Surgical Management for Severe Heart Failure

-Alternative to Heart Transplantation-

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Byoung Wook Choi MD, Young Jin Kim MD,
Sang-Hyun Lim MD, Sak Lee MD, Yoo Sun Hong, MD

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Yonsei University, Seoul, Korea
Background

Congestive Heart Failure in USA

- Heart transplantation
  - Most effective therapy (~90% / 1 yr ; 50% /10 yr)
  - Scarcity of organs (2500 donors)
  - Transplantation related problems
    - infection
    - rejection
    - post-transplant lymphoproliferative disease
    - accelerated coronary artery disease
Background

Ventricular Remodeling in CHF

- This process is characterized by a progressive change in shape of the LV and a progressive increase of LV muscle mass. The remodeling process may be the primary mechanism for a reduction in LV wall motion that accompanies a reduced LVEF. Thus, the systolic dysfunction described above may often result not from a primary deficit of contraction but rather an enlargement of the chamber as a results of remodeling.

Jay N. Cohn, 2000
The fundamental principle of surgery is the alteration of structure to improve function.
Background

The Law of Laplace

\[ T = P \cdot r^2 \]

\[ T = \frac{P \cdot r}{2 \cdot \delta} \]

\( T \) = force across the total cross-sectional area

\( T \) = force per unit cross-sectional area of muscle

Badeer HS, AHJ 1963
Background

Normal Helical Shape Heart

Spherical Shape Failing Heart

Less Wall Tension and Effective Outflow
Surgical Concept

Spherical Shape Failing Heart

Normal Helical Shape Heart

Stress = Pressure \times \frac{\text{Radius}}{\text{Wall Thickness}}

Resecting

Wrapping

Overlapping

Plicating

Piercing

Clasping

From A. Kawaguchi
Alternatives to Heart Transplantation

• LV Volume reduction surgery
  (Batista, MyoSplint, Acorn.....)
• Mitral annuloplasty (Bolling)
• Cardiomyoplasty
• Implantable LVAD (REMATCH trial)
• Artificial heart (AbioCor, 2001)
• Xeno-transplantation (?)
Batista procedure
-Partial Left Ventriculectomy-
## Partial Left Venticulectomy (Batista Procedure)

<table>
<thead>
<tr>
<th>Nations</th>
<th>Institutes</th>
<th>Cases</th>
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<tbody>
<tr>
<td>USA</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>Brazil</td>
<td>1</td>
<td>670</td>
</tr>
<tr>
<td>France</td>
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<td>Germany</td>
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<td>Italy</td>
<td>3</td>
<td>35</td>
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<td>Netherland</td>
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<td>6</td>
</tr>
<tr>
<td>Yugoslavia</td>
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<td>38</td>
</tr>
<tr>
<td>Japan</td>
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<td>245</td>
</tr>
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<td>Korea</td>
<td>5</td>
<td>25</td>
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<td>9</td>
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<tr>
<td>Taiwan</td>
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<td>11</td>
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<tr>
<td>Thailand</td>
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<td>14</td>
</tr>
<tr>
<td>Turkey</td>
<td>1</td>
<td>29</td>
</tr>
</tbody>
</table>

**USA**

**Brazil**

**Europe**

**Asia**

**Total**

13 58 1239
Survival Year of Surgery

1999 ≤ (n=222)
1Y=67.3% (88)
1Y=66.4% (330)
3Y=57.1% (14)
3Y=51.2% (48)
5Y=47.1% (4)
5Y=47.0% (4)

1996 < (n=480)
1Y=57.4% (274)
3Y=40.2% (17)
5Y=21.9% (7)

1997-98 (n=531)
3Y=57.1% (14)
3Y=51.2% (48)
5Y=47.1% (4)
5Y=47.0% (4)

Survival significantly different between 1996< and others
Myosplint for Dilated Cardiomyopathy and Coapsys for Functional Mitral Regurgitation

Kiyotaka Fukamachi, MD, PhD

Cardiovascular Dynamics Laboratory
Department of Biomedical Engineering
Lerner Research Institute

The Cleveland Clinic Foundation
Cleveland, OH, U.S.A.
Myosplint ® Concept

Dilated Heart

![Diagram of dilated heart and modified radius](image)

Modified Radius

\[ T = \frac{P \times R1}{h} \]

Dilated Radius

\[ T = \frac{P \times R2}{h} \]

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation
End-systolic Wall Stress
Pacing induced, canine HF model

Test (n=8)  Control (n=7)

ESWS (10^3 dynes cm^{-2})

Baseline 4Wks

Test: Baseline 4Wks
Control: Baseline 4Wks

P = 0.003  P = 0.006

From Kiyotaka Fukamachi, MD
The Cleveland Clinic Foundation
Ejection Fraction (3D Echo)

Pacing induced, canine HF model

Test (n=7)                  Control (n=7)

Baseline 4Wks

P = 0.005

P = 0.006

Test (n=7) Control (n=7)

P = 0.006

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation

Yonsei
Myosplint Clinical Trial

• **Institutions**
  – Leipzig Heart Center, Leipzig, Germany
  – University Hospital Munich-Grosshadern, Munich, Germany
  – The Cleveland Clinic Foundation, Cleveland, U.S.A.

• **Primary Objective**
  – To assess the intraoperative and perioperative safety.

• **Secondary Objective**
  – To gather preliminary device efficacy data through assessments of NYHA functional class, LVEDV, LVEF, and MR grade at enrollment and during follow-up.
## Patient Demographics

<table>
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<tr>
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<th>Myosplint</th>
<th>Myosplint + MVR</th>
<th>All patients</th>
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<tbody>
<tr>
<td>Number</td>
<td>N = 9</td>
<td>N = 17</td>
<td>N = 26</td>
</tr>
<tr>
<td>Age</td>
<td>52.8 ± 7.0</td>
<td>52.8 ± 12.5</td>
<td>52.4 ± 10.8</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>7 (78%)</td>
<td>12 (71%)</td>
<td>19 (73%)</td>
</tr>
<tr>
<td>Female</td>
<td>2 (22%)</td>
<td>5 (29%)</td>
<td>7 (27%)</td>
</tr>
<tr>
<td>Years with HF</td>
<td>3.8 ± 2.0</td>
<td>8.4 ± 4.7*</td>
<td>6.9 ± 4.5</td>
</tr>
</tbody>
</table>

*From Kiyotaka Fukamachi, MD*
**LV End-diastolic Volume**

**Myosplint (n=7)**
- Baseline: 342 mL
- 6 Months: 296 mL

- P = NS

**Myosplint + MVR (n=10)**
- Baseline: 365 mL
- 6 Months: 313 mL

- P = 0.03

**All (n=17)**
- Baseline: 355 mL
- 6 Months: 306 mL

- P = 0.008

From Kiyotaka Fukamachi, MD
Myosplint Patient

Pre-operative

<table>
<thead>
<tr>
<th>Time</th>
<th>LVEF (%)</th>
<th>EDV (ml)</th>
<th>MR Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>14</td>
<td>334</td>
<td>2</td>
</tr>
<tr>
<td>6 month</td>
<td>37</td>
<td>145</td>
<td>1</td>
</tr>
<tr>
<td>18 month</td>
<td>40</td>
<td>80</td>
<td>Trace</td>
</tr>
<tr>
<td>24 month</td>
<td>40</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Photographs courtesy of Professor Friedrich Mohr, University of Leipzig.

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation

Yonsei
Mitral Regurgitation

Myosplint (n=7)

Myosplint + MVR (n=12)

All (n=19)

P = NS

P = 0.002

P = 0.02

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation

Yonsei
NYHA Functional Class

Myosplint (n=7)  Myosplint + MVR (n=12)  All (n=19)

\[ P = 0.04 \quad P = 0.03 \quad P = 0.002 \]

Baseline 6 Months  Baseline 6 Months  Baseline 6 Months

NYHA Class

From Kiyotaka Fukamachi, MD

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Clinical Status

- 3 patients died during follow-up
  - 2 patients from sepsis
  - 1 patient from a sudden ventricular tachyarrhythmia

- 2 patients underwent heart transplantation

- The MR grade had a significant linear relationship with the NYHA functional class
  \[(NYHA = 0.285 \times MR + 1.97. \ P = 0.002)\]
Surgical Concept

Coapsys™ Therapeutic

- Draws mitral leaflets together to increase valve **coaptation**
- Repositions papillary muscles

Functional MR

Poor coaptation

Treated with Coapsys

Good coaptation

Displacement of PM

Reposition of PM

AML

PML

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation

Yonsei
Advantages

• Ability to affect both the mitral annulus and the papillary muscle.

• Off-Pump: Elimination of cardiopulmonary bypass. No atriotomy. Immediate evaluation.

• Technically simple. Reversible implantation.

• Potential for a more stable repair which does not interfere with annular dynamics.
Mitral Regurgitation
Average ± SD (7 animals)

* $P < 0.05$ vs. $L_0$
† $P < 0.01$ vs. $L_0$
‡ $P < 0.001$ vs. $L_0$

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation

Yonsei
TRACE Summary

- The Coapsys device was safe and effective in significantly reducing MR in the beating heart.

- The device significantly reduced
  - S-L annular diameter
  - Interpapillary muscle distance
  - Posterior papillary muscle to intervalvular fibrosa distance
  - Tenting area

- Thus, restoring MV geometry appears to be responsible for the clinical effects of the device

- MR reduction is sustained at 12 months follow up

From Kiyotaka Fukamachi, MD

The Cleveland Clinic Foundation
Acorn Device
Dynamic Cardiomyoplasty

1. Systolic assist
2. limitation of ventricular dilatation
3. Reduction in ventricular wall stress
4. Ventricular remodeling with an active girdling effects
5. Angiogenesis
6. Neurohormonal effects

Chachques JC, 1997,
Eur J Cardiothorac Surg

LDM transposition and cardiac wrapping
Dynamic Cardiomyoplasty
-long term results-

7-year survival ; 54%

Causes of long-term mortality
- Heart failure(41%)
- Sudden death(30%)
- MI, GI bleeding, cancer(7%)

Six patients underwent heart transplantation after CMP.

Chachques JC ,1997, Eur J Cardiothorac Surg
Mitral annuloplasty
Mitral annuloplasty

-Long Term Results-

• 1994-2003; 200 patients with end stage cardiomyopathy underwent mitral valve repair with undersized flexible annuloplasty ring
• F/U period; 49 months (1-74)
• All patients showed improvement in EF (preop; 16±5% → postop; 26±8%), cardiac output, end-diastolic volume with reduction in spherical index and regurgitant fraction.

Bolling SF, 2004, J Card Surg
• 1995-2002; 126 patients with MR (moderate to severe) and LV dysfunction (LVEF<30%) underwent Mitral valve annuloplasty
• Risk factors; coronary artery disease, blood urea nitrogen, cancer, digoxin use
• Favorable factors; ACE use, beta-blockers, higher mean arterial pressure, higher serum sodium
Impact of Mitral Valve Annuloplasty on Mortality Risk in Patients With Mitral Regurgitation and Left Ventricular Systolic Dysfunction

Audrey H. Wu, MD, MPH,* Keith D. Aaronson, MD, MS,* Steven F. Bolling, MD, FACC,† Francis D. Pagani, MD, PhD, FACC,† Kathy Welch, MS, MPH,‡ Todd M. Koelling, MD, FACC.*

No clearly demonstrable mortality benefit conferred by MVA

Bolling SF, 2005, JACC

Figure 1. Event free survival for non-MAP (solid) and MVA (dotted line)

Figure 2. Event free survival in patients without CAD.

CONCLUSIONS

In this analysis, there is no clearly demonstrable mortality benefit conferred by MVA for significant LV dysfunction. A prospective randomized control trial is warranted for further study of mortality benefit.

2005;45:3871-3876. 2005 by the American College of Cardiology Foundation.
Surgical Ventricular Restoration

Athanasuleas et al, RESTORE group, 2004, JACC
Surgical Ventricular Restoration in the Treatment of Congestive Heart Failure due to Post-Infarction Ventricular Dilatation

- 1998-2003; 1,198 pts with post-infarction CHF
- SVR improved LVEF (29.6±11.0% → 39.5±12.3%) and reduced LVESVI (80.4±51.4ml/m² → 56.6±34.3ml/m²).

Risk factors
- EF ≤ 30%
- LVESVI ≥ 80ml/m²
- Advanced NYHA class
- Age ≥ 75 years

Athanasuleas et al, RESTORE group, 2004, JACC
Hypothesis

Mechanism of MR in d-CMP

Normal LV

Spherical LV with MR

Sabbah HN et al AJC 1993
Hypothesis

Left Ventriculoplasty and Mitral Annuloplasty in Patients of d-CMP and MR

Chang BC et al J Cardiac Surg 2001
Hypothesis

Left Ventriculoplasty and Mitral Annuloplasty in Patients of CMP and MR

M/56 Pre-OP. Cine-MRI:
LVEF:29.1%, LVEDV 265.3ml, SV 77.2ml, MR vol: 46.3 ml
Purpose

**Left Ventriculoplasty and/or Mitral Annuloplasty in Severe Heart Failure**

- We reviewed early and long-term clinical outcome after mitral annuloplasty and/or left ventriculoplasty in severe heart failure.

- To evaluate the functional changes of left ventricle before and after MAP and/or left Ventriculoplasty.
Patient Profiles

- Periods: November, 1997 – June, 2005
- Patients: 34
  - male: 24, female: 10
- Mean age: 60.0 ± 9.4 (37 - 76) years
- Causes of Operation
  - ischemic CMP: 18
  - dilated CMP: 14
  - valvular: 2
Preop. Profiles

- Preop. NYHA class
  - III: 13  IV: 15,  dobutamine dependent: 6
- Preop. Rhythm
  - NSR: 18,  Atrial Fib.: 16
- Preop. MR grade
  - < I: 5,  II: 8,  III: 10,  IV: 11
## Surgical Procedures

- **Mitral Annuloplasty (n=28)**
  - only: 5
  - CABG: 9
  - modified Dor. Procedure: 6
  - modified Dor. Procedure and CABG: 6
  - Aortic valve replacement: 2

- **Modified Dor Procedure (n=6)**
  - only: 1
  - CABG: 5
Postop. Results

- **Early results**
  - operative death: 1 with sepsis
  - bypass weaning failure: 1
    - implantable LVAD for 502 days (HeartMate®)
    → heart transplantation

- **Late results:**
  - late death: 5
    - heart failure (POD # 8, 9 months) in 2
    - sudden death (POD # 4, 5, 65 months) in 3
# Echocardiography Results

<table>
<thead>
<tr>
<th>Mean</th>
<th>Preop. (n=34)</th>
<th>Postop. (n=34)</th>
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<tbody>
<tr>
<td>*LVEF (%)</td>
<td>25.6 ± 6.3</td>
<td>34.2 ± 15.0</td>
</tr>
<tr>
<td>range</td>
<td>15 – 39</td>
<td>13 - 76</td>
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<tr>
<td>* LAD (mm)</td>
<td>53.2 ± 8.5</td>
<td>48.1 ± 7.8</td>
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<tr>
<td>range</td>
<td>41 – 70</td>
<td>37 - 66</td>
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<tr>
<td>* LVESD (mm)</td>
<td>59.1 ± 9.3</td>
<td>50.8 ± 12.2</td>
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<tr>
<td>range</td>
<td>45 – 77</td>
<td>25 - 79</td>
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<tr>
<td>* LVEDD (mm)</td>
<td>69.0 ± 9.4</td>
<td>61.7 ± 9.8</td>
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<tr>
<td>range</td>
<td>46 – 85</td>
<td>43 – 85</td>
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<td>*: p&lt;0.05</td>
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# Changes of MR

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<th>Grade</th>
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<th>Postoperative</th>
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<tr>
<td>0 - I</td>
<td>5</td>
<td>32 (4)</td>
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<tr>
<td>II</td>
<td>8</td>
<td>0</td>
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<tr>
<td>III</td>
<td>10</td>
<td>1 (1)</td>
</tr>
<tr>
<td>IV</td>
<td>10</td>
<td>0</td>
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( ): Number of death
## Changes of NYHA Class

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<th>NYHA Class</th>
<th>Preoperative</th>
<th>Postoperative</th>
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<tr>
<td>I</td>
<td>0</td>
<td>11 (1)</td>
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<tr>
<td>II</td>
<td>0</td>
<td>19 (2)</td>
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<tr>
<td>III</td>
<td>13</td>
<td>2 (1)</td>
</tr>
<tr>
<td>IV</td>
<td>21</td>
<td>1 (1)</td>
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( ): Number of death

(Yonsei)
Kaplan-Meier Survival

Patients at risk

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<th>years</th>
<th>0</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tr>
<td>ischemic</td>
<td>17</td>
<td>10</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>dilated</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

ischemic: 84.9±10.0 year
dilated:   84.6±10.0 year
Pre and Postop cine-MRI
MV annuloplasty & CABG (2003-3-17)
Echo; EF 25%->31%, LV dimension 83 to 64mm

Choi YR, M/63

Preop. 2003-3-3
Postop. 2003-4-10
Analysis of LV geometry & function in modified Dor procedure and MVA using MRI
Analysis of LV geometry & function in modified Dor procedure and MVA using MRI

• Materials: 21 cases of MAP and/or LVP

• Analysis
  – Short-axis cine images: 1cm thickness slices from mitral valve plane toward apex
  – Measurement of pre- & postoperative cross-sectional area at End-diastole & End-systole
  – Comparison of changes of cross-sectional area at ED, ES & segmental EF
Group I (Dor + MVA)

7 cases

Case 1: Chung CS 4106326 MVA, CABG, Dor
Case 2: Park NS 2736259 MVA, Dor
Case 3: Choi YN 2261126 MVA, CABG, Dor
Case 4: Kim JY 4126445 MVA, CABG, Dor
Case 5: Choi JH 3032390 MVA, CABG, Dor
Case 6: Shin MC 1905478 MVA, CABG, Dor
Case 7: Kim JK 2983777 MVA, CABG, Dor
# Group II (Dor)

8 cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Name</th>
<th>ID</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 8</td>
<td>Jang OH</td>
<td>1604921</td>
<td>Dor, CABG</td>
</tr>
<tr>
<td>Case 9</td>
<td>Lee WS</td>
<td>2286574</td>
<td>Dor, CABG</td>
</tr>
<tr>
<td>Case 10</td>
<td>Kim TW</td>
<td>4029029</td>
<td>Dor, CABG</td>
</tr>
<tr>
<td>Case 11</td>
<td>Lee JH</td>
<td>3333027</td>
<td>Dor, CABG</td>
</tr>
<tr>
<td>Case 12</td>
<td>Park SW</td>
<td>4227617</td>
<td>Dor, CABG</td>
</tr>
<tr>
<td>Case 13</td>
<td>Kim KH</td>
<td>4254598</td>
<td>Dor, CABG, AVR</td>
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<tr>
<td>Case 14</td>
<td>Kwon HY</td>
<td>2753298</td>
<td>Dor, Tricuspid A</td>
</tr>
<tr>
<td>Case 15</td>
<td>Jung JS</td>
<td>3014199</td>
<td>Dor, CABG</td>
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</table>
### Group III (MVA)

6 cases

<table>
<thead>
<tr>
<th>Case</th>
<th>Name</th>
<th>ID</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 16</td>
<td>Jang IN</td>
<td>2372250</td>
<td>MVA only</td>
</tr>
<tr>
<td>Case 17</td>
<td>Hyun PA</td>
<td>2600789</td>
<td>MVA + CABG</td>
</tr>
<tr>
<td>Case 18</td>
<td>Chun NM</td>
<td>4135787</td>
<td>MVA + CABG</td>
</tr>
<tr>
<td>Case 19</td>
<td>Kim SB</td>
<td>4142017</td>
<td>MVA + CABG</td>
</tr>
<tr>
<td>Case 20</td>
<td>Ka JH</td>
<td>4073802</td>
<td>MVA + CABG</td>
</tr>
<tr>
<td>Case 21</td>
<td>Whang</td>
<td>4093979</td>
<td>MVA only</td>
</tr>
</tbody>
</table>
Group I
1905478 Shin MC, Male/54

Preop 2003-12-15
Postop 11d 2003-12-30
Postop 9 m 2004-9-10
Group II (SAVER)
3333027 Lee JH Male/53

Preop 2002-8-13

Postop 2002-10-7

Yonsei
Group III
4135787 Chun NM
Male/40
MAP and CABG

Preop 2003-11-13
Postop 2004-1-5
Changes of LVEDV

Group I

- Preop: 211.2±54.9
- Postop: 146.9±48.9

P=0.0018

Group II

- Preop: 145.1±78.4
- Postop: 103.5±20.7

P=0.0090

Group III

- Preop: 134.5±61.2
- Postop: 104.0±24.8

P=0.0042

LVEDVI;
**Changes of LVESV**

**LVESVI;**  
Preop. 169.4±59.9  
Postop. 111.0±51.7

**P=0.0026**

Preop. 110.0±40.3  
Postop. 62.6±20.9

**P=0.0015**

Preop. 95.3±28.1  
Postop. 71.0±29.9

**P=0.0076**
Changes of LVEF

Group I
Preop EF(%): 21.32 ± 2.8
Postop EF(%): 20.78 ± 3.6
P=0.7717

Group II
Preop EF(%): 25.37 ± 3.6
Postop EF(%): 40.71 ± 3.9
P=0.0002

Group III
Preop EF(%): 30.41 ± 4.2
Postop EF(%): 34.32 ± 6.3
P=0.3266
Changes of Sphericity Index

Group I

Preop SI: 0.8268 ± 0.0292
Postop SI: 0.8478 ± 0.0433
P=0.6444

Group II

Preop SI: 0.6496 ± 0.0291
Postop SI: 0.7793 ± 0.0392
P=0.0082

Group III

Preop SI: 0.7445 ± 0.0341
Postop SI: 0.6519 ± 0.0308
P=0.0180

Sphericity ↑

Sphericity ↓
Changes of Segmental EF

Group I

Group II

Group III

Distance from MV plane (cm)

Segmented EF (%)
Conclusion(1)

• In patients with severe left heart failure with significant mitral regurgitation, mitral annuloplasty c/s left ventriculoplasty improved morphological and functional status of LV.

• Long-term results of mitral annuloplasty c/s left ventriculoplasty appeared to be good and can be performed in patients of end-stage heart failure, not indicated for heart transplantation.
Conclusion(2)

• Pre and Postoperative MRI revealed that LV Volumes are decreased significantly during End- diastole and End-systole.
• Postoperative segmental LVEFs were increased significantly from 5 cm from of mitral plane in Group 1 and 3. However segmental LVEFs were increased in all segment in Group 2.
• With these results, it appeared that earlier surgical approach is important in improving LV function before irreversible myocardial damage.
• However, these results are limited with small numbers, and with heterogeneous data.
Mitral Annuloplasty and Apical Left Ventricleplasty in I-CMP

Choi JH, 56/M

Pre-op: SV=293.1-215.3=77.8ml, EF=26.5%
Simulation: SV=151-99=52ml, EF=34%
Post-op: SV=54.1ml, EF 32% (Echo)
Changes of LV Dynamic Morphology before and after LVPlasty

Chang OH, Male, 72y-o

Preop (LVEF=24%)  Postop 10 days

Yonsei
Mitral Annuloplasty and Apical Left Ventriculoplasty in I-CMP

Choi JH, 56/M

Preop

Postop

Pre-OP. : LVEF:29.1%, LVEDV 265.3ml, SV 77.2ml
Pre and Postop. Chest P-A

F/59, ARs, MR
HeartMate LVAS for BTT
Changes of LV Dynamic Morphology before and after MAP

Preop

Postop

Yonsei
Changes of LV Dynamic Morphology before and after MAP

Preop

Postop
Changes of LV Dynamic Morphology before and after MAP

Preop

Postop