Derivation and Validation of a Novel **Right-Sided Heart Failure** Model After Implantation of Continuous Flow **Left Ventricular Assist Devices**: the **EUROMACS-RHF Risk Score**

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Http://www.rhfriskscore.com
Background

• Left ventricular assist devices (LVADs) are increasingly used for patients with end-stage heart failure as a bridge-to-HTx or destination therapy.

• Right-sided heart failure (RHF) is a frequent complication early after LVAD implantation and associated with high morbidity and mortality.
Objective

• To derive and validate a Novel Risk Score for early Right-sided Heart Failure (RHF) after LVAD implantation from The European Registry for Patients with Mechanical Circulatory Support (EUROMACS Registry).
3897 consecutive patients included in the EUROMACS database

- 171 patients younger than 18 years
- 97 patients had devices other than LVAD (SVAD, TAH)
- 641 patients had LVAD devices other than mainstream (ABS5000, Berlin heart)

2988 patients had **mainstream** LVAD comprised the final study cohort
Study endpoints

- **Early** (<30 days) **severe** postoperative **RHF**,
  - defined as patients receiving short or long-term right-sided circulatory support (**RVAD**) and/or
  - continuous **inotropics** support for ≥14 days, and/or
  - **nitric oxide** ventilation for ≥48h.

- **Secondary outcome** was all-cause **mortality** and length of **stay** in the intensive care unit (ICU).
Randomly selected, balanced in preoperative (clinical, laboratory, echocardiographic, hemodynamic) and operative characteristics
LVAD strategy

Derivation Cohort
- BTT: 24%
- BTC: 38%
- DT: 17%
- Others: 21%

Validation Cohort
- BTT: 24%
- BTC: 35%
- DT: 17%
- Others: 24%
Mainstream LVAD brands

Derivation Cohort

- HeartWare: 51%
- HeartMate II: 40%
- HeartMate 3: 9%

Validation Cohort

- HeartWare: 52%
- HeartMate II: 41%
- HeartMate 3: 7%
### Primary Outcome (RHF components)

#### Derivation cohort (n=2000)

- **RHF**: 22%
- **No RHF**: 78%

#### Right-Sided Heart Failure Components (n=433)

<table>
<thead>
<tr>
<th>Component</th>
<th>Count (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inotropic ≥14 days</td>
<td>327 (76%)</td>
</tr>
<tr>
<td>RVAD need</td>
<td>141 (33%)</td>
</tr>
<tr>
<td>NO ≥48 hrs use</td>
<td>17 (4%)</td>
</tr>
<tr>
<td>Variables</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>RA to PCWP &gt;0.54</td>
<td>2.075</td>
</tr>
<tr>
<td>Hemoglobin ≤10 g/dL</td>
<td>1.611</td>
</tr>
<tr>
<td>Multiple (≥3) IV inotropes</td>
<td>3.197</td>
</tr>
<tr>
<td>INTERMACS Class 1-3</td>
<td>2.903</td>
</tr>
<tr>
<td>Severe RV dysfunction</td>
<td>2.055</td>
</tr>
<tr>
<td>CPB time &gt;100 min</td>
<td>2.032</td>
</tr>
</tbody>
</table>
EUROMACCS-RHF RISK SCORE VALIDATION

Validation cohort (n=988)

- Validation in independent population
- Validation against known predictors
Mean ± SD = 2.7 ± 1.9
Median = 2 [IQR 2 to 3]
P-value versus VC = 0.32

Mean ± SD = 2.6 ± 2.0
Median = 2 [IQR 2 to 4]
## Performance of the EUROMAC-S-RHF score

**Derivation cohort (n=2000)**

<table>
<thead>
<tr>
<th>Predictors for right-sided heart failure</th>
<th>C (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk scores</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• EUROMAC-S-RHF risk score</td>
<td>0.70 (0.67 to 0.73)</td>
<td>1 - reference</td>
</tr>
<tr>
<td>• Postoperative (+CPB) EUROMAC-S-RHF risk score</td>
<td>0.71 (0.68 to 0.74)</td>
<td>0.41</td>
</tr>
<tr>
<td>• Kormos et al. score(^1)</td>
<td>0.58 (0.54 to 0.61)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• CRITT score(^2)</td>
<td>0.63 (0.60 to 0.66)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Hemodynamic parameters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• RA pressure, mmHg</td>
<td>0.60 (0.55 to 0.65)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• TPG, mmHg</td>
<td>0.55 (0.50 to 0.61)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• PVR, woods unit</td>
<td>0.56 (0.51 to 0.61)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• RVSWI, g/m²/beat</td>
<td>0.52 (0.47 to 0.56)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>• Severe RV dysfunction</td>
<td>0.57 (0.52 to 0.61)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Incidence of Right-Sided HF

P-value <0.001 (for both cohorts)

EUROMACCS-RHF Risk Score

Derivation Cohort
Validation Cohort
Linear (Derivation Cohort)

Right-sided Heart Failure (%)
Survival

A

19%

B

25%

Log-rank test, P<0.001

Number at risk

No RHF

RHF

0 3 6 9 12 15 18 21 24

Time (months)

1412 1049 919 770 660 546 454 370 306

382 242 189 153 124 96 81 70 58

Cumulative survival (%)

79 71 65 58 61

80 73 60 66 56

66 54 46 46 43

Low risk 0-2

Intermediate risk 2.5-4

High risk >4

Log-rank test, P<0.001
ICU stay (days)

Duration of stay in the ICU in days

- NO RHF: 7 (IQR 4 to 15)
- RHF: 24 (IQR 14 to 38)

P<0.001

Duration of stay in the ICU in days

- Low: 6 (IQR 4 to 13)
- Intermediate: 13 (IQR 6 to 25)
- High: 19 (IQR 9 to 31)

P<0.001

EUROMACS RHF Risk Score categories
Causes of death

- Multi-organ failure: 6.8% (P<0.001)
- Sepsis: 11.6% (P<0.001)
- Cerebro-vascular accident: 2.9% (P<0.001)
- Bleeding: 1.5% (P<0.001)
- Cardio-pulmonary failure: 1.2% (P<0.001)

No RHF
RHF
Take home message (1/2) – the score

• We derived and validated a novel and simple risk score for RHF in 2988 adults undergoing LVAD implantation with mainstream devices in the EUROMACS Registry

• This model included:
  – Need of ≥3 inotropic agents,
  – INTERMACS class 1 to 3,
  – Severe RV dysfunction,
  – RA to PCWP ratio >0.54
  – Anemia (Hb ≤10 g/dL).

• CPB time >100 minutes for the postoperative risk calculator.
Take home message (1/2) – clinical application

• This novel **EUROMACS-RHF Risk Score** is highly predictive, **outperforming** currently known risk scores and clinical predictors of early post-LVAD RHF.

• This score may help to target future optimal strategies aiming at **early and intensive RHF management** for high risk subgroups of the LVAD patients.

• **Future studies** should determine whether early RVAD implantation and/or intensive RHF medication can improve survival and reduce ICU stay among LVAD candidates at high risk for RHF.
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The EUROMACS (European Registry for Patients with Mechanical Circulatory Support) Right-Sided Heart Failure Risk Score

Editorial, see p XXX

BACKGROUND: The aim of the study was to derive and validate a novel risk score for early right-sided heart failure (RHF) after left ventricular assist device implantation.

METHODS: The European Registry for Patients with Mechanical Circulatory Support (EUROMACS) was used to identify adult patients undergoing continuous-flow left ventricular assist device implantation with mainstream devices. Eligible patients (n=2988) were randomly divided into derivation (n=2000) and validation (n=988) cohorts. The primary outcome was early (<30 days) severe postoperative RHF, defined as receiving short- or long-term right-sided circulatory support, continuous inotropic support for ≥14 days, or nitric oxide ventilation for ≥48 hours. The secondary outcome was all-cause mortality and length of stay in the intensive care unit. Covariates found to be associated with RHF (exploratory univariate P<0.10) were entered into a multivariable logistic regression model. A risk score was then generated using the relative magnitude of the exponential regression model coefficients of independent predictors at the last step after checking for collinearity, likelihood ratio test, c index, and clinical weight at each step.

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The paper will be simultaneously published in Circulation at the day of presentation

Risk score calculator is available online

Http://www.RHFriskscore.com
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