The impact of ventricular-arterial coupling in cardiovascular diseases and therapeutic means for improvement

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ventricular-arterial coupling

- interaction between left ventricle (LV) and arterial system
- key determinant of global cardiovascular performance.
- investigating the properties of LV itself and the modulating role of the arterial system on LV performance and cardiac energetics.
- **Ventricular elastance (Ees)**
  \[ E_{LV} = \frac{ESP}{ESV} \text{ (ESV LV end-systolic volume)} \]
- **Arterial elastance (Ea)**
  \[ E_A = \frac{ESP}{SV} \text{ (SV stroke volume)} \]
- When \( EA/EES \approx 1.0 \), LV and arterial system are optimally coupled.
- When \( EA/EES \) ratio is <1.0, the stroke work remains close to optimal values
- but when \( EA/EES \) ratio is >1.0, the stroke work significantly falls and the LV becomes progressively less efficient.

Markers of arterial function
- Aortic characteristic impedance ($Z_c$)
- Aortic distensibility
- Beta stiffness index
- Large artery stiffness (aortic PWV)

Markers of myocardial performance
- TDI
- 2D speckle tracking
- 3D speckle tracking
Calculating ventricular-arterial coupling

EA = ESP/SV, EES = ESP/ESV
VAC=EA/EES = (ESP/SV)/(ESP/ESV)
VAC=EA/EES = ESV/SV

EA = (SBP × 0.9)/SV
EES = (DBP − (E_{nd(est)}× SBP × 0.9))/E_{nd(est)}× SV

systolic and diastolic blood pressures
stroke volume, ejection fraction, preejection and total systolic period

Redefining ventricular-arterial coupling (1)

Vecera J et al 2016 European Heart Journal – Cardiovascular Imaging
Boe E et al 2015 European Heart Journal – Cardiovascular Imaging
Conclusions: Pulse wave velocity to global longitudinal strain ratio but not the echocardiography derived arterial elastance to left ventricular elastance index is related to impaired carotid-intima media thickness, coronary-flow reserve and diastolic function in hypertensives.

Ikonomidis, I., Katsanos, S., Triantafyllidi, H., Parissis, J., Tzortzis, S., Pavlidis, G., ... Iliodromitis, E. (2018). Pulse wave velocity to global longitudinal strain ratio in hypertension. European Journal of Clinical Investigation,
Clinical applications of single beat VAC

<table>
<thead>
<tr>
<th>Study</th>
<th>Population</th>
<th>N</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mehra et al., (2004)</td>
<td>Heart transplant recipients</td>
<td>40</td>
<td>Elevation in BNP is explained by ventricular-arterial uncoupling</td>
</tr>
<tr>
<td>Osranek et al., (2008)</td>
<td>HTN patients</td>
<td>18</td>
<td>Treatment of hypertension determines a net increase in mechanical efficiency</td>
</tr>
<tr>
<td>Antonini-Canterin et al., (2009)</td>
<td>Patients with a history of myocardial infarction</td>
<td>41</td>
<td>EA/EES ratio is an independent correlate of BNP levels and predicts long-term cardiovascular mortality</td>
</tr>
<tr>
<td>Young Her et al., (2009)</td>
<td>Dilated cardiomyopathy, hypertensive patients, and marathon runners</td>
<td>25</td>
<td>EA/EES ratio and diastolic elastance seem reliable predictors of exercise capacity</td>
</tr>
<tr>
<td>Zanon et al., (2009)</td>
<td>Patients eligible to CRT</td>
<td>78</td>
<td>High EA/EES ratio is a predictor of responsiveness to cardiac resynchronization therapy, especially in nonischemic patients</td>
</tr>
<tr>
<td>Authors</td>
<td>Subjects with cardiovascular risk factors</td>
<td>Patients</td>
<td>Findings</td>
</tr>
<tr>
<td>------------------</td>
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<tr>
<td>Miyoshi et al., (2011)</td>
<td>Impaired left atrial and left ventricular relaxation in the longitudinal direction, evaluated by speckle tracking analysis, are early signs of abnormal left atrial-left ventricular-arterial coupling</td>
<td>64 patients</td>
<td></td>
</tr>
<tr>
<td>Lam et al., (2013)</td>
<td>Hypertensive patients with diastolic dysfunction and normal systolic function</td>
<td>527 patients</td>
<td>Reduction of EA/EES is related to the degree of blood pressure lowering, in parallel with reductions in LV mass, concentric remodeling and BNP levels</td>
</tr>
<tr>
<td>Reil et al., (2013)</td>
<td>Patients with systolic heart failure (EF ≥ 35%) from the SHIFT trial</td>
<td>275 patients</td>
<td>Reduction of heart rate with ivabradine causes a reduction of EA/EES, mainly due to the reduction of EA as a consequence of decreased vascular pulsatile load</td>
</tr>
<tr>
<td>Guarracino et al., (2013)</td>
<td>Patients selected for MitraClip procedure</td>
<td>18 patients</td>
<td>MitraClip procedure does not deteriorate EA/EES ratio, despite a reduction in ejection fraction</td>
</tr>
<tr>
<td>Lancellotti et al., (2010)</td>
<td>Asymptomatic severe aortic stenosis and normal systolic function</td>
<td>163 patients</td>
<td>Valvular-arterial impedance (Zva) emerged as a relevant determinant of disease progression</td>
</tr>
<tr>
<td>Hachicha et al., (2009)</td>
<td>Asymptomatic moderate-to-severe aortic stenosis</td>
<td>544 patients</td>
<td>The level of Zva was indirectly related to their survival at a median follow-up of 2.1 years</td>
</tr>
</tbody>
</table>
AVC changes after antihypertensive monotherapy

Iakovou et al 2003 International journal of cardiology
At week 12, sacubitril/valsartan reduced central aortic systolic pressure to a greater extent than olmesartan by $-3.7$ mmHg. After 52 weeks, more patients required add-on antihypertensive therapy with olmesartan (47%) vs. sacubitril/valsartan (32%).

VAC in HFrEF

- Wohlfahrt P, Melenovs ky V, Redfield MM. *Aortic waveform analysis to individualize treatment in heart failure.* Circ Heart Fail 2017;10

- ....
Hemodynamic effects of long-term cardiac resynchronization therapy: analysis by pressure-volume loops.

Ventricular-arterial coupling in patients with heart failure treated with cardiac resynchronization therapy: may we predict the long-term clinical response?

a cut-off value of 2 may identify 88% of responders to CRT as evaluated through the QoL and 69% of responders as defined through ESV.

Zanon et al 2009, European journal of Echocardiography
CRT ACUETELY REDUCES ARTERIAL LOAD

PAOLO PIERAGNOLI et al 2015, PACE
Effects of Cardiac Resynchronization Therapy on Cardiac Remodeling and Contractile Function: Results From Resynchronization Reverses Remodeling in Systolic Left Ventricular Dysfunction (REVERSE)

Martin St. John Sutton, MBBS; Jeffrey Cerkvenik, MS; Barry A. Borlaug, MD; Claude Daubert, MD; Michael R. Gold, MD, PhD; Stefano Ghio, MD; Julio A. Chirinos, MD, PhD; Cecilia Linde, MD; Bonnie Ky, MD, MSCE

<table>
<thead>
<tr>
<th>Clinical or Echocardiographic Parameter</th>
<th>CRT OFF (n=191)</th>
<th>CRT ON (n=419)</th>
<th>All Patients (n=610)</th>
<th>Normal Values*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ea/Ees_{sb}</td>
<td>2.4 (1.1)</td>
<td>2.3 (0.8)</td>
<td>2.3 (1.0)</td>
<td>0.69 (0.15)</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>CRT OFF</th>
<th>CRT ON</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>Baseline</td>
<td>6-Month</td>
</tr>
<tr>
<td>Ea/Ees_{sb}</td>
<td>150</td>
<td>2.47</td>
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</table>
Pressure-Volume Loop Analysis of Multipoint Pacing With a Quadripolar Left Ventricular Lead in Cardiac Resynchronization Therapy

Wouter M. van Everdingen, MD, PhD, a Alwin Zweerink, MD, b Odette A.E. Salden, MD, a Maarten J. Cramer, MD, PhD, a Pieter A. Doevendans, MD, PhD, a Elien B. Engels, PhD, a Albert C. van Rossum, MD, PhD, b Frits W. Prinzen, PhD, c Kevin Vernooy, MD, PhD, d Cornelis P. Allaart, MD, PhD, b Mathias Meine, MD, PhD a
68 years old male patient
Non-ischemic
Pre CRT
ECG SR LBBB QRS 168ms
LVEF 35% LVESV 112 ml
Sep to lateral delay 120ms
Ea/Ees 1.86
GLS -7.1%
cfPWV/GLS 1.90
3 months after CRT

ECG SR QRS 128ms
LVEF 44% LVESV 72 ml
Sep to lateral delay 20ms
Ea/Ees 1,27
GLS -10.8%
cfPWV/GLS 0.96
Myocardial work pre and after CRT

GWE 65%

GWE 75%
• 47 years old male patient
• Non-ischemic
• Pre CRT

• ECG SR LBBB QRS 156ms
• LVEF 33% LVESV 108 ml
• Sep to lateral delay 70ms
• Ea/Ees 2,03
• GLS -9,3%
• cfPWV/GLS 0,91
After CRT
ECG SRQRS 132ms
LVEF 48% LVESV 65 ml
Sep to lateral delay 20ms
Ea/Ees 1.08
GLS -14.1%
cfPWV/GLS 0.60
Myocardial work pre and after CRT

GWE 71%

GWE 88%
Background: Endothelial dysfunction (ED) is a hallmark of chronic heart failure (CHF) and has been related with disease progression, increase in hospitalizations and mortality. Purpose: to evaluate the impact of Cardiac resynchronization therapy (CRT) in ED and to determine predictors of response to CRT

Karamichalakis N, Ikonomidis I, Parissis J et al. To be published
VAC in HFpEF

- ...
ventricular-arterial coupling in inflammatory diseases
Take home messages

• VAC provides insight and diagnostic and prognostic value in cardiac diseases
• Traditional and novel approaches can be used to describe better the mechanics and energetics in arterial function and myocardial performance
• VAC guided therapies can be applied to improve each component
• VAC guided therapies can improve clinical and functional status and delay the progression to HF
• Further studies are required
Οργάνωση:
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Λάμπρος Κ. Μιχάλης

Σύγχρονες Μέθοδοι Πρόληψης,
Τεχνικές Απεικόνισης & Θεραπείες,
Παρουσίαση Περιπτώσεων

30 Μαρτίου 2019
CROWNE PLAZA ATHENS CITY CENTRE HOTEL ΑΘΗΝΑ
3ο ΣΕΜΙΝΑΡΙΟ
Εξειδικευμένων Χωκαρδιογραφικών Τεχνικών

Δυναμική (Stress Echo)
Χωκαρδιογραφία & Αντίθεος (Contrast Echo)
Εφαρμογές στην κλινική πράξη

19-20 Απριλίου 2019
Κεντρικό Αμφιθέατρο
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Ελληνικό Κολλέγιο Καρδιολόγων

Διανομένος
ΜΑΣΤΕΡΜΙΝΟ

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Ελληνικού Κολλεγίου Καρδιολογίας

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Konstantinos P. Toutouzas
Dimitris I. Karmpaliotis

Cardio-Cath
Meeting 2019
Live Demonstration Course

27-29 Ιουνίου/June
2019

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Ευχαριστώ για την προσοχή σας!