Enhanced External Counterpulsation (EECP)-
Role in Management of Heart Failure

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History of External Counterpulsation

1950’s:  - Kantrowitz Brothers - diastolic augmentation
         - Sarnoff - LV unloading
         - Birtwell - combined concepts
         - Gorlin - defined counterpulsation

1960’s:  - Birtwell & Soroff - Dennis- Osborne – hydraulic external counterpulsation

1970’s:  - Soroff - cardiogenic shock
         - Banas - stable angina
         - Amsterdam - acute MI

1980’s:  - Failure to gain acceptance
         - China; redeveloped technology- pneumatic system
         - Soroff, Hui, Zheng collaboration at Stony Brook
Early external counterpulsation devices had hydraulic pulsator chambers.
• In the early 1980’s, a Chinese group lead by Z.S. Zheng redeveloped technology - pneumatic system

• Their positive clinical experience led to the installation of more than 1500 external counterpulsation units in China
EECP-Pneumatic device
EECP-Mechanism

• Involves the use of three paired inflatable cuffs wrapped around the patient’s lower extremities
• The patient is connected to an ECG monitor and a finger plethysmograph
• Pressures in the range of 250-275 mmHg applied
• Treatment course consists of 35 one-hour sessions 1 hour per day over 7 weeks
The cuffs are sequentially inflated (calves \(\rightarrow\) lower thighs \(\rightarrow\) upper thighs) during diastole.
The R wave of the ECG is used as the trigger for inflation and deflation.
All pressure is released at the onset of systole
• ↑ diastolic pressure
• ↑ intracoronary perfusion pressure
• ↑ myocardial perfusion
• ↑ venous return
• ↑ preload
• ↑ cardiac output

• ↓ systemic vascular resistance
• ↓ cardiac workload
• ↓ myocardial O₂ consumption
• ↓ afterload
Intra-Aortic Balloon Pump

- Deflation
- Inflation
- Systole
- Diastole

Arterial Pressure

- Standby
- Counter pulsation

Increased Venous Return

Diastolic Augmentation

Improve LV Diastolic Filling

Systolic Unloading
Mechanism of Effect in angina & HF

EECP believed to increase the development of collateral circulation resulting in improved myocardial perfusion

Chronic exposure to EECP increases shear stress in the coronary circulation

Shear stress results in a cascade of growth factors which stimulate angiogenesis

Increased transmyocardial pressure open collaterals
EECP is a recently approved treatment modality for selected patients with Heart failure
Indications for EECP Therapy

A. **Chronic CAD**
   Primary utilization of EECP to revascularize Anginal Patient refractory to Medical treatment

B. **Surgery /PTCA not contemplated**
   - Patient refused
   - Diffuse distal disease.
   - Target lesion is inaccessible.
   - Co-morbid states create high risk
   - LV dysfunction – High risk CABG.
   - Restenosis after PTCA
   - CABG graft occlusion

C. **Preparation for Revascularization**
   - Severe LV Dysfunction with lot of hibernation to stabilize Heart Function.
   - Waiting due to some other reason.

D. **Heart Failure**
   - Non-Ischemic Cardiomyopathy
   - Ischemic Cardiomyopathy
   - Patient with LV Dysfunction
   - Patient with moderate to severe levels of CHF.

E. **Cardiac X Syndrome**
• The first multicenter randomized sham-controlled trial was the MUlticenter STudy of Enhanced External CounterPulsation (MUST-EECP)

• MUST-EECP compared full EECP treatment –vs- sham on exercise treadmill scores and subjective angina
Follow-up analysis of patients in the MUST-EECP trial at 1 yr showed greater improvement in the health-related quality of life measures in the active treatment group.
## Published Controlled & Uncontrolled Trials of EECP® Therapy in Patients With Stable Angina

<table>
<thead>
<tr>
<th>Study (Ref.)</th>
<th>Year</th>
<th>N</th>
<th>Treatment Duration (h)</th>
<th>Angina (% ≥1 CCS)*2</th>
<th>Nitrate Use</th>
<th>Exercise Tolerance</th>
<th>Time to ST Depression</th>
<th>Cardiac Perfusion (%)*</th>
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<tbody>
<tr>
<td>Lawson et al.</td>
<td>1998</td>
<td>60</td>
<td>35</td>
<td>↓</td>
<td></td>
<td>↑</td>
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<td>↑ (75)</td>
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<td>Arora et al.</td>
<td>1999</td>
<td>139</td>
<td>35</td>
<td>↓</td>
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<td>↑</td>
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<td>Lawson et al.</td>
<td>2000</td>
<td>33</td>
<td>35-36</td>
<td>↓</td>
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<td>↑ (79)</td>
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<tr>
<td>Lawson et al.</td>
<td>2000</td>
<td>2,289</td>
<td>35</td>
<td>↓(74)*</td>
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<td>Urano et al.</td>
<td>2001</td>
<td>12</td>
<td>35</td>
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<td>Masuda et al.</td>
<td>2001</td>
<td>11</td>
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<td>Stys et al.</td>
<td>2001</td>
<td>395</td>
<td>35</td>
<td>↓(88)*</td>
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<td>Barsness et al.</td>
<td>2001</td>
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<td>↓(81)*</td>
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<td>Stys et al.</td>
<td>2002</td>
<td>175</td>
<td>35</td>
<td>↓(85)</td>
<td></td>
<td>↑</td>
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<td>↑ (83)</td>
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</tbody>
</table>

1 Adapted from Bonetti, et al

* % of patients for whom this criterion applies are listed in parentheses.

** CCS = Canadian Cardiovascular Society

↓ = Reduced, ↑ = Increased
In January 1998, Phase 1 of the International EECP Patient Registry (IEPR) was established to document patient characteristics, safety, efficacy, and long-term outcomes of EECP therapy.
Two-Year Clinical Outcomes After Enhanced External Counterpulsation (EECP) Therapy in Patients With Refractory Angina Pectoris and Left Ventricular Dysfunction (Report from the International EECP Patient Registry)

Ozlem Soran, MD, MPH, Elizabeth D. Kennard, PhD, Abdallah Georges Kfoury, MD, Sheryl F. Kelsey, PhD and IEPR Investigators

American Journal of Cardiology
Volume 97, Issue 1, Pages 17-20 (January 2006)
Analysis of long-term outcomes demonstrate that the clinical benefits achieved with EECP are sustained up to at least 24 months.
A modified course of Enhanced External Counterpulsation improved myocardial perfusion in patients with severe left ventricular dysfunction

Pradeep G.Nayar\textsuperscript{1}, S.Ramasamy\textsuperscript{1}, Madhu.N.Sankar\textsuperscript{1}, K.M.Cherian\textsuperscript{1}, William E Lawson\textsuperscript{2} and John CK Hui\textsuperscript{2}

\textsuperscript{1}Frontier Lifeline & Dr.K.M.Cherain Heart Foundation, \textsuperscript{2}Cardiology, SUNY at Stony Brook, NY, USA
**Standard treatment protocol**

- One (1) hour per day
- Six (6) days per week
- Six (6) weeks

**EECP Therapy Treatment**
For Angina & Heart Failure

**Modified treatment protocol**

- Two (2) hours per day
- Six (6) days per week
- Three (3) weeks

**Short course treatment protocol**

- One (1) hour per day
- 10-15 sessions.
- Seven (7) days per week
Summary

Short course of EECP in patient with Severe LV Dysfunction prior to CABG improves myocardial perfusion and LV contractility.

Short course EECP can reduce post CABG hospitalization and IABP insertion.
Effect of Enhanced External Counterpulsation on Ejection Fraction in Patients with Ischemic Heart Disease

William E Lawson¹, Himanshu Padh², Subramanian Ramasamy³, John CK Hui¹

• EECP significantly improved LV ejection fraction, stroke volume, cardiac output in patients with ischemic heart disease and
  
  – Left ventricular EF > 35%
  – Left ventricular EF ≤ 35%

• The increase in Left Ventricular EF is mediated predominately by a decrease in end-systolic volumes.

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Prospective Evaluation of EECP in Congestive Heart Failure (PEECH) Trial
**PEECH Trial**

187 patients with stable heart failure with NYHA class II/III symptoms, Ischemic or non-ischemic etiology, LVEF ≤35%, optimal pharmacologic therapy, ability to exercise ≥3 minutes, limited by SOB or fatigue (not angina)
24% female, mean age 63 years
76% received ACE-inhibitors, 19% ARB, 85% beta-blockers

**EECP + ACE-Inhibitors or EECP + ARB & beta-blockers,**
EECP as 35, 1 hour sessions for 7 weeks
n=93

**ACE Inhibitors or ARB & beta-blockers**
n=94

**Primary Endpoint:** Percentage of subjects with 1) at least a 60 second increase in exercise duration from baseline to 6 months or 2) at least 1.25 ml/min/kg increase in peak VO2 from baseline to 6 months

**Secondary Endpoint:** Adverse events or changes in exercise duration and peak VO2, NYHA classification, quality of life
PEECH Trial: Primary Endpoint

Primary endpoints of increase in exercise duration at 6 months & increase in peak VO2

- The primary endpoint of increase in exercise duration by at least 60 seconds occurred more frequently in the EECP group compared with the control group at a 6 month follow-up.

- The co-primary endpoint of increase in peak VO2 of at least 1.25 ml/min/kg was the same between the two groups.
The change in exercise duration was longer in the EECP group versus the control group, which actually had a decrease in exercise duration at 1 week and 6 months.

The increase in the EECP group’s exercise duration was maintained at the 6 month follow-up.
There was more improvement in NYHA classification in the EECP group compared to the control group.

The was no significant difference in the occurrence of serious adverse events between groups.
Evaluation Of EECP in Congestive Heart Failure (PEECH) trial (n=187), four sets of registry data ranging from 127 to 1958 and one case series (n=32)

There were numerous methodological limitations to the registry data and case series such as lack of comparison group, conclusions based on subjective assessment and lack of completion of the case series study for HF.

In the studies that investigated EECP for HF adverse events (AEs) include major adverse cardiac events (MACEs), death, PCI & incidence of all-cause hospitalisations, and rates ranged from 5% to 72%.
EECP for Heart Failure: Is the Juice Worth the Squeeze

We need to know much more about EECP in HF before it is used (and reimbursed) for HF care.
Conclusions

EECP - Refractory angina and heart failure

RCTs indicate that EECP may be beneficial in both chronic stable angina & HF

Registry data & case series also suggest that EECP may improve patient outcomes such as improved LVEF, NYHA functional class, decreased rate of exacerbation & improved QoL

EECP is safe in HF but its efficacy is still uncertain

Long-term follow-up trials are required to investigate the benefits of EECP in HF