterial stiffness.***

Lederle FA et al **Relationship of age, gender, race, and body size to infrarenal aortic diameter. The Aneurysm Detection and Management (ADAM) Veterans Affairs Cooperative Study Investigators.** J Vasc Surg 1997; 26: 595-601.
Collin J et al **Oxford screening program for abdominal aortic aneurysm in men aged 65 to 74 years**. Lancet 1988; 2: 613-615.
Lederle FA et **al.Prevalence and associations of abdominal aortic aneurysm detected through screening.** Ann Intern Med 1997; 126:441–449.
Ernst CB. **Abdominal aortic aneurysm.** N Engl J Med 1993; 328: 1167-1172.
Salo JA et al **Familial occurrence of abdominal aortic aneurysm.** Ann Intern Med 1999; 130: 637-642.

Purpose

- Endovascular repair (EVAR) with stent-grafts is a well established treatment of AAA
- *May stent-graft placement cause changes in aortic stiffness within a very short time?*
  - Does the choice of stent-graft type (fabric) affect the magnitude of this effect?
- **The aim was to assess the short-term impact of endograft implantation on arterial stiffness indices in patients undergoing AAA repair (EVAR)**

Methods

- Prospective study
- Consecutive patients with AAA , n=***45***
  - aged 72±7 years
  - **89%** males
- EVAR , using two types of stent grafts
  - **Dacron**
  - **ePTFE** (expanded polytetrafluoroethylene)

Methods

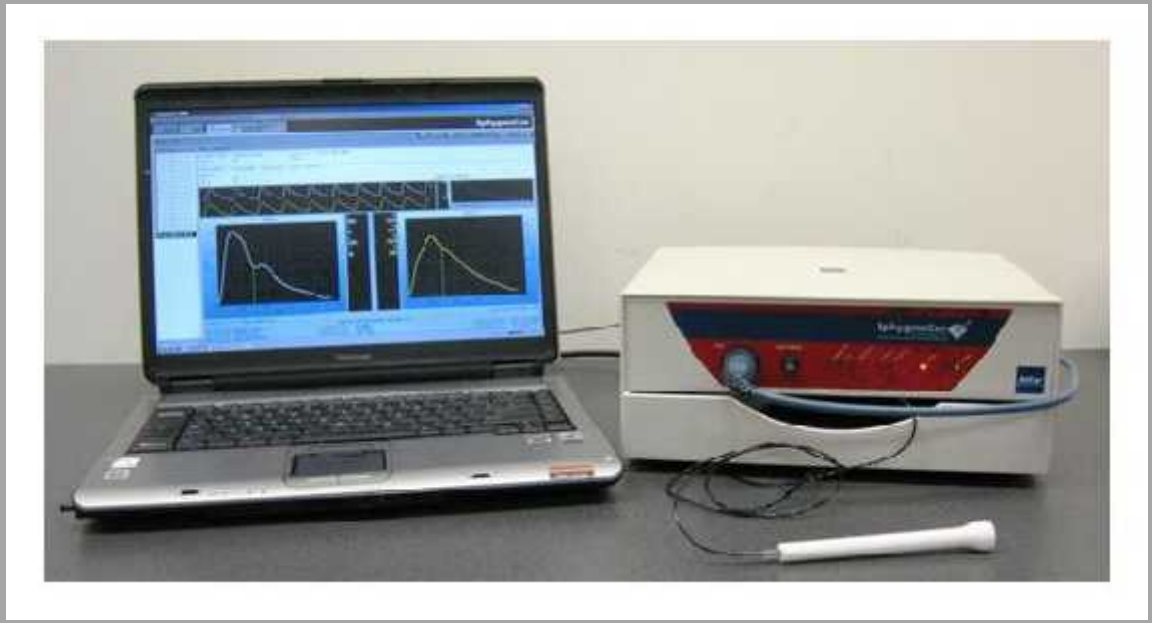
Performing a series of tests measuring arterial stiffness including:

mainly {
- ***PWV (Pulse Wave Velocity)*** *using Sphygmocor*
- ***AIx (Augmentation Index)*** *using Sphygmocor*

- ***CASP (Central Aortic Systolic Pressures)***
- ***ABI (Ankle-Brachial Index)***
- ***C1 & C2 (large & small conduits elasticity indices)*** *using HDI PW CR-2000*

Flow chart

- ✓ Two days before EVAR (baseline)
- ✓ One (1) month after EVAR (follow up)



Sphygmocor

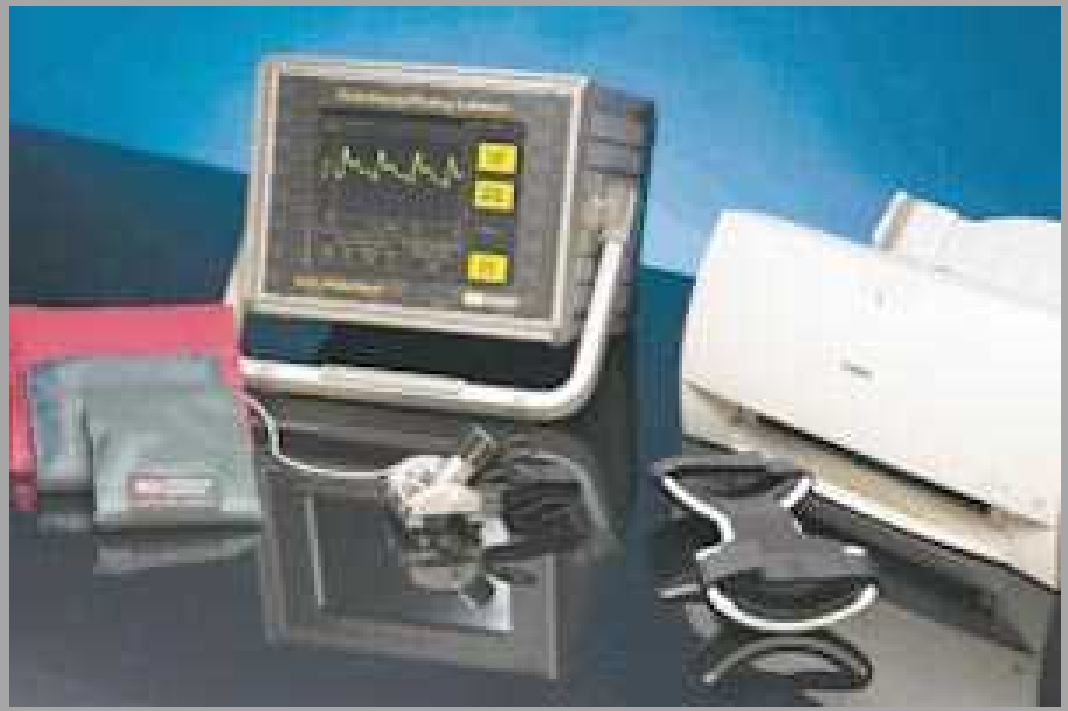
(tonometer)

PWV – PWA

HDI PW CR-2000

(modif. Windkessel effect)

Systemic Stiffness - SVR



Characteristics of patients undergoing EVAR

AAA patients undergoing EVAR			
	Baseline	**Follow-Up**	**P-value**
Age, years	72 ± 7		
Glucose, mg/dl	114 ± 26		
eGFR, ml/min/1.73 m^2	76 ± 26		
Total cholesterol, mg/dl	179 ± 55		
Non-HDL, mg/dl	130 ± 49		
Body mass index, kg/m^2	28.2 ± 3.6	27.6 ± 3.4	***0.008***
SBP, mmHg	134 ± 18	129 ± 14	0.095
DBP, mmHg	78 ± 13	71 ± 7	***0.002***
AIx, %	27.0 ± 7.3	25.3 ± 7.5	0.218
Central PP, mmHg	47 ± 12	45 ± 12	0.421
ABI	0.98 ± 0.14	0.98 ± 0.15	0.694
C1, ml/mmHg	12.6 ± 4.6	11.8 ± 4.6	0.276
C2, ml/mmHg	3.1 ± 1.2	3.4 ± 1.2	0.152

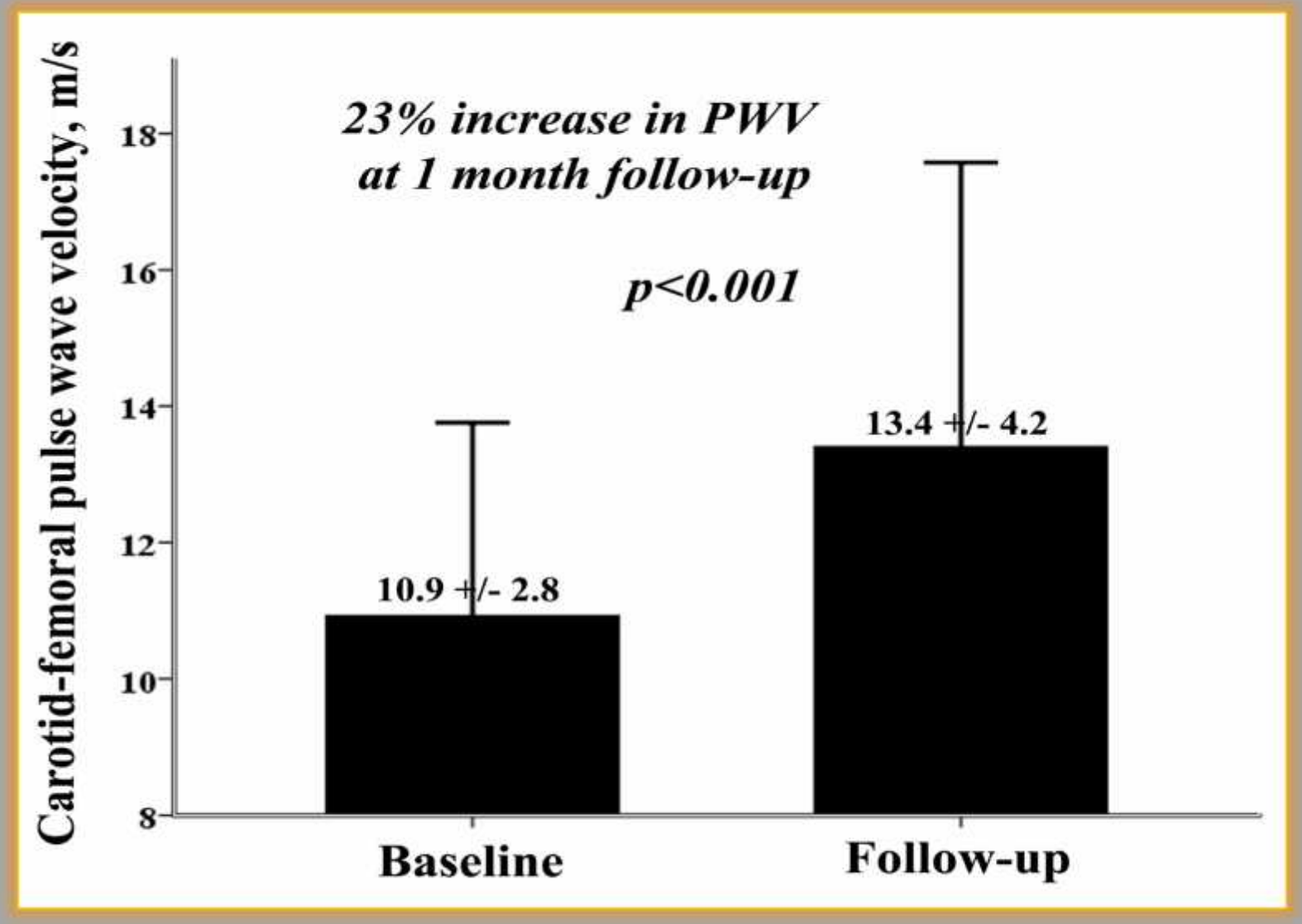
Results

Patients characteristics

- 91% hypertension , 87% hypercholesterolemia
- 33% diabetes
- 33% current smokers
- 20% concomitant TAA, 11% sCAD, 4% stroke history

At 1 month after EVAR, **BMI** and **diastolic blood pressure (BP)** decreased *($p<0.01$ for both)* compared to pre-EVAR

Results


Carotid-femoral pulse wave velocity, m/s
18
16
14
12
10
8
23% increase in PWV
at 1 month follow-up
p<0.001
10.9 +/- 2.8
13.4 +/- 4.2
Baseline
Follow-up

Results

- Higher aPWV at 1 month follow up

  10.9±2.8 vs 13.4±4.2 m/s

  (p<0.001)

- A greater increase in PWV at follow-up was observed in
  - smokers

    (p=0.045, RMANOVA)
  - patients with greater increase in systolic BP at follow-up

    (p=0.046, RMANOVA)
  - patients with higher glucose levels at baseline

    (p=0.034, RMANOVA)

- No significant changes were observed in AIx, cPP, LAEI or SAEI

  (p>0.1 for all)

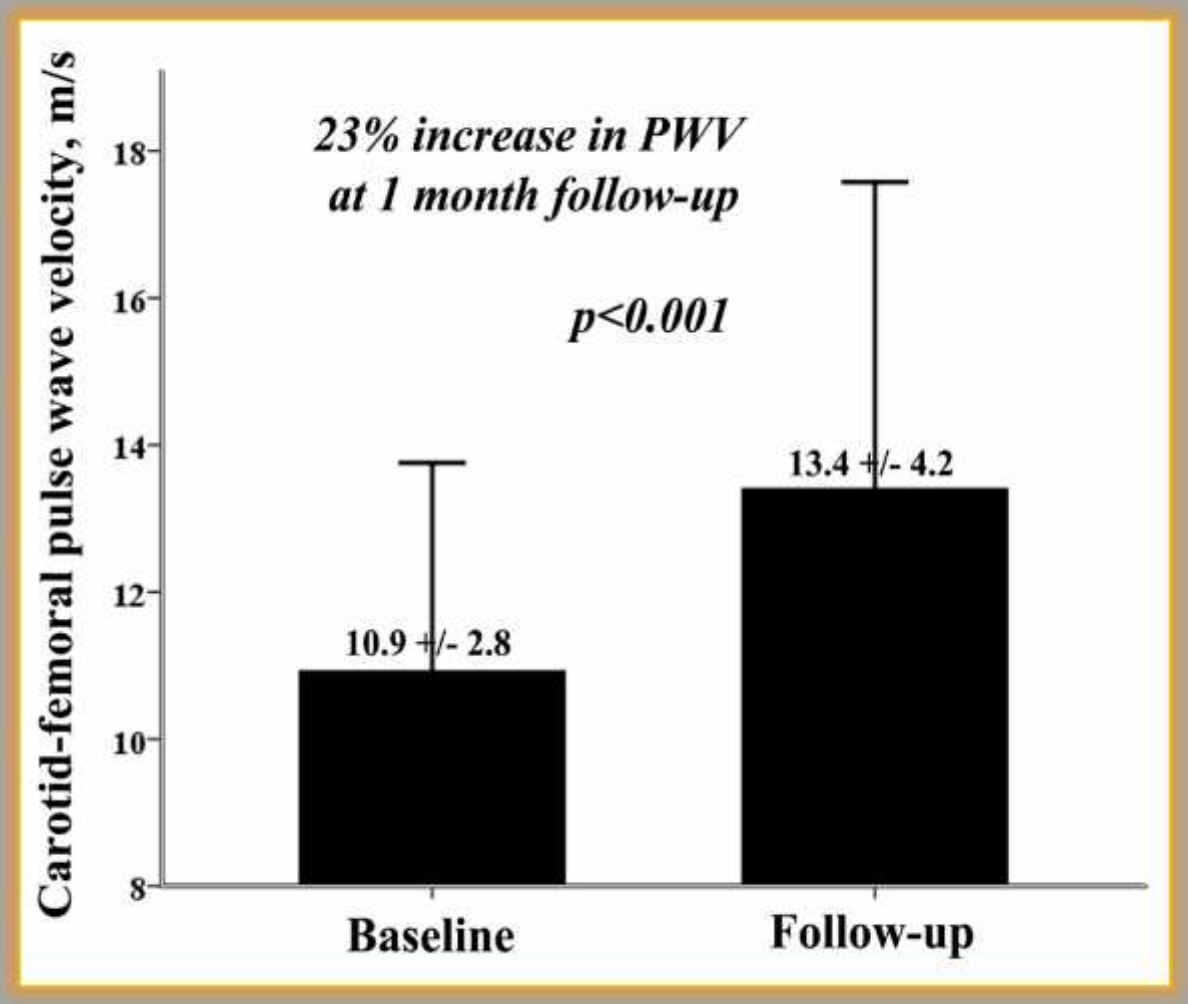
Results

- stent graft type received,
  - Dacron ***47%***
  - ePTFE ***53%***

- **There was no difference in PWV changes at follow-up according to endograft type**

(p=0.166)

Results



Interaction analysis

- No differences according to endograft type (*Dacron vs ePTFE*)
- Greater increase in smokers, higher baseline glucose and patients that increased SBP at follow-up

Is there any clinical significance of the arterial stiffness increase after EVAR ?

- Is it the type of the graft or only the presence of graft that has an effect on arterial stiffness?
  - ✓ The effect of graft type in EVAR procedure requires further investigation
  - ✓ Especially the long-term effect has yet to be evaluated

- *Effect of alterations on cardiac structure and function?*
  - ✓ EVAR increased vascular stiffness and induced LVH without elevating BP in the short-term postoperative period
    (Takeda Y et al Circ J 2014)
  - ✓ Although endograft is considered to be a minimally invasive procedure, it may have serious long-term effects on the cardiovascular system and should be included in the risk factors
    (Liapis C. et al. Phlevology Forum 2014 - CACVS 2014)

Is there any clinical significance of the arterial stiffness increase after EVAR ?

- *Is there any correlation with AAA diameter and rupture risk?*
  - ✓ carotid-femoral PWV is negatively correlated with aortic diameter

    (Bailey, Hypertension Research 2014)

    (Paraskevas KI et al. Open Cardiovasc Med J. 2009)
  - ✓ size alone may not be a sufficient criterion to determine AAA rupture risk
  - ✓ A low aortic PWV preoperatively has been associated with an increased rupture risk

    (Paraskevas KI et al. Open Cardiovasc Med J. 2009)

Conclusions

- **EVAR of AAA resulted in a significant increase of aortic stiffness, *as assessed by higher aortic PWV at 1 month*, independent of the stent-graft type (Dacron, ePTFE)**
- ***Central hemodynamics, reflected waves and vascular compliance did not change* in the short term after EVAR**
- **Smoking, higher glucose and concomitant increase in systolic BP at follow-up were associated with *a greater increase in PWV after EVAR***
- **The pathophysiological importance, prognostic role and longer-term temporal evolution of these changes need further research**

Thank you for your attention

Changes in arterial stiffness in AAA patients compared to age-matched healthy controls

Table 4 Distribution of pulse wave velocity (m/s) according to the age category in the normal values population (1455 subjects)

Age category (years)	Mean (±2 SD)	Median (10–90 pc)
<30	6.2 (4.7–7.6)	6.1 (5.3–7.1)
30–39	6.5 (3.8–9.2)	6.4 (5.2–8.0)
40–49	7.2 (4.6–9.8)	6.9 (5.9–8.6)
50–59	8.3 (4.5–12.1)	8.1 (6.3–10.0)
60–69	10.3 (5.5–15.0)	9.7 (7.9–13.1)
≥70	10.9 (5.5–16.3)	10.6 (8.0–14.6)

SD, standard deviation; 10 pc, the upper limit of the 10th percentile; 90 pc, the lower limit of the 90th percentile.

Determinants of pulse wave velocity in healthy people and in the presence of cardiovascular risk factors: 'establishing normal and reference values' The Reference Values for Arterial Stiffness

P. Boutouyrie and S.J. Vermeersch - *European Heart Journal (2010) 31, 2338–2350*

Changes in arterial stiffness in AAA patients compared to age-matched healthy controls

Table 5 Distribution of pulse wave velocity (PWV) values (m/s) in the reference value population (11 092 subjects) according to age and blood pressure category

Age category (years)	Blood pressure category				
	Optimal	Normal	High normal	Grade I HT	Grade II/III HT
PWV as mean (±2 SD)					
<30	6.1 (4.6–7.5)	6.6 (4.9–8.2)	6.8 (5.1–8.5)	7.4 (4.6–10.1)	7.7 (4.4–11.0)
30–39	6.6 (4.4–8.9)	6.8 (4.2–9.4)	7.1 (4.5–9.7)	7.3 (4.0–10.7)	8.2 (3.3–13.0)
40–49	7.0 (4.5–9.6)	7.5 (5.1–10.0)	7.9 (5.2–10.7)	8.6 (5.1–12.0)	9.8 (3.8–15.7)
50–59	7.6 (4.8–10.5)	8.4 (5.1–11.7)	8.8 (4.8–12.8)	9.6 (4.9–14.3)	10.5 (4.1–16.8)
60–69	9.1 (5.2–12.9)	9.7 (5.7–13.6)	10.3 (5.5–15.1)	11.1 (6.1–16.2)	12.2 (5.7–18.6)
≥70	10.4 (5.2–15.6)	11.7 (6.0–17.5)	11.8 (5.7–17.9)	12.9 (6.9–18.9)	14.0 (7.4–20.6)
PWV as median (10–90 pc)					
<30	6.0 (5.2–7.0)	6.4 (5.7–7.5)	6.7 (5.8–7.9)	7.2 (5.7–9.3)	7.6 (5.9–9.9)
30–39	6.5 (5.4–7.9)	6.7 (5.3–8.2)	7.0 (5.5–8.8)	7.2 (5.5–9.3)	7.6 (5.8–11.2)
40–49	6.8 (5.8–8.5)	7.4 (6.2–9.0)	7.7 (6.5–9.5)	8.1 (6.8–10.8)	9.2 (7.1–13.2)
50–59	7.5 (6.2–9.2)	8.1 (6.7–10.4)	8.4 (7.0–11.3)	9.2 (7.2–12.5)	9.7 (7.4–14.9)
60–69	8.7 (7.0–11.4)	9.3 (7.6–12.2)	9.8 (7.9–13.2)	10.7 (8.4–14.1)	12.0 (8.5–16.5)
≥70	10.1 (7.6–13.8)	11.1 (8.6–15.5)	11.2 (8.6–15.8)	12.7 (9.3–16.7)	13.5 (10.3–18.2)

SD, standard deviation, 10 pc, the upper limit of the 10th percentile, 90 pc, the lower limit of the 90th percentile; HT, hypertension.

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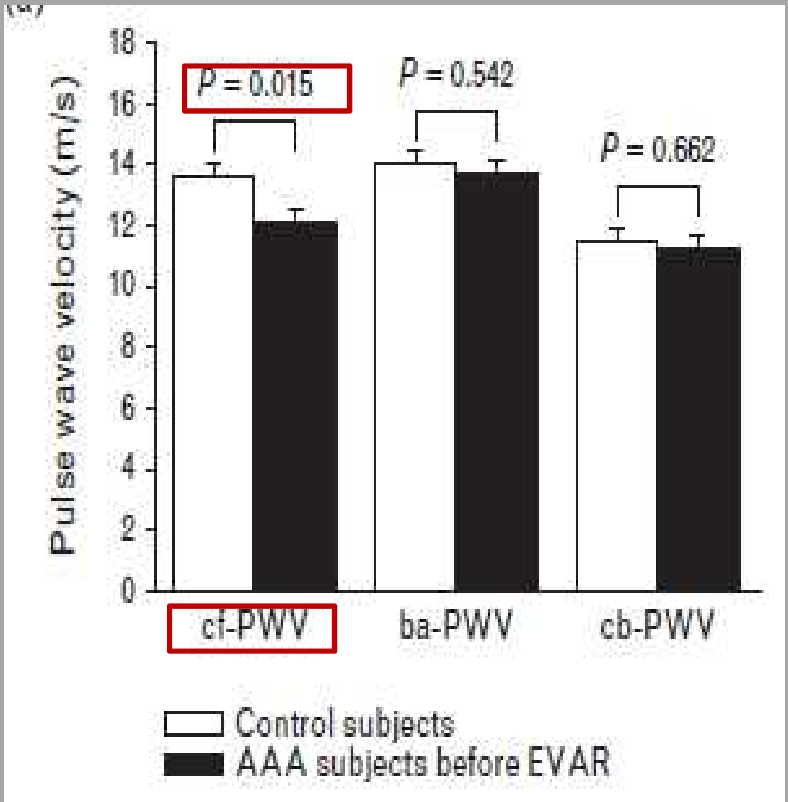

aneurysm repair

	Patients with AAA, n = 51			Control group, n = 51	
	Before EVAR	After EVAR	P	Controls	P*
Brachial SBP (mmHg)	135 ± 18	128 ± 17	0.020	134 ± 17	0.668
Brachial DBP (mmHg)	77 ± 8	77 ± 10	<0.001	75 ± 11	0.406
Brachial MBP (mmHg)	96 ± 10	93 ± 11	0.001	95 ± 12	0.478
Brachial PP (mmHg)	58 ± 15	57 ± 12	0.417	58 ± 13	0.943
Heart rate (beats/min)	65.7 ± 10.7	72.6 ± 11.9	<0.001	66.4 ± 11.7	0.498
Carotid SBP (mmHg)	124 ± 17	118 ± 15	0.013	125 ± 17	0.833
Carotid DBP (mmHg)	79 ± 8	78 ± 9	<0.001	78 ± 11	0.685
Carotid PP (mmHg)	46 ± 14	44 ± 9	0.275	47 ± 12	0.550
PP amplification	0.78 ± 0.07	0.77 ± 0.06	0.520	0.80 ± 0.09	0.092
cf-PWV (m/s)	12 ± 2.7	14.4 ± 3.8	<0.001	13.6 ± 3.5	0.009
ba-PWV (m/s)	15.7 ± 2.3	16.2 ± 2.5	0.224	14.0 ± 2.9	0.795
cb-PWV (m/s)	11.3 ± 1.4	10.8 ± 1.1	0.028	11.4 ± 1.8	0.889
cAI (%)	30.8 ± 12.2	26.4 ± 14.5	0.024	23.1 ± 23.3	0.040
cAI_{HR} (%)	26.7 ± 10.8	23.4 ± 13.6	0.103	19.7 ± 22.3	0.047
cAP (mmHg)	15 ± 8	11 ± 6	0.005	13 ± 7	0.292
Pf (mmHg)	32 ± 8	30 ± 10	0.295	34 ± 9	0.261
Pb (mmHg)	18 ± 6	18 ± 6	0.860	18 ± 5	0.774
RWTT (ms)	38 ± 10	40 ± 9	0.152	35 ± 16	0.401

AAA, abdominal aortic aneurysm; cAI, carotid augmentation index; cAI_{HR}, heart rate adjusted cAI at 75/min; cAP, carotid augmented pressure; ba-PWV, brachial–ankle pulse wave velocity; cb-PWV, carotid–brachial pulse wave velocity; cf-PWV, carotid–femoral pulse wave velocity; EVAR, endovascular aneurysm repair; Pf and Pb, forward and backward pressure wave amplitudes from the decomposed carotid pressure wave; PP, pulse pressure; RWTT, reflected wave transit time.
*Comparisons with AAA individuals before EVAR.

Changes in arterial stiffness in AAA patients compared to age-matched healthy controls

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''mask effect''= lower value of PWV in AAA does not reflect the real arterial stiffness

reason?

Probably the lack of stiffness

in the AAA segment of aorta because of

anatomical and structural variations