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Heart Failure Surgery

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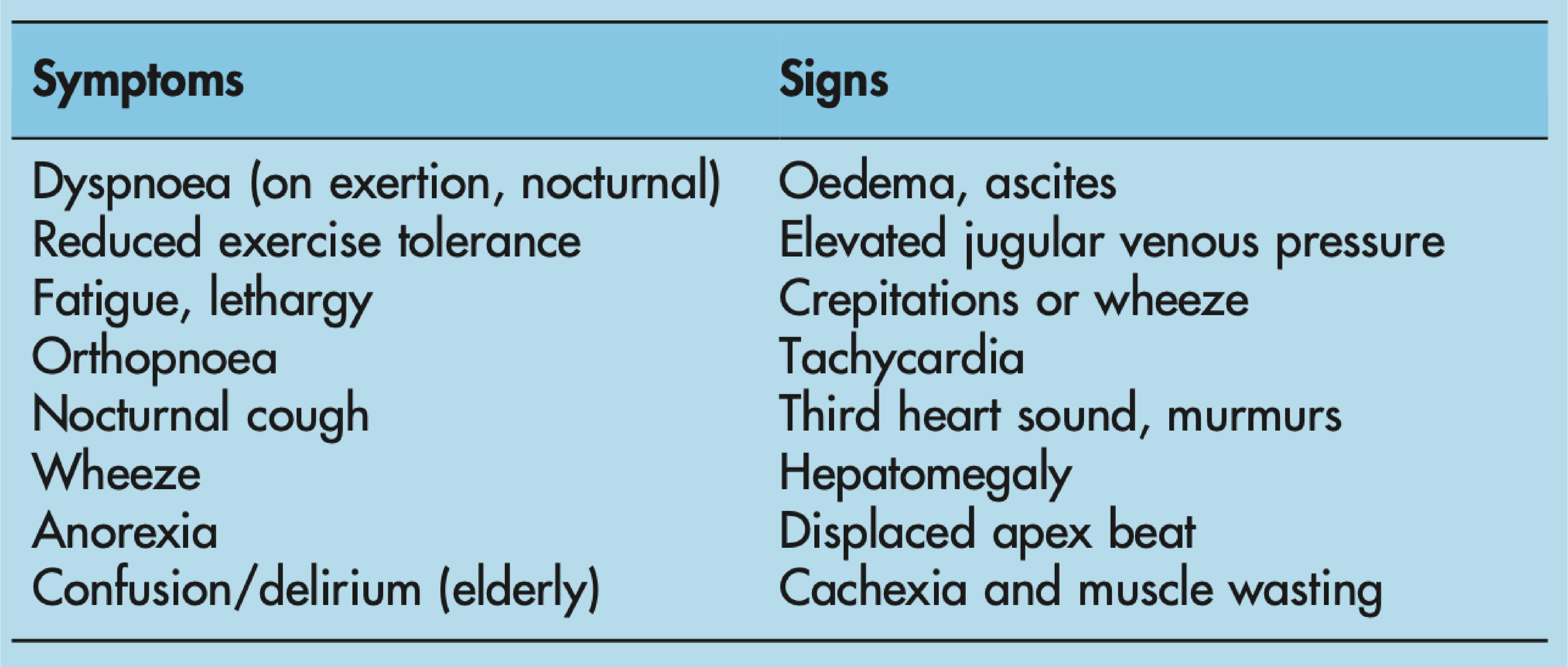
Heart failure - definition

- Definition
  - Complex clinical syndrome
    - Symptoms and signs
    - Any structural or functional impairment of ventricular filling or ejection of blood.

Heidenreich PA, et al. J Am Coll Cardiol. 2022 May 3;79(17):e263-e421.

Heart failure – symptom & sign



Symptoms	Signs
Dyspnoea (on exertion, nocturnal) Reduced exercise tolerance Fatigue, lethargy Orthopnoea Nocturnal cough Wheeze Anorexia Confusion/delirium (elderly)	Oedema, ascites Elevated jugular venous pressure Crepitations or wheeze Tachycardia Third heart sound, murmurs Hepatomegaly Displaced apex beat Cachexia and muscle wasting

Arend Mosterd & Arno W Hoes Heart 2007 Sep;93(9):1137-46.

Heart failure - causes

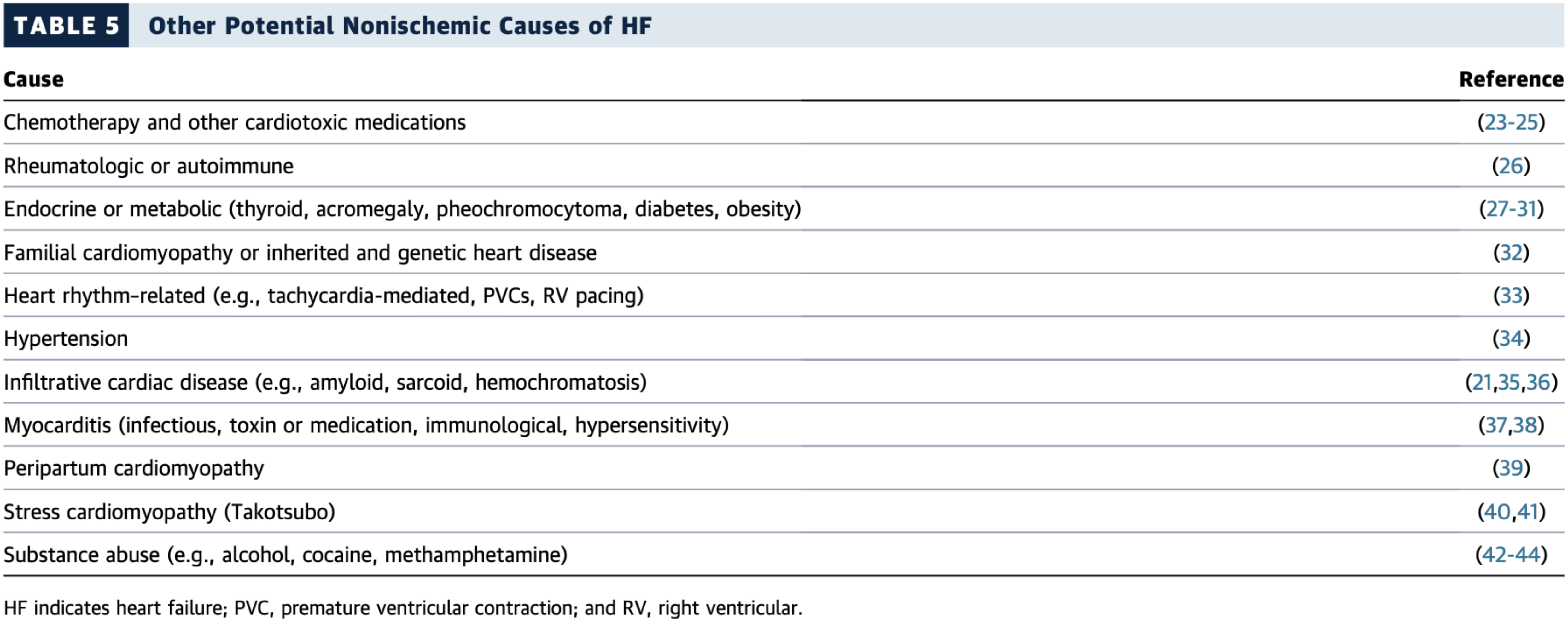
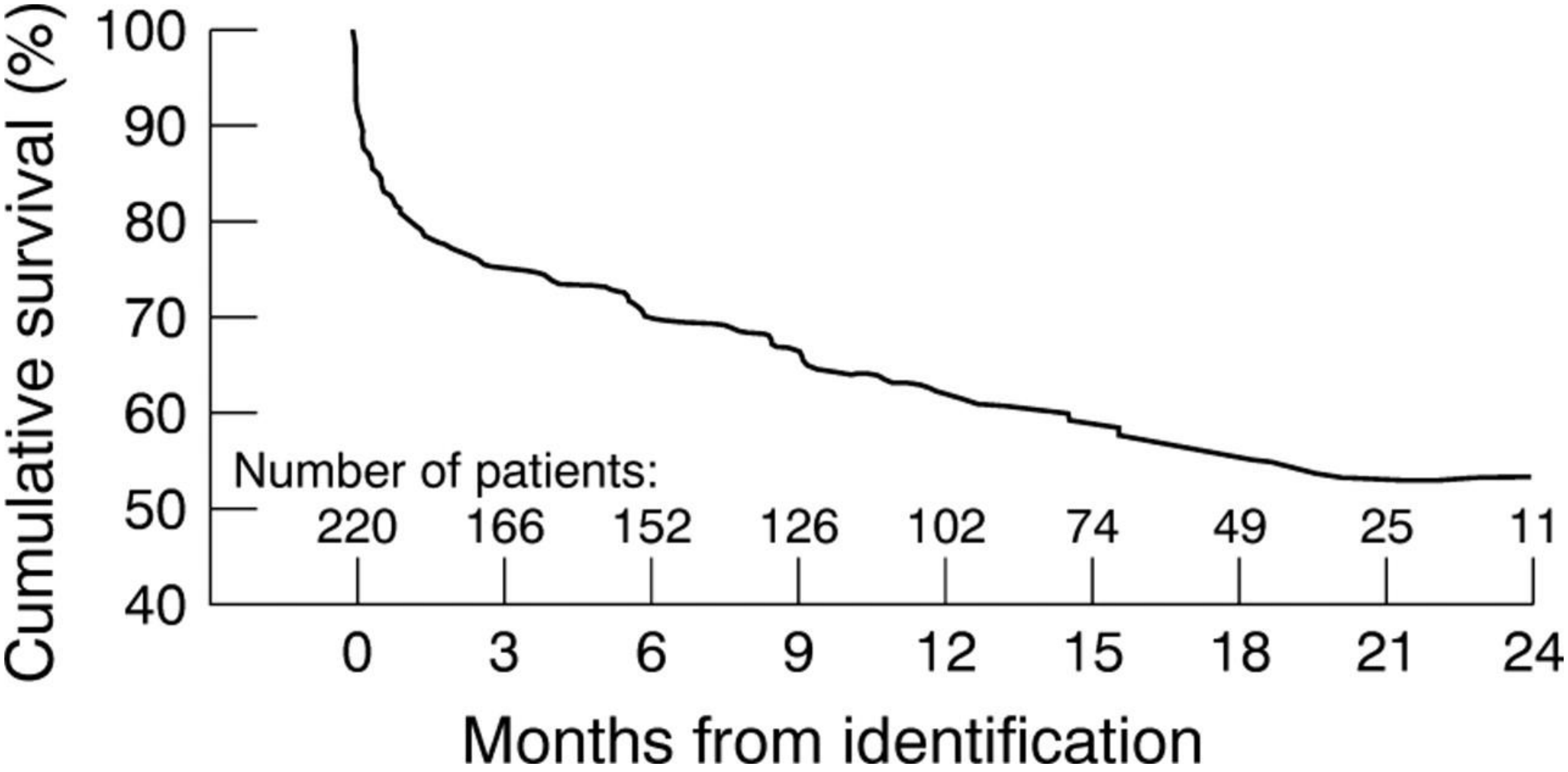


TABLE 5 Other Potential Nonischemic Causes of HF

Cause	Reference
Chemotherapy and other cardiotoxic medications	(23-25)
Rheumatologic or autoimmune	(26)
Endocrine or metabolic (thyroid, acromegaly, pheochromocytoma, diabetes, obesity)	(27-31)
Familial cardiomyopathy or inherited and genetic heart disease	(32)
Heart rhythm-related (e.g., tachycardia-mediated, PVCs, RV pacing)	(33)
Hypertension	(34)
Infiltrative cardiac disease (e.g., amyloid, sarcoid, hemochromatosis)	(21,35,36)
Myocarditis (infectious, toxin or medication, immunological, hypersensitivity)	(37,38)
Peripartum cardiomyopathy	(39)
Stress cardiomyopathy (Takotsubo)	(40,41)
Substance abuse (e.g., alcohol, cocaine, methamphetamine)	(42-44)

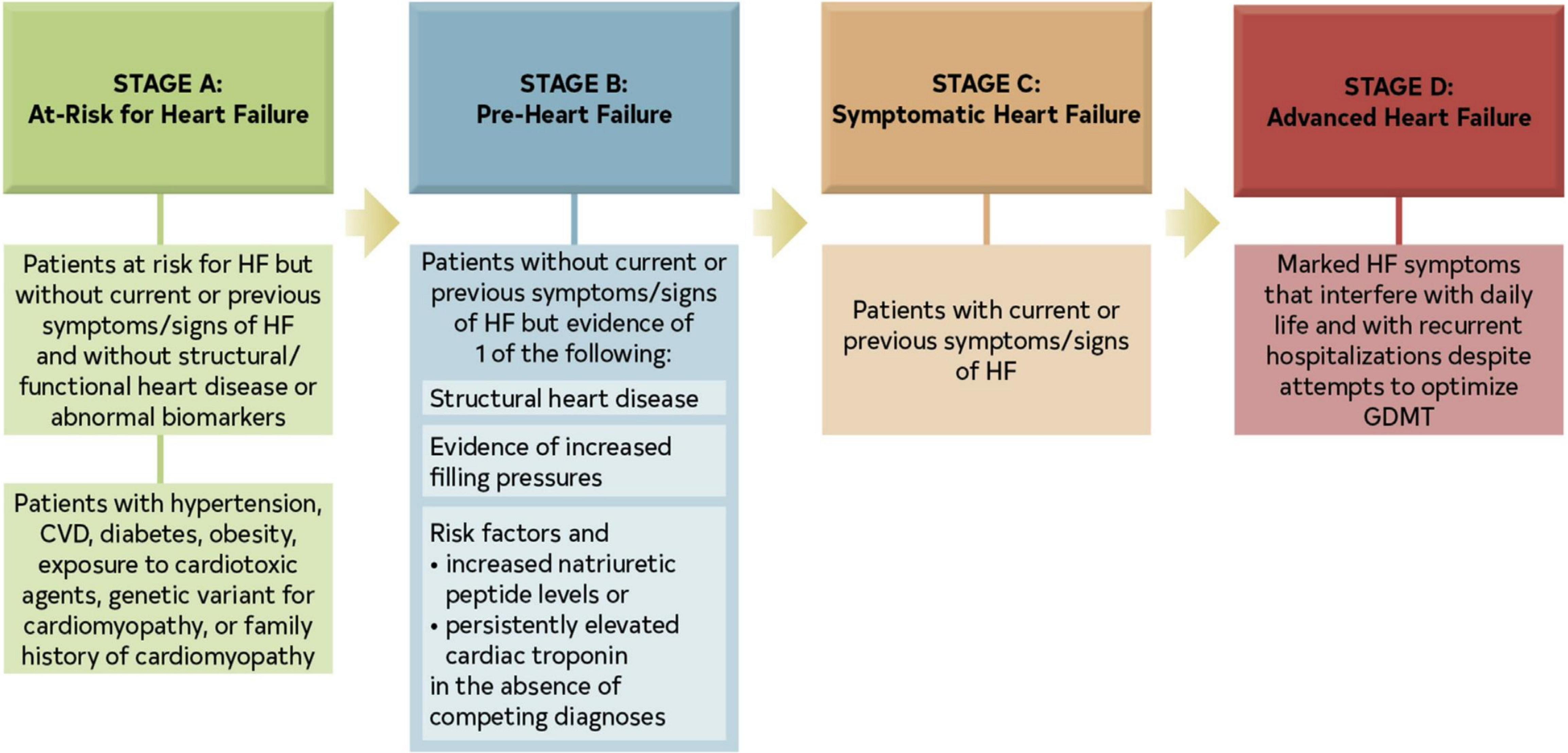
HF indicates heart failure; PVC, premature ventricular contraction; and RV, right ventricular.

Heart failure - survival



M R Cowie et al. Heart 2000;83:505-510

Heart failure - stage



STAGE A:
At-Risk for Heart Failure

Patients at risk for HF but without current or previous symptoms/signs of HF and without structural/ functional heart disease or abnormal biomarkers

Patients with hypertension, CVD, diabetes, obesity, exposure to cardiotoxic agents, genetic variant for cardiomyopathy, or family history of cardiomyopathy

STAGE B:
Pre-Heart Failure

Patients without current or previous symptoms/signs of HF but evidence of 1 of the following:

Structural heart disease

Evidence of increased filling pressures

Risk factors and
- increased natriuretic peptide levels or
- persistently elevated cardiac troponin

in the absence of competing diagnoses

STAGE C:
Symptomatic Heart Failure

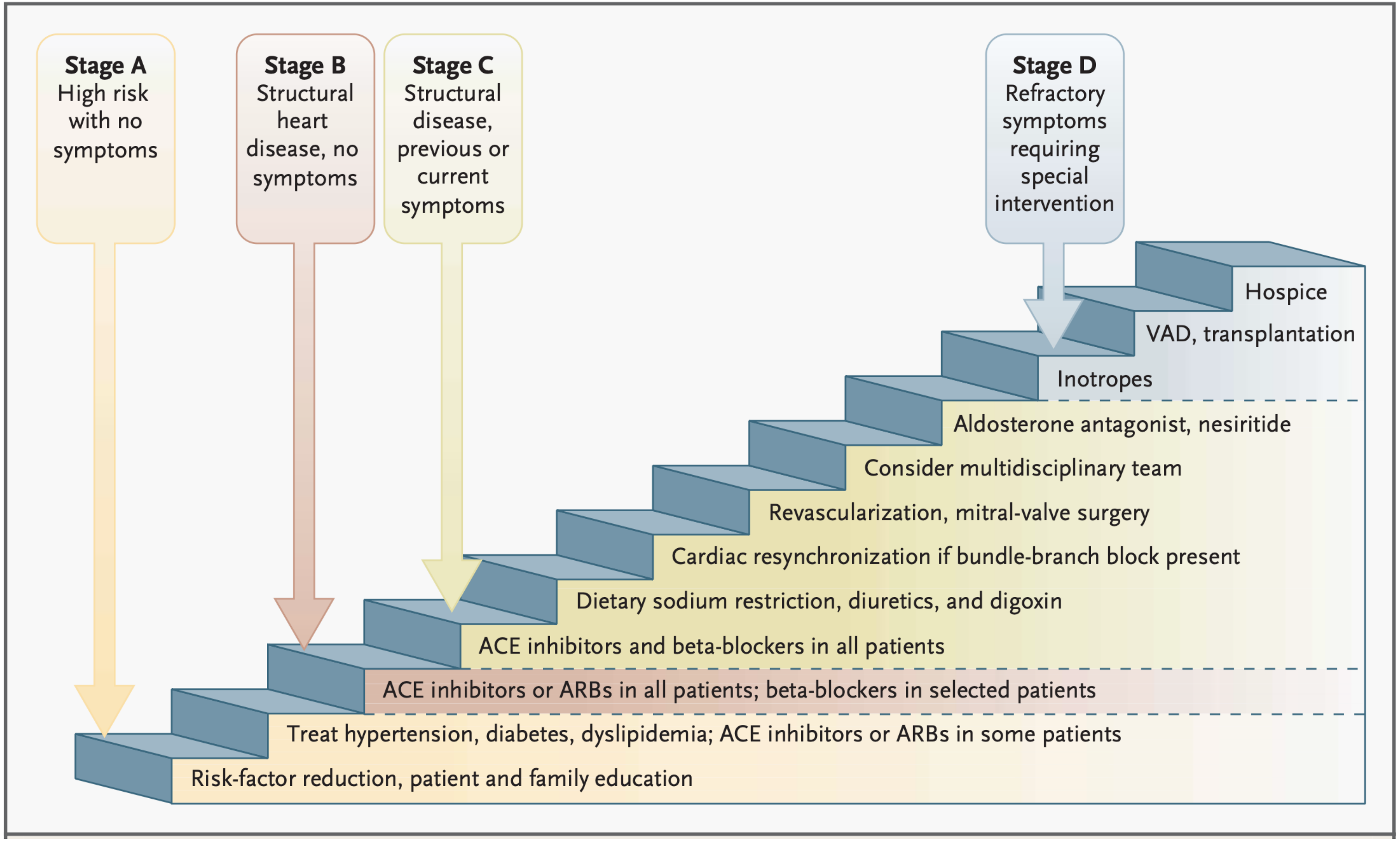
Patients with current or previous symptoms/signs of HF

STAGE D:
Advanced Heart Failure

Marked HF symptoms that interfere with daily life and with recurrent hospitalizations despite attempts to optimize GDMT

Heidenreich PA, et al. J Am Coll Cardiol. 2022 May 3;79(17):e263-e421.

Heart failure - treatment



Stage A
High risk with no symptoms

Stage B
Structural heart disease, no symptoms

Stage C
Structural disease, previous or current symptoms

Stage D
Refractory symptoms requiring special intervention

Hospice

VAD, transplantation

Inotropes

Aldosterone antagonist, nesiritide

Consider multidisciplinary team

Revascularization, mitral-valve surgery

Cardiac resynchronization if bundle-branch block present

Dietary sodium restriction, diuretics, and digoxin

ACE inhibitors and beta-blockers in all patients

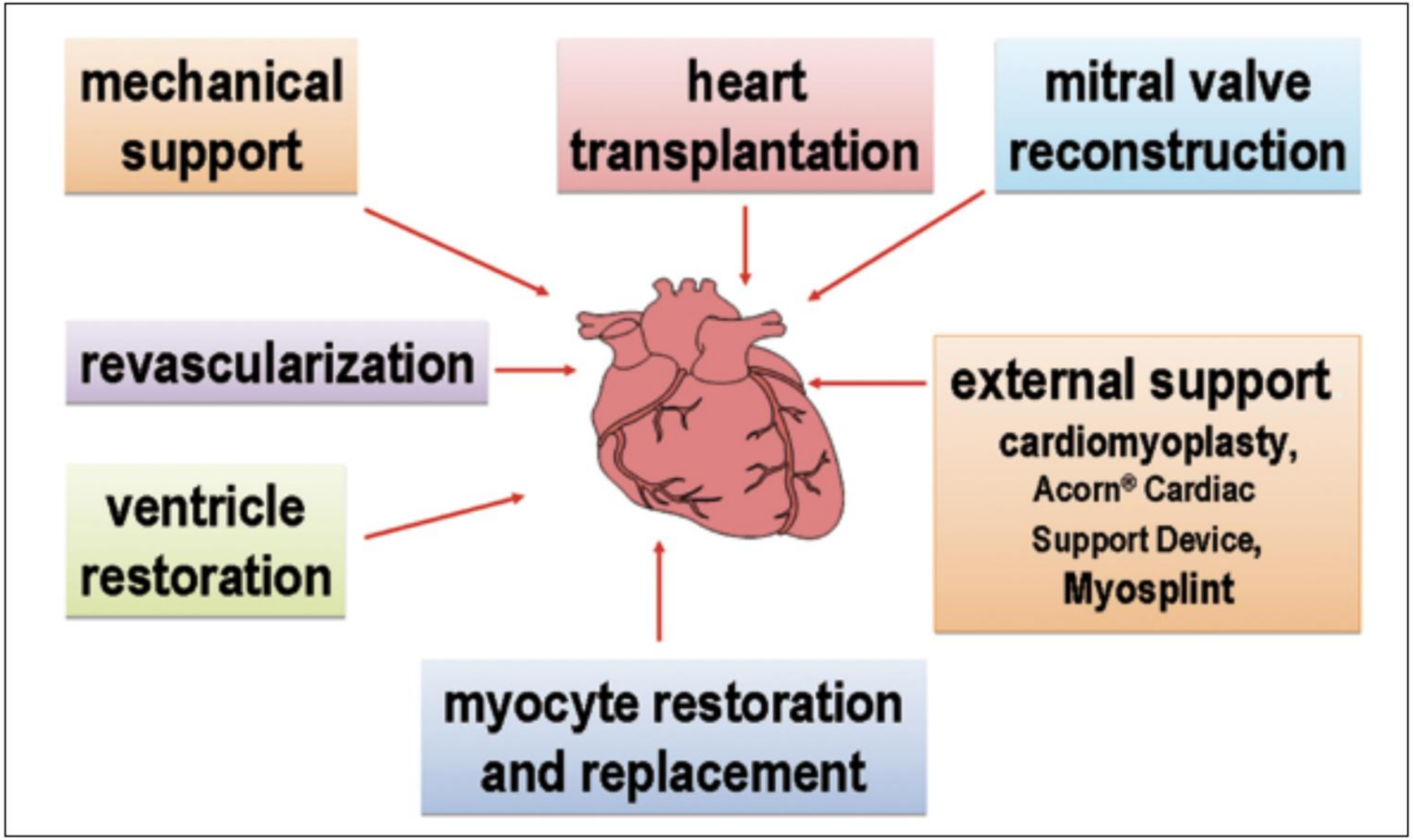
ACE inhibitors or ARBs in all patients; beta-blockers in selected patients

Treat hypertension, diabetes, dyslipidemia; ACE inhibitors or ARBs in some patients

Risk-factor reduction, patient and family education

Mariell Jessup & Susan Brozena. J N Engl J Med. 2003 May 15;348(20):2007-18.

Heart failure – Surgical treatment



mechanical support

heart transplantation

mitral valve reconstruction

revascularization

external support

cardiomyoplasty,
Acorn® Cardiac Support Device,
Myosplint

ventricle restoration

myocyte restoration and replacement

E M Delmo Walter & R Hetzer HSR Proc Intensive Care Cardiovasc Anesth. 2013;5(2):69-75.

INTERMACS Profiles

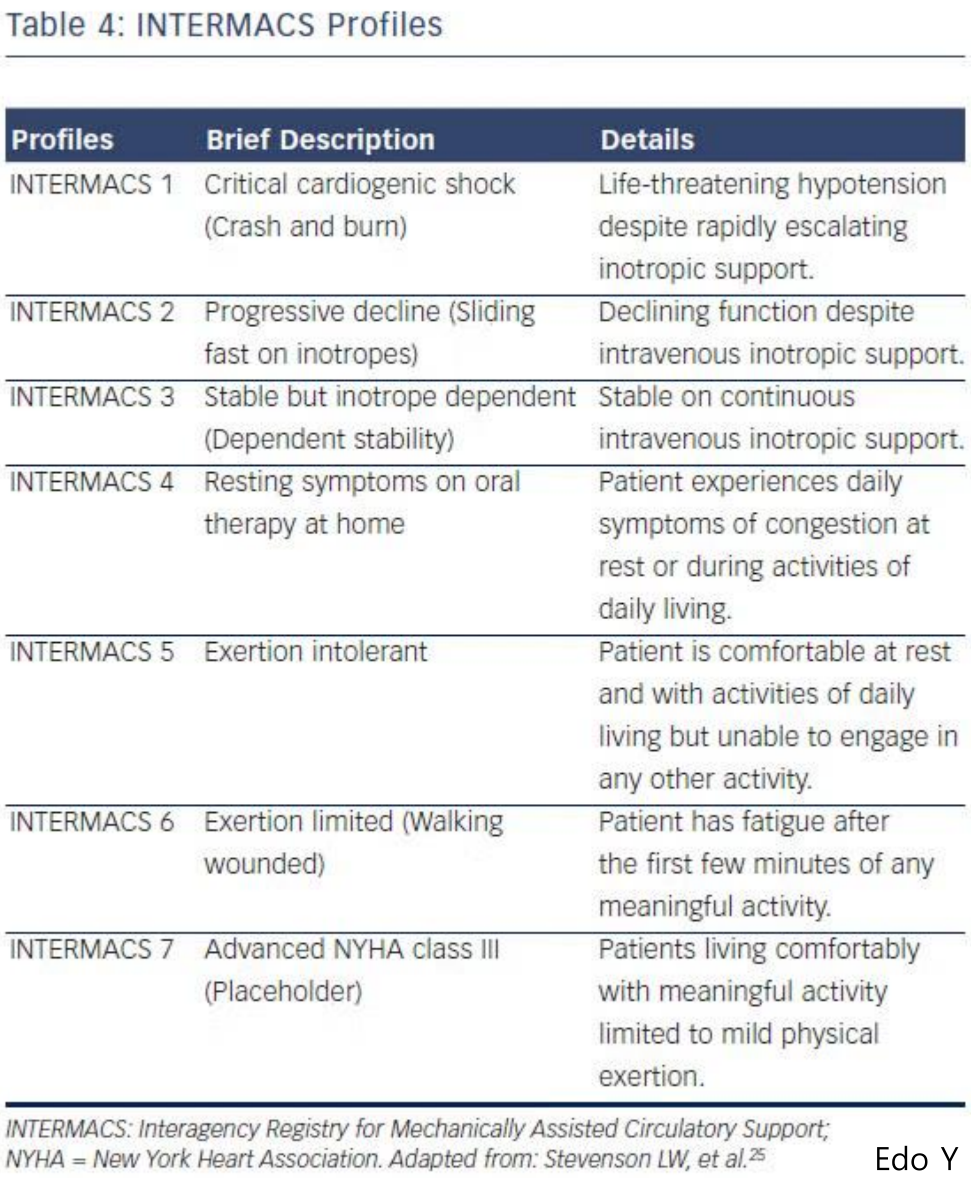


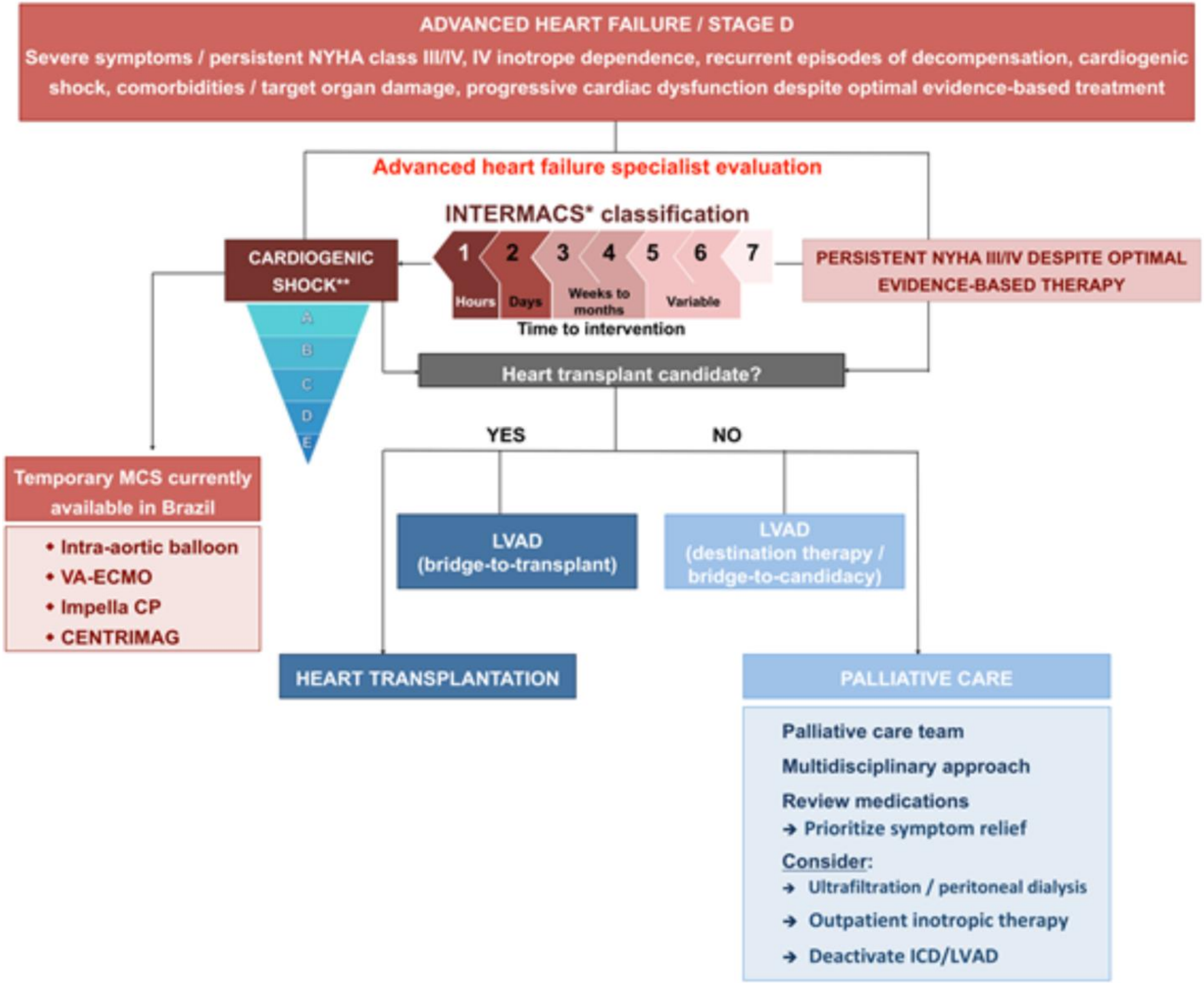
Table 4: INTERMACS Profiles

Profiles	Brief Description	Details
INTERMACS 1	Critical cardiogenic shock (Crash and burn)	Life-threatening hypotension despite rapidly escalating inotropic support.
INTERMACS 2	Progressive decline (Sliding fast on inotropes)	Declining function despite intravenous inotropic support.
INTERMACS 3	Stable but inotrope dependent (Dependent stability)	Stable on continuous intravenous inotropic support.
INTERMACS 4	Resting symptoms on oral therapy at home	Patient experiences daily symptoms of congestion at rest or during activities of daily living.
INTERMACS 5	Exertion intolerant	Patient is comfortable at rest and with activities of daily living but unable to engage in any other activity.
INTERMACS 6	Exertion limited (Walking wounded)	Patient has fatigue after the first few minutes of any meaningful activity.
INTERMACS 7	Advanced NYHA class III (Placeholder)	Patients living comfortably with meaningful activity limited to mild physical exertion.

INTERMACS: Interagency Registry for Mechanically Assisted Circulatory Support; NYHA = New York Heart Association. Adapted from: Stevenson LW, et al.[25]

Edo Y Birati, & Mariell Jessup Cardiac Failure Review 2015;1(1):25–30

Heart failure – Surgical treatment



ADVANCED HEART FAILURE / STAGE D

Severe symptoms / persistent NYHA class III/IV, IV inotrope dependence, recurrent episodes of decompensation, cardiogenic shock, comorbidities / target organ damage, progressive cardiac dysfunction despite optimal evidence-based treatment

Advanced heart failure specialist evaluation

INTERMACS* classification

CARDIOGENIC SHOCK**

PERSISTENT NYHA III/IV DESPITE OPTIMAL EVIDENCE-BASED THERAPY

Heart transplant candidate?

YES

NO

Temporary MCS currently available in Brazil

- Intra-aortic balloon
- VA-ECMO
- Impella CP
- CENTRIMAG

LVAD (bridge-to-transplant)

LVAD (destination therapy / bridge-to-candidacy)

HEART TRANSPLANTATION

PALLIATIVE CARE

Palliative care team

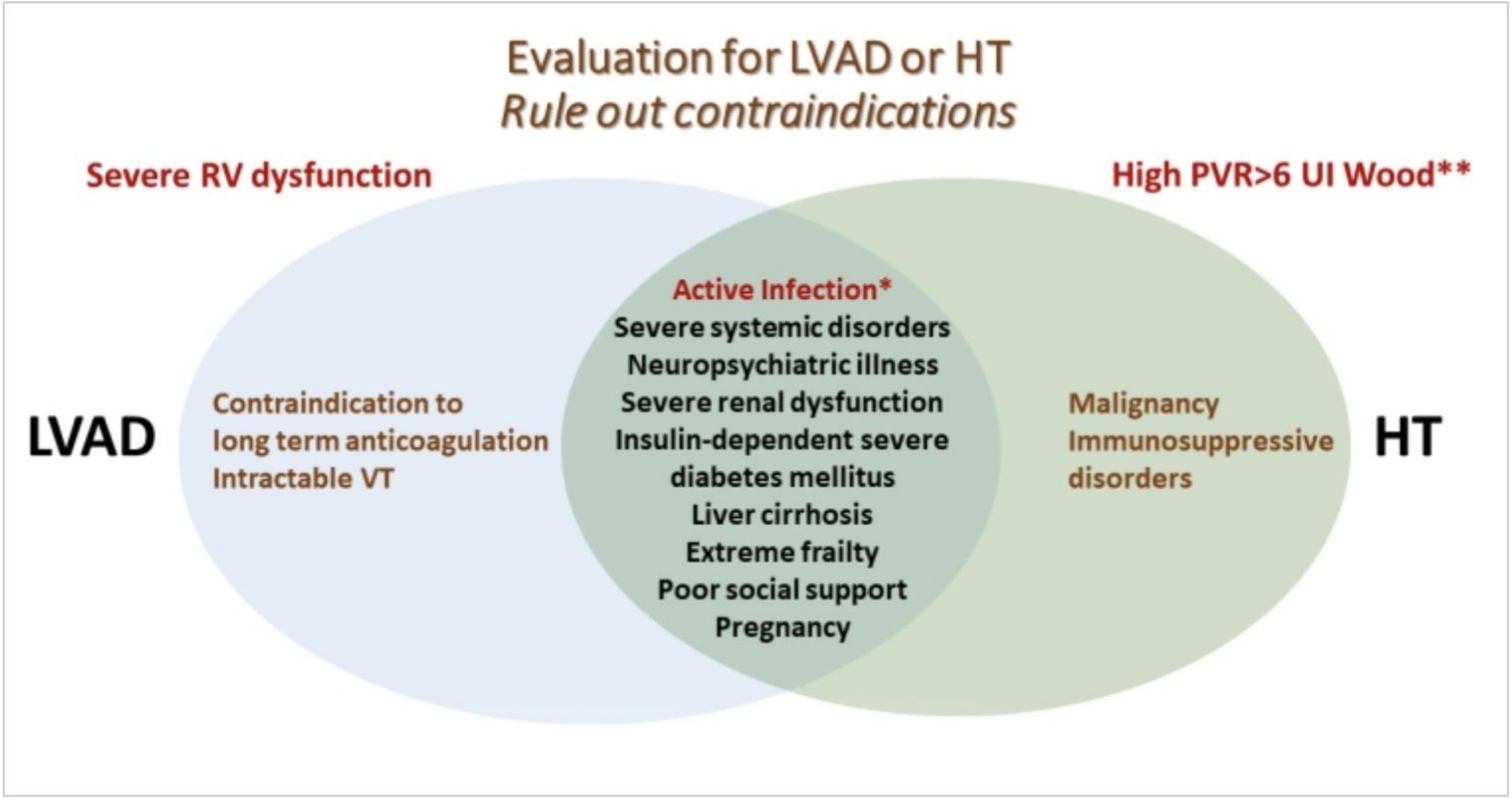
Multidisciplinary approach

Review medications
→ Prioritize symptom relief

Consider:
→ Ultrafiltration / peritoneal dialysis
→ Outpatient inotropic therapy
→ Deactivate ICD/LVAD

Oliveira MT Jr, et al. Arq Bras Cardiol. 2020 Dec;115(6):1193-1196.

Contraindication for LVAD or HT



Evaluation for LVAD or HT
Rule out contraindications

Severe RV dysfunction

High PVR>6 UI Wood**

LVAD

Contraindication to
long term anticoagulation
Intractable VT

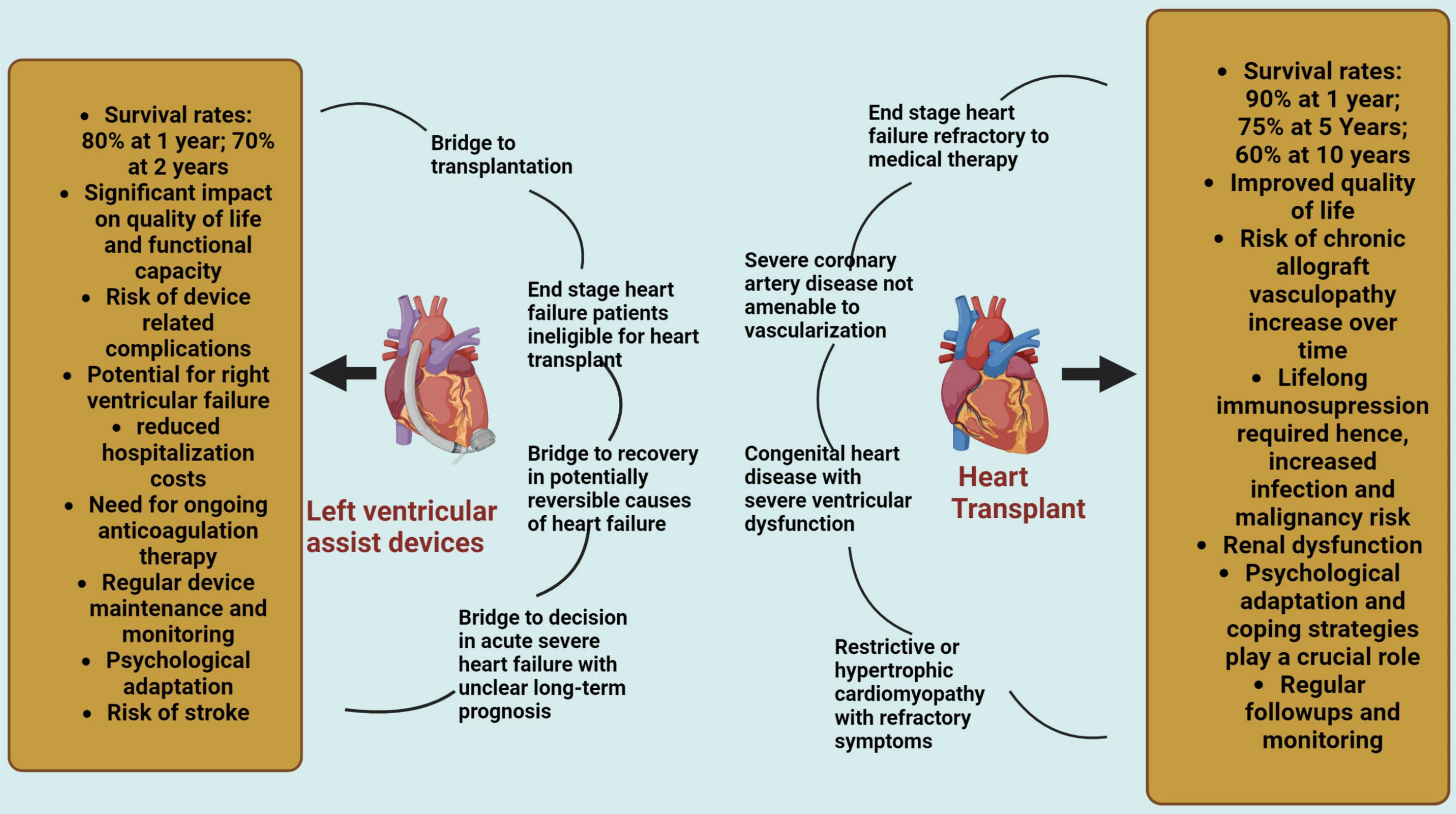
Active Infection*
Severe systemic disorders
Neuropsychiatric illness
Severe renal dysfunction
Insulin-dependent severe diabetes mellitus
Liver cirrhosis
Extreme frailty
Poor social support
Pregnancy

Malignancy
Immunosuppressive disorders

HT

https://www.escardio.org/Councils/Council-for-Cardiology-Practice-%28CCP%29/Cardiopractice/durable-therapies-in-advanced-chronic-heart-failure

Characteristic features of LVAD & HT



- Survival rates: 80% at 1 year; 70% at 2 years
- Significant impact on quality of life and functional capacity
- Risk of device related complications
- Potential for right ventricular failure
- reduced hospitalization costs
- Need for ongoing anticoagulation therapy
- Regular device maintenance and monitoring
- Psychological adaptation
- Risk of stroke

Left ventricular assist devices

Bridge to transplantation

End stage heart failure patients ineligible for heart transplant

Bridge to recovery in potentially reversible causes of heart failure

Bridge to decision in acute severe heart failure with unclear long-term prognosis

End stage heart failure refractory to medical therapy

Severe coronary artery disease not amenable to vascularization

Congenital heart disease with severe ventricular dysfunction

Restrictive or hypertrophic cardiomyopathy with refractory symptoms

Heart Transplant

- Survival rates: 90% at 1 year; 75% at 5 Years; 60% at 10 years
- Improved quality of life
- Risk of chronic allograft vasculopathy increase over time
- Lifelong immunosupression required hence, increased infection and malignancy risk
- Renal dysfunction
- Psychological adaptation and coping strategies play a crucial role
- Regular followups and monitoring

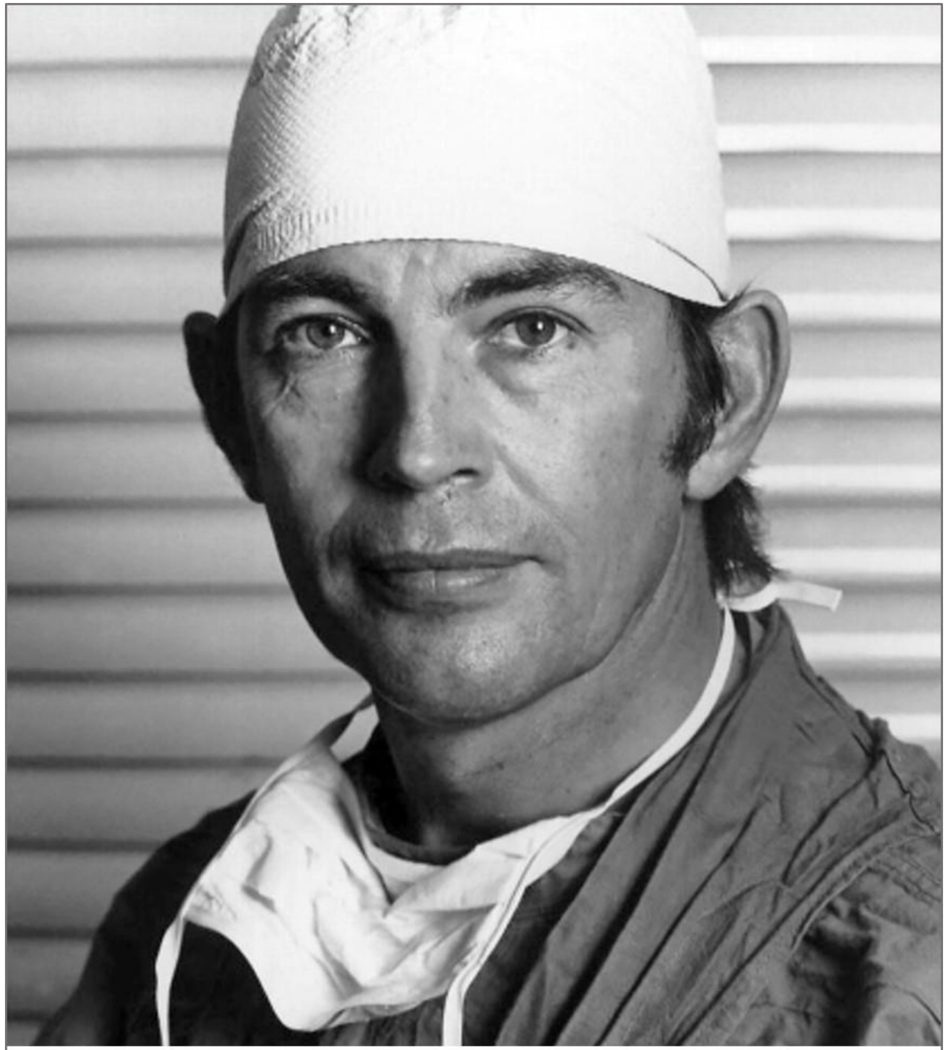
Lakhani HA, et al. Cureus. 2024 Sep 5;16(9):e68691.

Heart transplantation

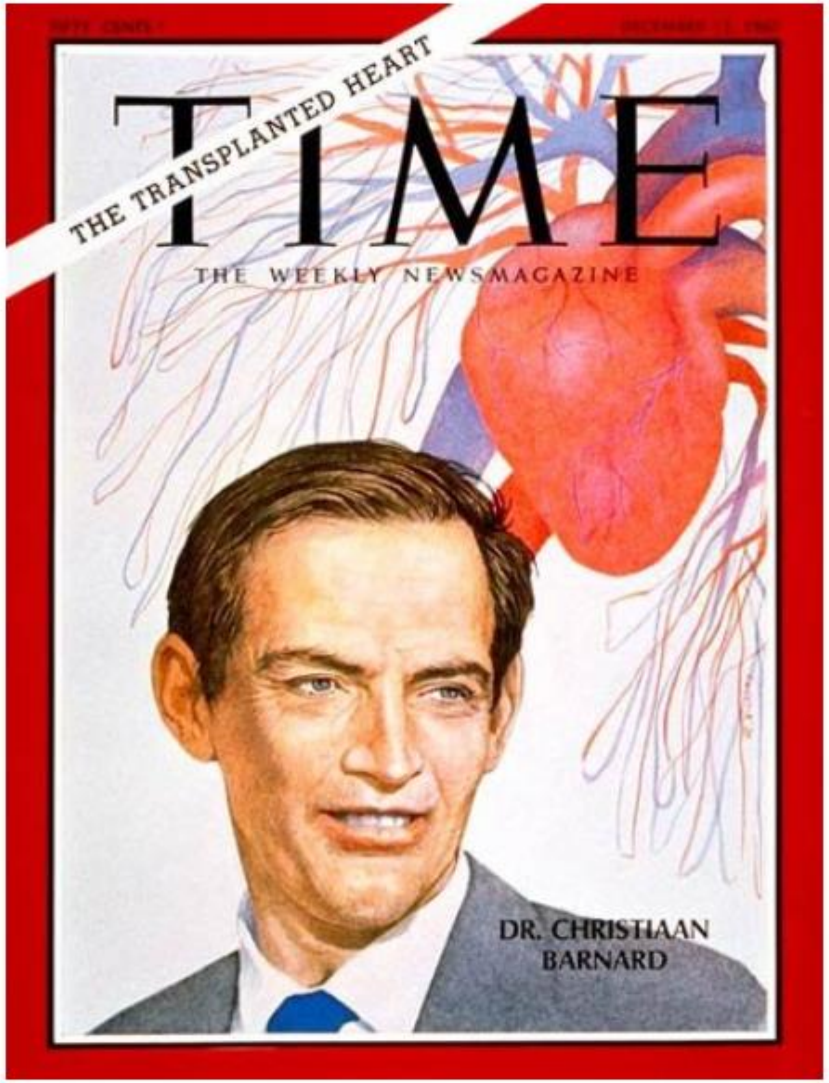
History of heart transplantation

1964	James Hardy (the University of Mississippi)	The first human cardiac transplant (chimpanzee xenograft)
1967	Christiaan Barnard (South Africa)	The first human-to-human heart transplant
1967	Adrian Kantrowitz (Maimonides Hospital in Brooklyn)	The first pediatric heart transplant
1968	Norman Shumway (Stanford)	The first adult heart transplant in the United States
1992	Myung-geun Song (AMC)	The first heart transplant in Korea

First human heart transplantation



Chris Barnard (1922 – 2001) was 45 years old when his heart transplant breakthrough made him world famous.
Source: Heart of Cape Town Museum


THE TRANSPLANTED HEART
TIME
THE WEEKLY NEWSMAGAZINE
DR. CHRISTIAAN BARNARD

The Dec. 15, 1967, cover of TIME TIME

Heart transplantation - indication

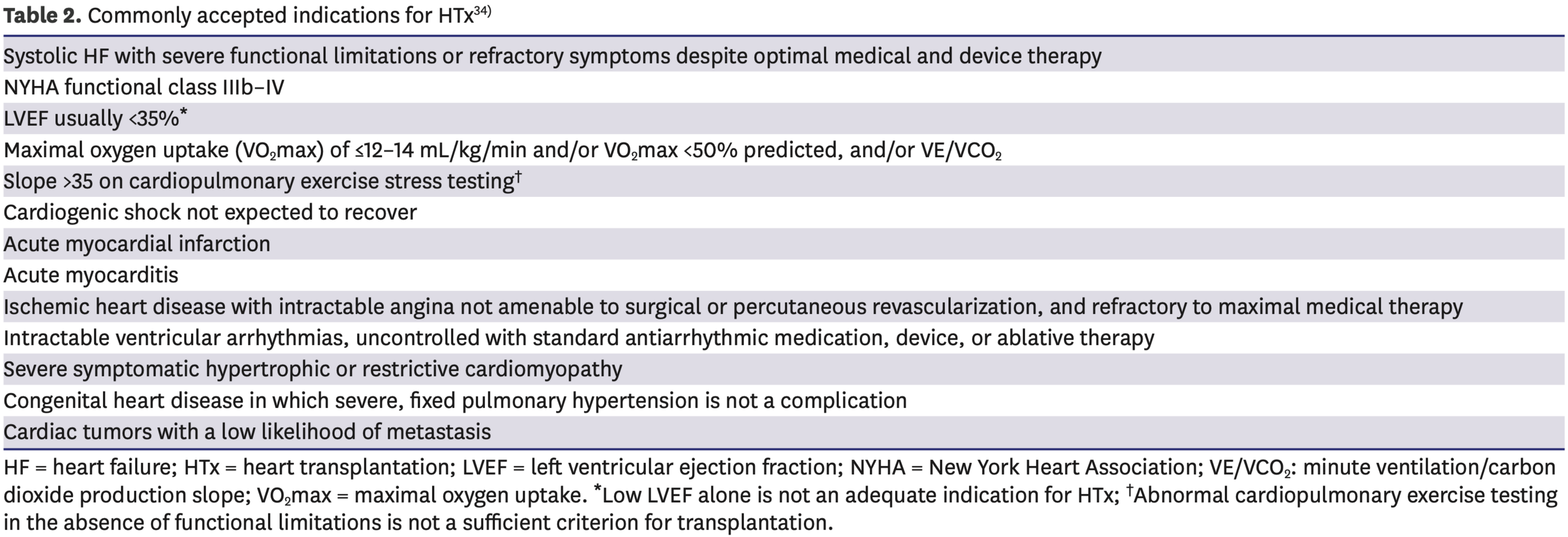


Table 2. Commonly accepted indications for HTx[34)]

Systolic HF with severe functional limitations or refractory symptoms despite optimal medical and device therapy
NYHA functional class IIIb–IV
LVEF usually <35%*
Maximal oxygen uptake (VO_2max) of ≤12–14 mL/kg/min and/or VO_2max <50% predicted, and/or VE/VCO_2
Slope >35 on cardiopulmonary exercise stress testing†
Cardiogenic shock not expected to recover
Acute myocardial infarction
Acute myocarditis
Ischemic heart disease with intractable angina not amenable to surgical or percutaneous revascularization, and refractory to maximal medical therapy
Intractable ventricular arrhythmias, uncontrolled with standard antiarrhythmic medication, device, or ablative therapy
Severe symptomatic hypertrophic or restrictive cardiomyopathy
Congenital heart disease in which severe, fixed pulmonary hypertension is not a complication
Cardiac tumors with a low likelihood of metastasis

HF = heart failure; HTx = heart transplantation; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; VE/VCO_2: minute ventilation/carbon dioxide production slope; VO_2max = maximal oxygen uptake. *Low LVEF alone is not an adequate indication for HTx; †Abnormal cardiopulmonary exercise testing in the absence of functional limitations is not a sufficient criterion for transplantation.

Kim IC, et al. Korean Circ J. 2018 Jul;48(7):565-590.

Heart transplantation - contraindication

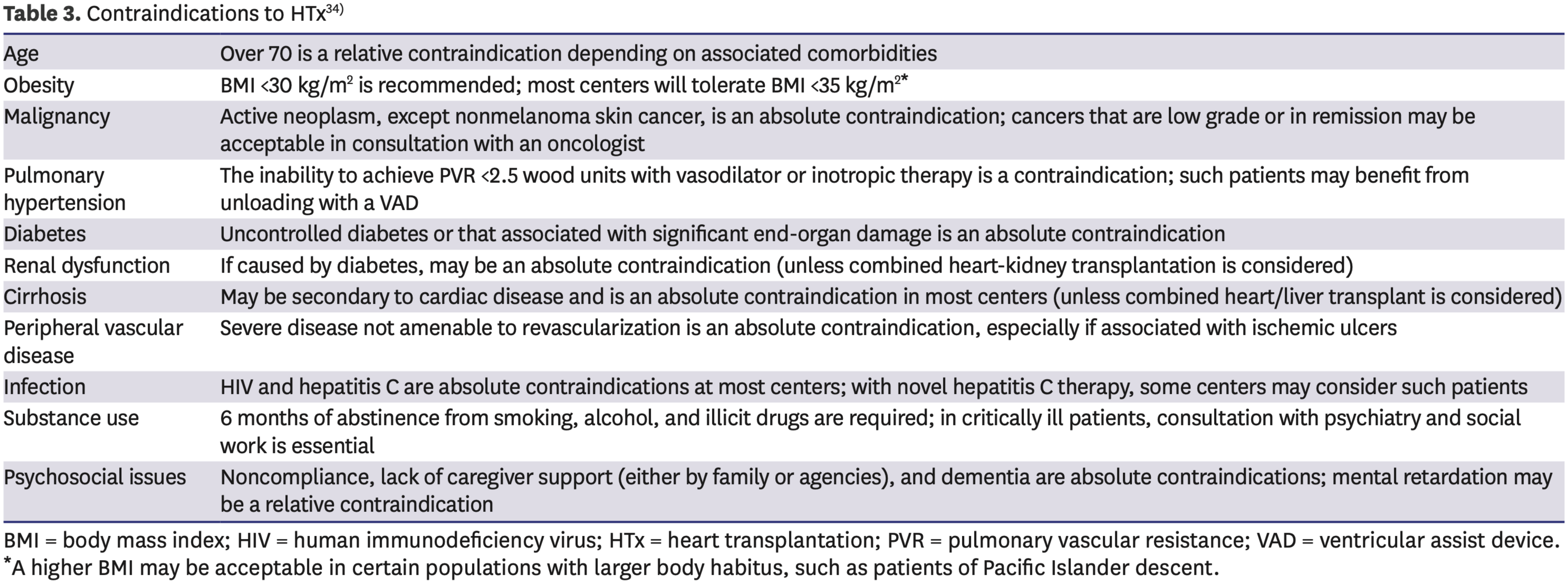


Table 3. Contraindications to HTx34)

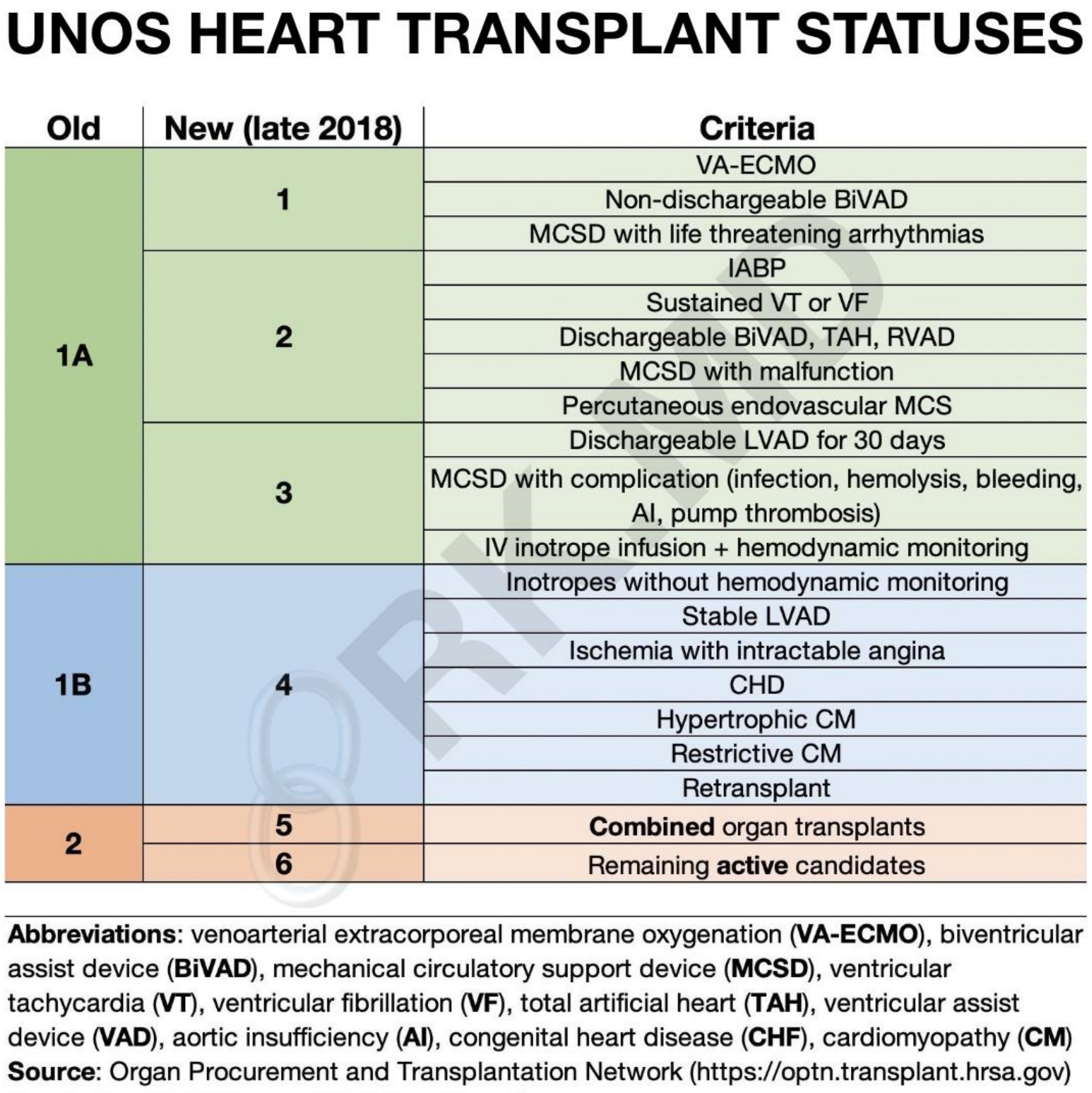
Age	Over 70 is a relative contraindication depending on associated comorbidities
Obesity	BMI <30 kg/m^2 is recommended; most centers will tolerate BMI <35 kg/m^{2*}
Malignancy	Active neoplasm, except nonmelanoma skin cancer, is an absolute contraindication; cancers that are low grade or in remission may be acceptable in consultation with an oncologist
Pulmonary hypertension	The inability to achieve PVR <2.5 wood units with vasodilator or inotropic therapy is a contraindication; such patients may benefit from unloading with a VAD
Diabetes	Uncontrolled diabetes or that associated with significant end-organ damage is an absolute contraindication
Renal dysfunction	If caused by diabetes, may be an absolute contraindication (unless combined heart-kidney transplantation is considered)
Cirrhosis	May be secondary to cardiac disease and is an absolute contraindication in most centers (unless combined heart/liver transplant is considered)
Peripheral vascular disease	Severe disease not amenable to revascularization is an absolute contraindication, especially if associated with ischemic ulcers
Infection	HIV and hepatitis C are absolute contraindications at most centers; with novel hepatitis C therapy, some centers may consider such patients
Substance use	6 months of abstinence from smoking, alcohol, and illicit drugs are required; in critically ill patients, consultation with psychiatry and social work is essential
Psychosocial issues	Noncompliance, lack of caregiver support (either by family or agencies), and dementia are absolute contraindications; mental retardation may be a relative contraindication

BMI = body mass index; HIV = human immunodeficiency virus; HTx = heart transplantation; PVR = pulmonary vascular resistance; VAD = ventricular assist device.

*A higher BMI may be acceptable in certain populations with larger body habitus, such as patients of Pacific Islander descent.

Kim IC, et al. Korean Circ J. 2018 Jul;48(7):565-590.

Heart transplantation – Allocation system



UNOS HEART TRANSPLANT STATUSES

Old	New (late 2018)	Criteria
1A	1	VA-ECMO
		Non-dischargeable BiVAD
		MCSD with life threatening arrhythmias
	2	IABP
		Sustained VT or VF
		Dischargeable BiVAD, TAH, RVAD
		MCSD with malfunction
		Percutaneous endovascular MCS
	3	Dischargeable LVAD for 30 days
		MCSD with complication (infection, hemolysis, bleeding, AI, pump thrombosis)
		IV inotrope infusion + hemodynamic monitoring
1B	4	Inotropes without hemodynamic monitoring
		Stable LVAD
		Ischemia with intractable angina
		CHD
		Hypertrophic CM
		Restrictive CM
		Retransplant
2	5	**Combined** organ transplants
	6	Remaining **active** candidates

Abbreviations: venoarterial extracorporeal membrane oxygenation (**VA-ECMO**), biventricular assist device (**BiVAD**), mechanical circulatory support device (**MCSD**), ventricular tachycardia (**VT**), ventricular fibrillation (**VF**), total artificial heart (**TAH**), ventricular assist device (**VAD**), aortic insufficiency (**AI**), congenital heart disease (**CHF**), cardiomyopathy (**CM**)
Source: Organ Procurement and Transplantation Network (https://optn.transplant.hrsa.gov)

https://rk.md/2019/united-network-for-organ-sharing-unos-2018-heart-transplant-listing-guidelines-revision/

심장이식 응급도

구분	심장 응급도 기준
응급도 0	다음 중 한 가지 이상 해당하여야 한다.(8일 이내 재등록) ① 체외막형 심페기(V-A ECMO) 가동중인 환자 ② 중환자실에서 심부전으로 인해 인공 호흡기를 부착하고 있는 환자 ③ 삽입형 심실조력장치(VAD)를 가진 환자가 심각한 합병증으로 중환자실에 입실하는 경우 ④비삽입형 심실조력장치(VAD)
응급도 1	입원한 환자로 등록일 기준으로 다음 한가지 이상 해당하여야 한다. 단, 2) 의 경우는 입원하지 않은 환자도 포함한다 (8일 이내 재등록) ① 인공심장(Artificial heart) ② 심실조력 장치 (VAD) ③ 대동맥내 풍선 펌프(IABP) ④ 연속적으로 4주 이상 정맥내 강심제 투여중인 환자 ⑤ 최소 1주 이상 고용량의 단일 정맥내 강심제 또는 두가지 이상의 중증도 이상 용량의 정맥내 강심제가 필요한 경우 ⑥ 지속성 심실빈맥/심실세동이 자주 반복되거나 심실 제세동기(ICD)가 자주 작동하는 경우 * 항부정맥제를 사용중이거나 부정맥 시술을 시행했던 경우로 24시간 이내 3회 혹은 그 이상의 심실빈맥/심실세동이 나타나거나 ICD가 3회 혹은 그 이상 작용한 경우(재신청 기간 내에 3회 이상 나타난 경우)
응급도 2	**다음 중 한 가지 이상 해당하여야 한다 (30일 이내 재등록)** **① 등록일 기준으로 최소 1주 이상 정맥 내 강심제 투여 중이나 응급되의 기준에 맞지 않는 경우** **② 항부정맥제를 사용중이거나 부정맥 시술을 시행했던 경우로 심실빈맥/심실세동이 나타나거나 ICD가 작동한 경우**
응급도 3	**응급도 0,1,2에 해당하지 않는 경우**
응급도 4	**- 심장이식 대기 보류인 상태**

심장이식 응급도

사) 심장 응급도 예외 심의위원회 운영

(1) **응급도 기준에 해당하지 않는 부득이한 사유**가 있는 경우 또는 **75세 이상** 이식대기 자의 **응급도를 0**으로 재등록하려는 경우는 심장 응급도 예외 심의위원회를 통해 응급도를 인정할 수 있다. 심의대상은 다음과 같다.

① 중증 심부전 상태이나 의학적 사유로 **심실보조장치 적용이 불가능**하거나 **심실보조 장치의 성공률이 매우 낮을 것으로 추정되는 경우**(선천성 심기형, 비후성 심근증, 아밀로이드 심근증, 불응성 심실 부정맥, 제한성 심근증, 부정맥 유발성 우심실심 근병증 등)

② **75세 이상 이식대기자**의 응급도 0으로 재등록하려는 경우

* 75세 이상 이식대기자는 응급도 0으로 재등록하기 위해서는 소견을 충실히 작성하여 예외 심의위원회 인정을 받아야 하며, 그렇지 않으면 응급도 3으로 변환됨

(2) 응급도 심의를 통해 한 단계 상향만 가능하다.

(3) 예외 응급도를 인정한 경우 대기기간은 응급도 0은 16일, 응급도 1은 60일, 응급도 2는 90일 인정하고, 그 이후 다시 인정받고자 하는 경우 사전에 재심의를 요청해야 함

(4) 운영 세부 사항은 심장•폐 분야 전문가 자문단에서 결정한다.

Acceptable Heart Donor

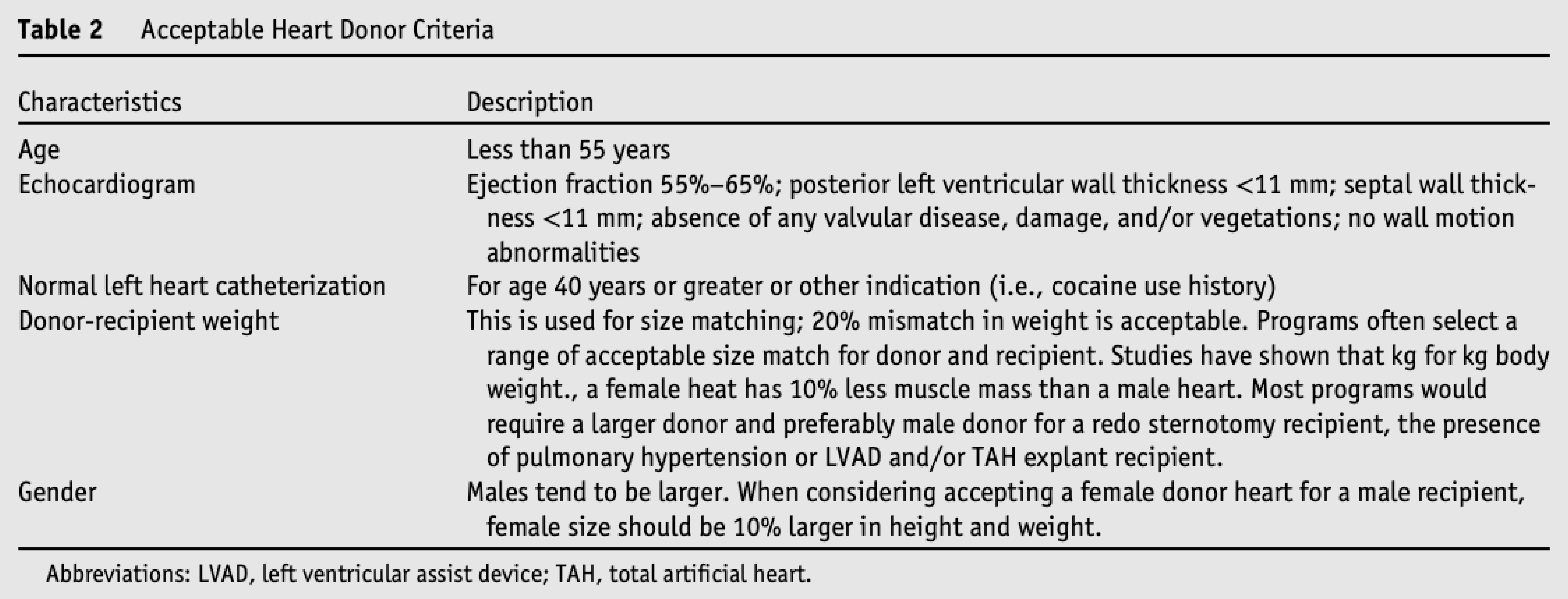


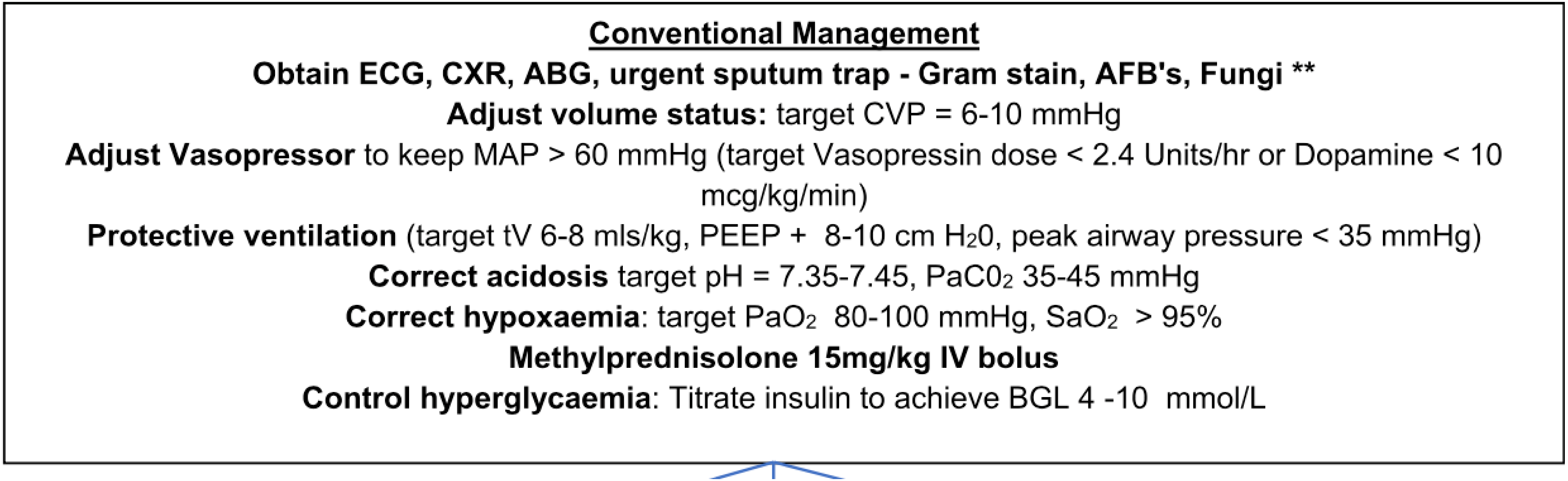
Table 2 Acceptable Heart Donor Criteria

Characteristics	Description
Age	Less than 55 years
Echocardiogram	Ejection fraction 55%–65%; posterior left ventricular wall thickness <11 mm; septal wall thickness <11 mm; absence of any valvular disease, damage, and/or vegetations; no wall motion abnormalities
Normal left heart catheterization	For age 40 years or greater or other indication (i.e., cocaine use history)
Donor-recipient weight	This is used for size matching; 20% mismatch in weight is acceptable. Programs often select a range of acceptable size match for donor and recipient. Studies have shown that kg for kg body weight., a female heat has 10% less muscle mass than a male heart. Most programs would require a larger donor and preferably male donor for a redo sternotomy recipient, the presence of pulmonary hypertension or LVAD and/or TAH explant recipient.
Gender	Males tend to be larger. When considering accepting a female donor heart for a male recipient, female size should be 10% larger in height and weight.

Abbreviations: LVAD, left ventricular assist device; TAH, total artificial heart.

Copeland H, et al. J Heart Lung Transplant. 2020 Jun;39(6):501-517.

Donor Heart Management



Conventional Management

Obtain ECG, CXR, ABG, urgent sputum trap - Gram stain, AFB's, Fungi **

Adjust volume status: target CVP = 6-10 mmHg

Adjust Vasopressor to keep MAP > 60 mmHg (target Vasopressin dose < 2.4 Units/hr or Dopamine < 10 mcg/kg/min)

Protective ventilation (target tV 6-8 mls/kg, PEEP + 8-10 cm H_20, peak airway pressure < 35 mmHg)

Correct acidosis target pH = 7.35-7.45, $PaC0_2$ 35-45 mmHg

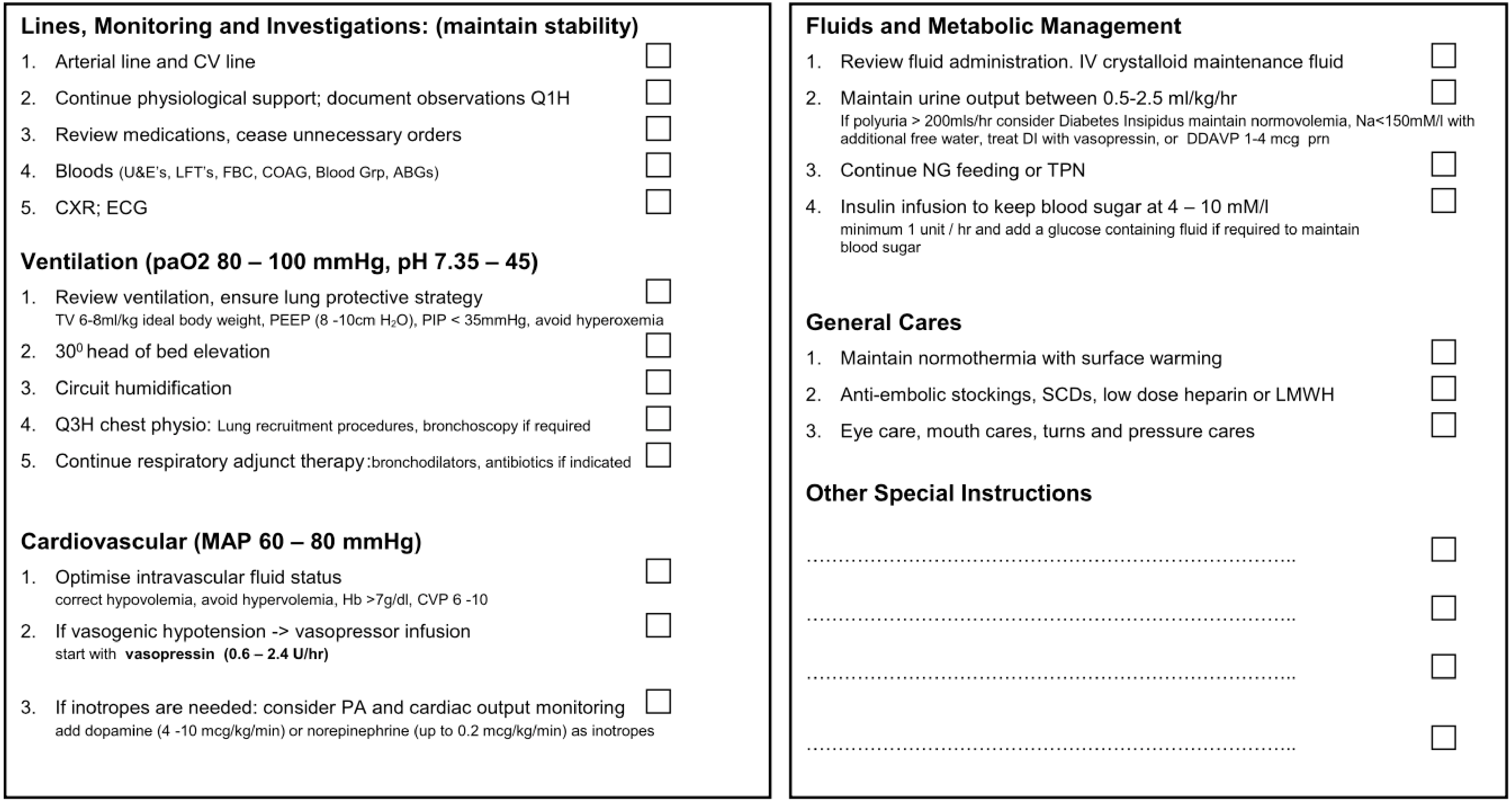
Correct hypoxaemia: target PaO_2 80-100 mmHg, SaO_2 > 95%

Methylprednisolone 15mg/kg IV bolus

Control hyperglycaemia: Titrate insulin to achieve BGL 4 -10 mmol/L

Copeland H, et al. J Heart Lung Transplant. 2020 Jun;39(6):501-517.

Donor Heart Management



Lines, Monitoring and Investigations: (maintain stability)

1. Arterial line and CV line ☐
2. Continue physiological support; document observations Q1H ☐
3. Review medications, cease unnecessary orders ☐
4. Bloods (U&E's, LFT's, FBC, COAG, Blood Grp, ABGs) ☐
5. CXR; ECG ☐

Ventilation (paO2 80 – 100 mmHg, pH 7.35 – 45)

1. Review ventilation, ensure lung protective strategy ☐
   TV 6-8ml/kg ideal body weight, PEEP (8 -10cm H_2O), PIP < 35mmHg, avoid hyperoxemia
2. 30^0 head of bed elevation ☐
3. Circuit humidification ☐
4. Q3H chest physio: Lung recruitment procedures, bronchoscopy if required ☐
5. Continue respiratory adjunct therapy :bronchodilators, antibiotics if indicated ☐

Cardiovascular (MAP 60 – 80 mmHg)

1. Optimise intravascular fluid status ☐
   correct hypovolemia, avoid hypervolemia, Hb >7g/dl, CVP 6 -10
2. If vasogenic hypotension -> vasopressor infusion ☐
   start with **vasopressin (0.6 – 2.4 U/hr)**
3. If inotropes are needed: consider PA and cardiac output monitoring ☐
   add dopamine (4 -10 mcg/kg/min) or norepinephrine (up to 0.2 mcg/kg/min) as inotropes

Fluids and Metabolic Management

1. Review fluid administration. IV crystalloid maintenance fluid ☐
2. Maintain urine output between 0.5-2.5 ml/kg/hr ☐
   If polyuria > 200mls/hr consider Diabetes Insipidus maintain normovolemia, Na<150mM/l with additional free water, treat DI with vasopressin, or DDAVP 1-4 mcg prn
3. Continue NG feeding or TPN ☐
4. Insulin infusion to keep blood sugar at 4 – 10 mM/l ☐
   minimum 1 unit / hr and add a glucose containing fluid if required to maintain blood sugar

General Cares

1. Maintain normothermia with surface warming ☐
2. Anti-embolic stockings, SCDs, low dose heparin or LMWH ☐
3. Eye care, mouth cares, turns and pressure cares ☐

Other Special Instructions

…………………………………………………………………………… ☐

…………………………………………………………………………… ☐

…………………………………………………………………………… ☐

…………………………………………………………………………… ☐

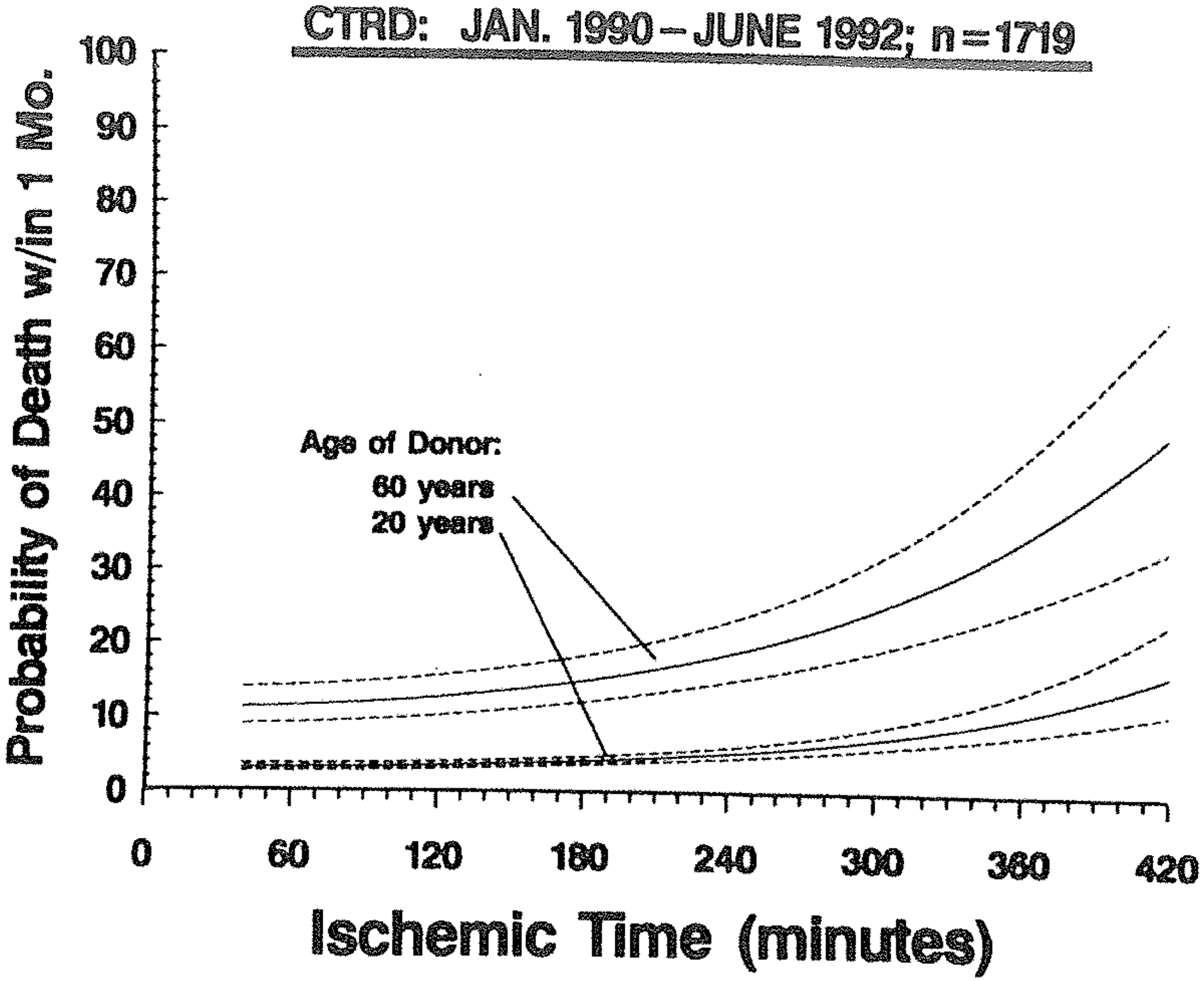
Copeland H, et al. J Heart Lung Transplant. 2020 Jun;39(6):501-517.

Donor Heart Procurement

- **Communication**
  - The timing of the dissection and excision of organs
  - Donor status
    - Stable – complete preliminary dissection
    - Unstable – should move expeditiously
  - Anatomic boundaries between organs
  - Disagreement
    - Where to divide the LA
    - Where to divide the MPA
    - Where and how to vent the heart
    - The level of IVC transection

Copeland H, et al. J Heart Lung Transplant. 2020 Jun;39(6):501-517.

Heart transplantation - donor



Young et al. J Heart Lung Transplant 1994;13(3):353-64

Donor Heart Procurement

- **Timing**
  - A member of the procurement team should contact **the transplant center**
    - On **arrival** at the donor hospital.
    - When the **donor arrives** in the OR.
    - At the completion of the heart and/or lung **evaluation**
    - With an **estimated time** of donor heparin administration
    - Administration of heparin → Receive confirmation
    - The aortic cross-clamp → Receive confirmation
    - **On departure** from the donor hospital, with **an estimated time** of the organ arriving at the transplant center.
    - **Fifteen minutes before** the organ reaches the transplant center

Copeland H, et al. J Heart Lung Transplant. 2020 Jun;39(6):501-517.

Donor Heart Preservation

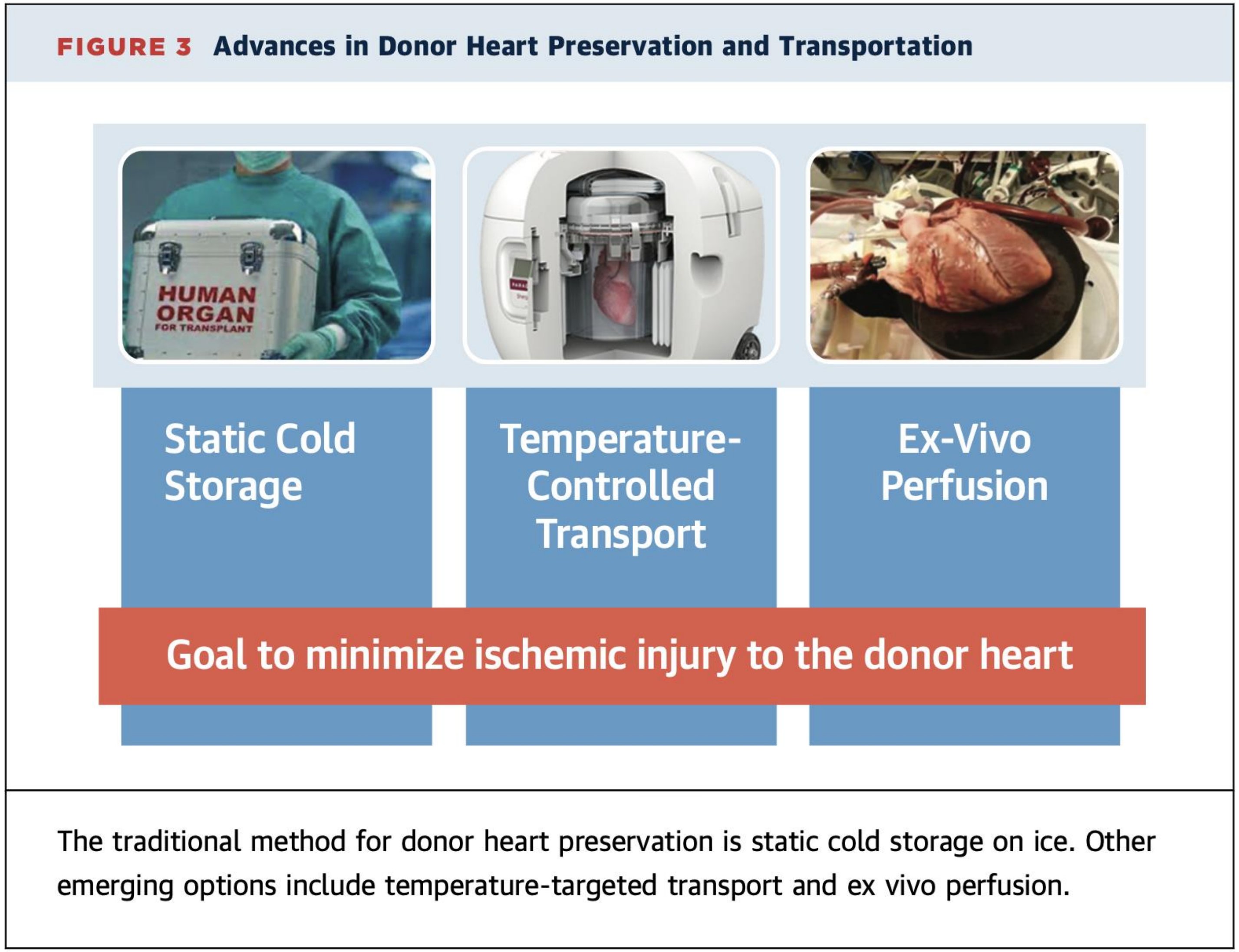


FIGURE 3 **Advances in Donor Heart Preservation and Transportation**

HUMAN
ORGAN
FOR TRANSPLANT

Static Cold Storage

Temperature-Controlled Transport

Ex-Vivo Perfusion

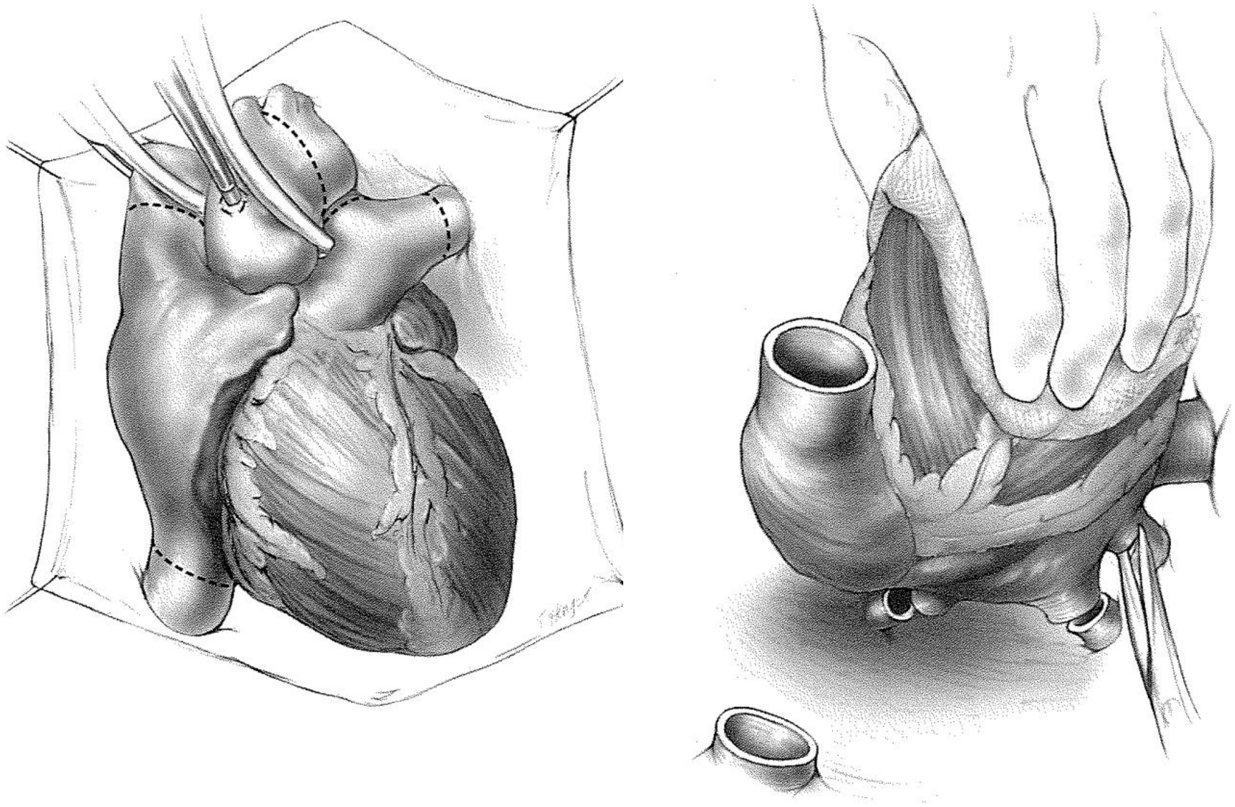
Goal to minimize ischemic injury to the donor heart

The traditional method for donor heart preservation is static cold storage on ice. Other emerging options include temperature-targeted transport and ex vivo perfusion.

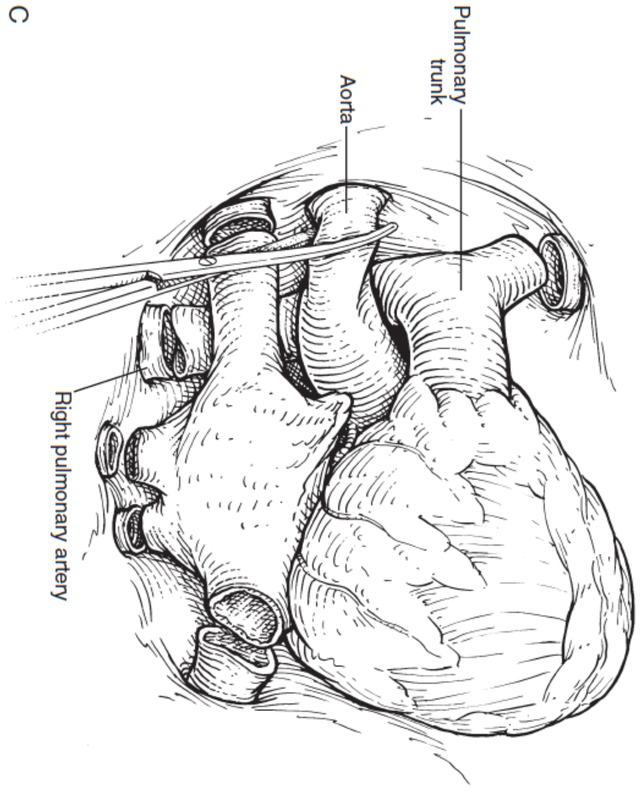
DeFilippis EM, et al. J Am Coll Cardiol. 2022 Mar 22;79(11):1108-1123.

Donor Heart Procurement

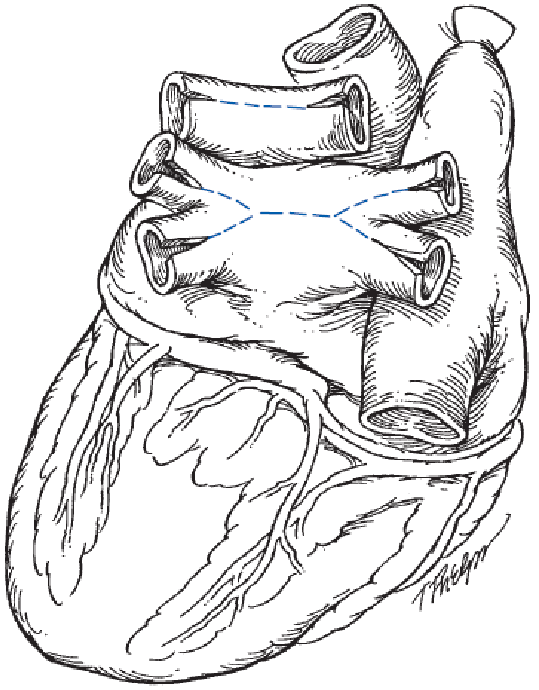
Heart Procurement Procedure (Heart donation only)



Siavosh Konsari, Cardiac surgery, Safeguard and pitfalls in operative Technique, 4th ed. 2008


C
Pulmonary trunk
Aorta
Right pulmonary artery

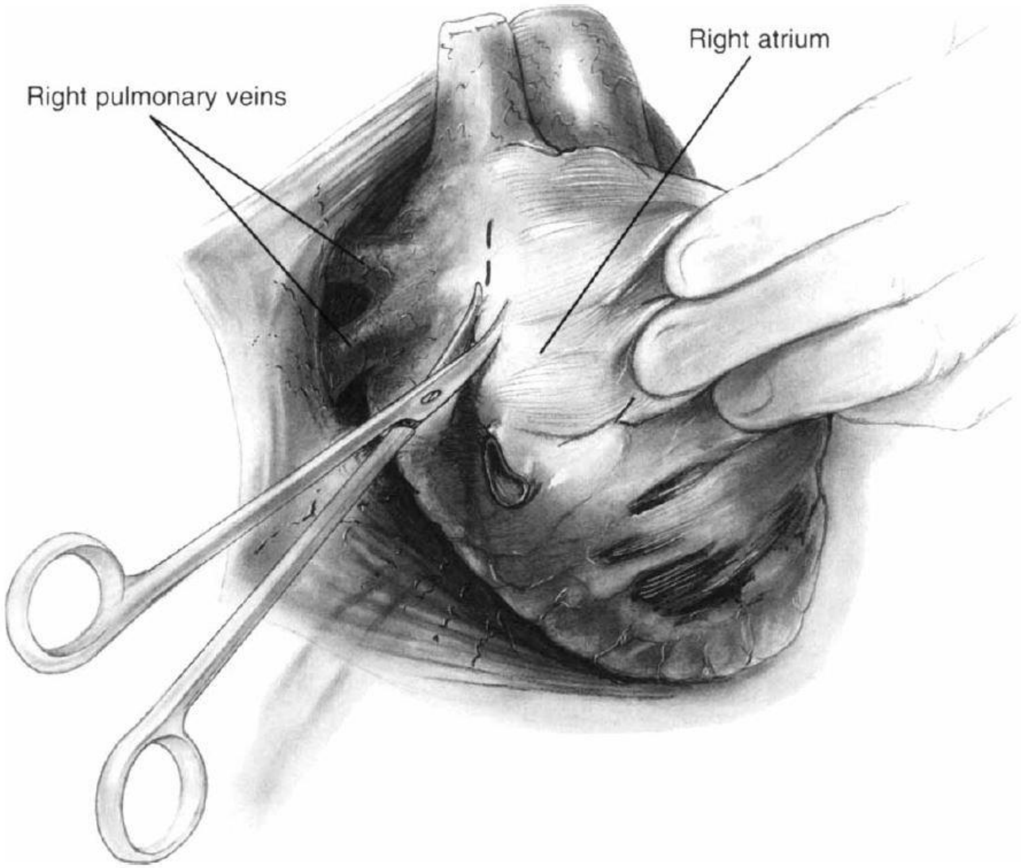
Nicholas T. Kouchoukos, Kirklin/Barratt-Boyes Cardiac Surgery, 4th ed. 2012

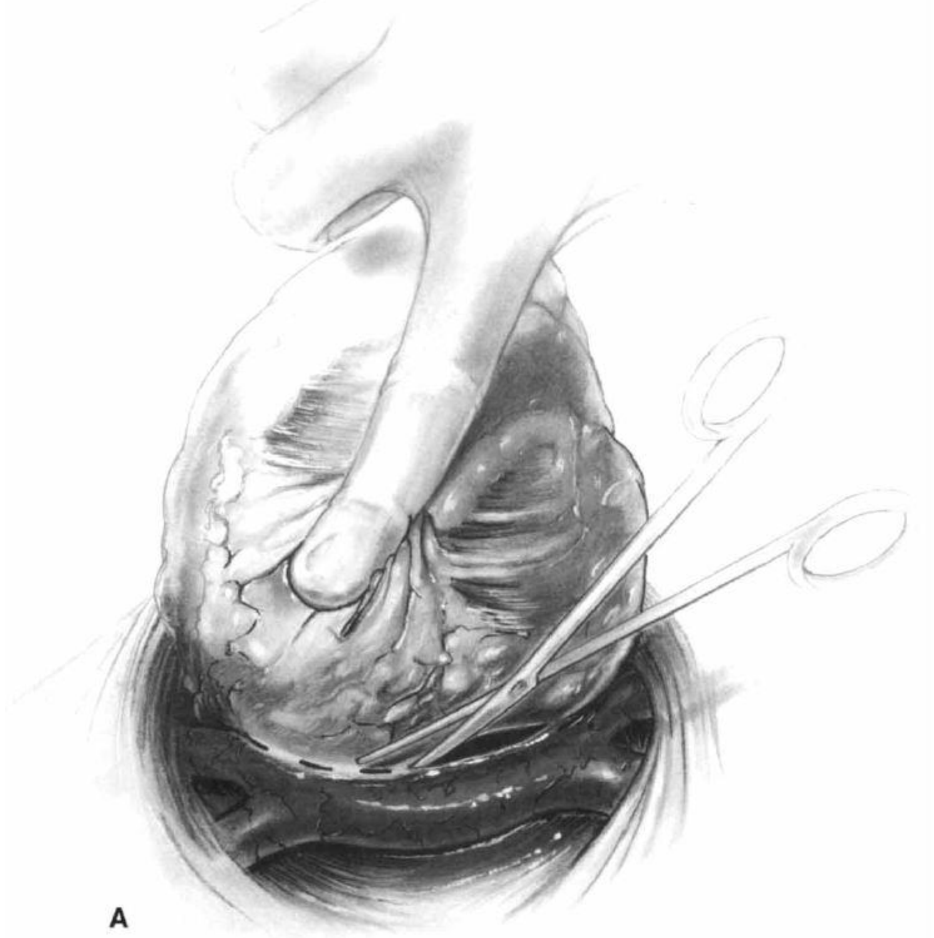


Lawrence H.Cohn, Cardiac surgery in the Adult, 3rd ed. 2008

Donor Heart Procurement

Heart Procurement Procedure (Heart and Lung donation)

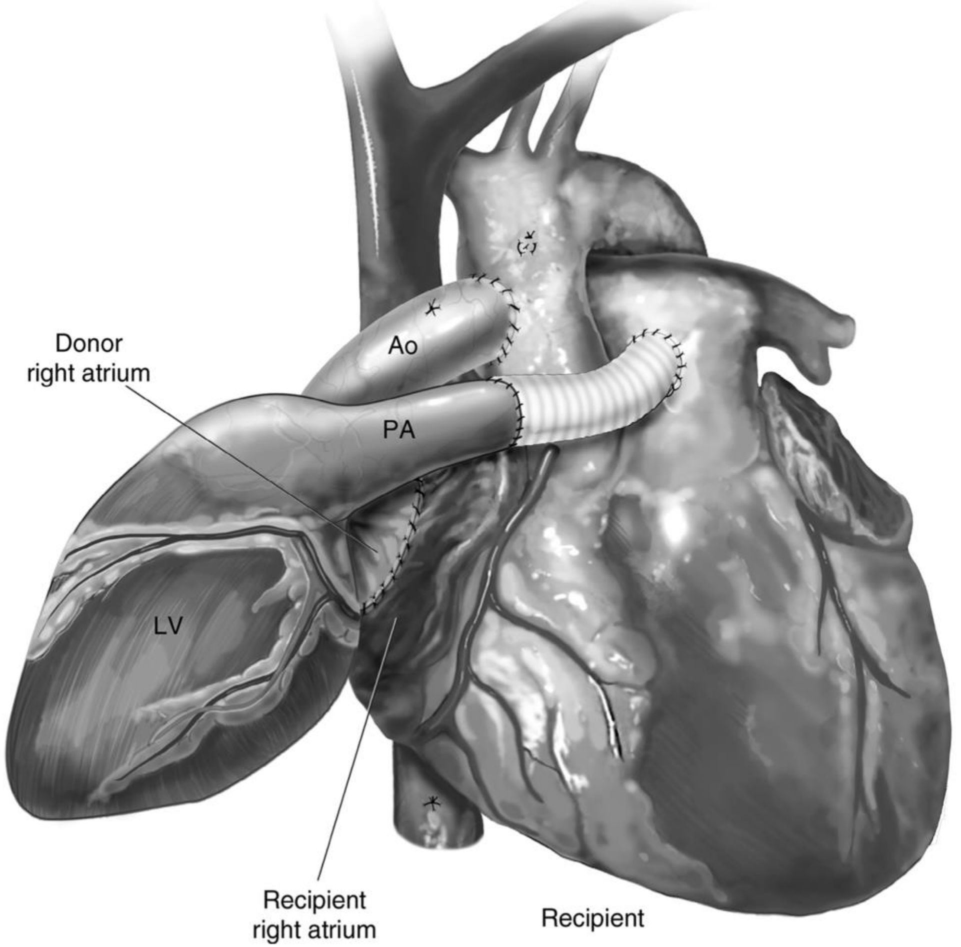

Right pulmonary veins
Right atrium



R. Morton Bolman III Oper Tech Thorac Cardiovasc Surg 1999

Heart transplantation - operation

- Heterotophic heart transplantation

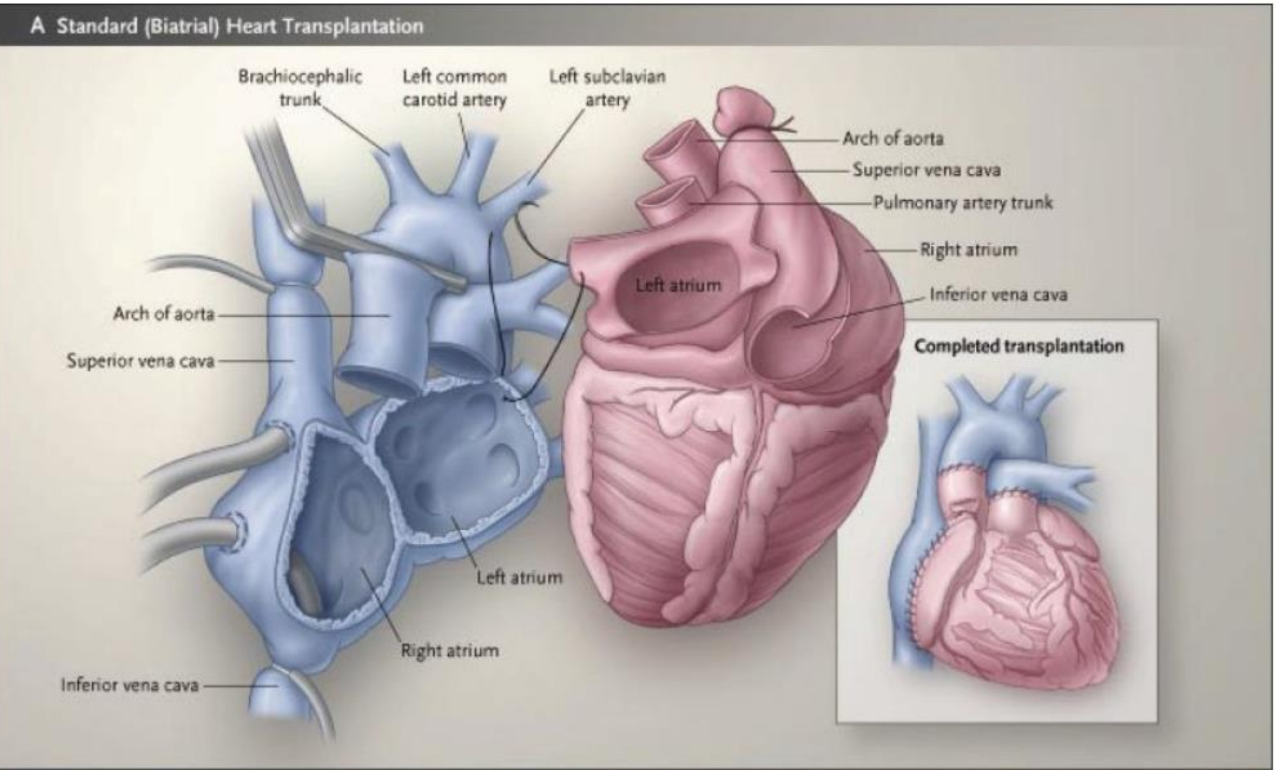

Donor
right atrium
Ao
PA
LV
Recipient
right atrium
Recipient

Copeland JG & Copeland H. Oper Tech Thorac Cardiovasc Surg. 2016;21(3):269-280.

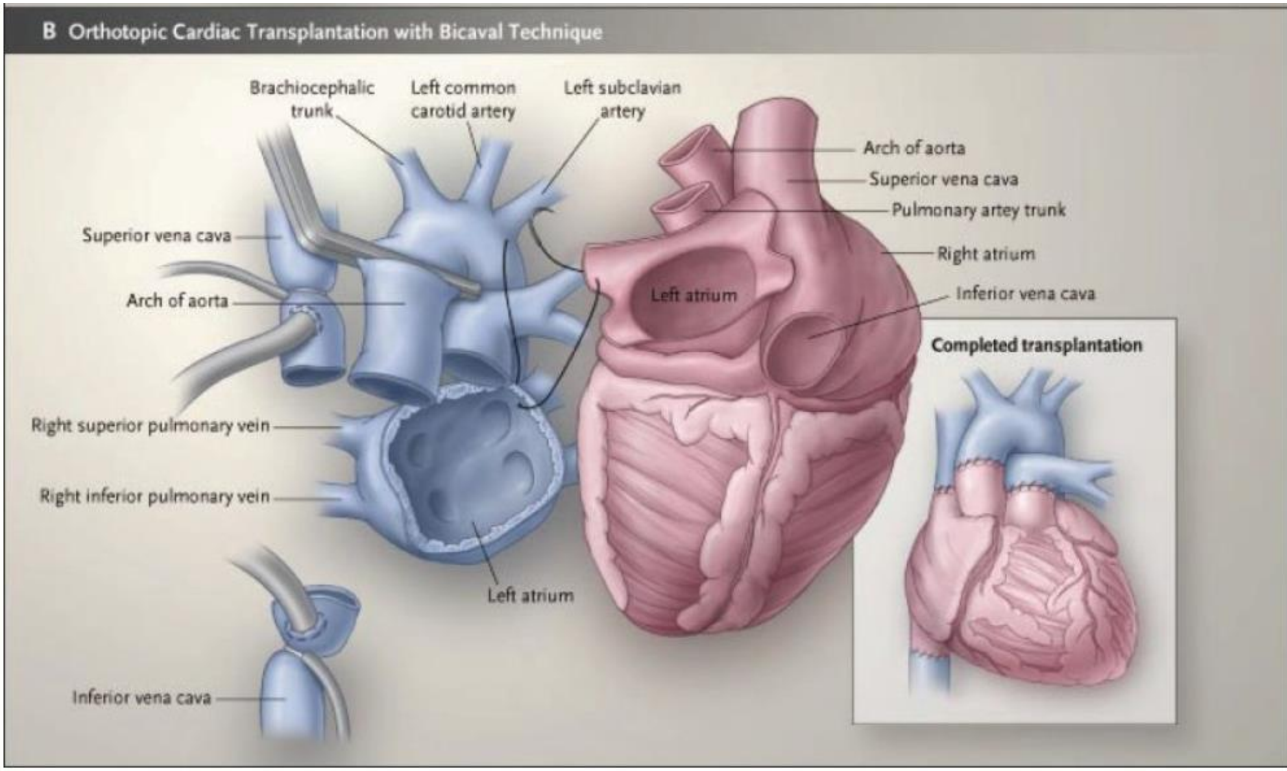
Heart transplantation - operation

- Orthotophic heart transplantation

Biatrial technique


A Standard (Biatrial) Heart Transplantation
Brachiocephalic trunk
Left common carotid artery
Left subclavian artery
Arch of aorta
Superior vena cava
Pulmonary artery trunk
Right atrium
Left atrium
Inferior vena cava
Arch of aorta
Superior vena cava
Completed transplantation
Left atrium
Right atrium
Inferior vena cava

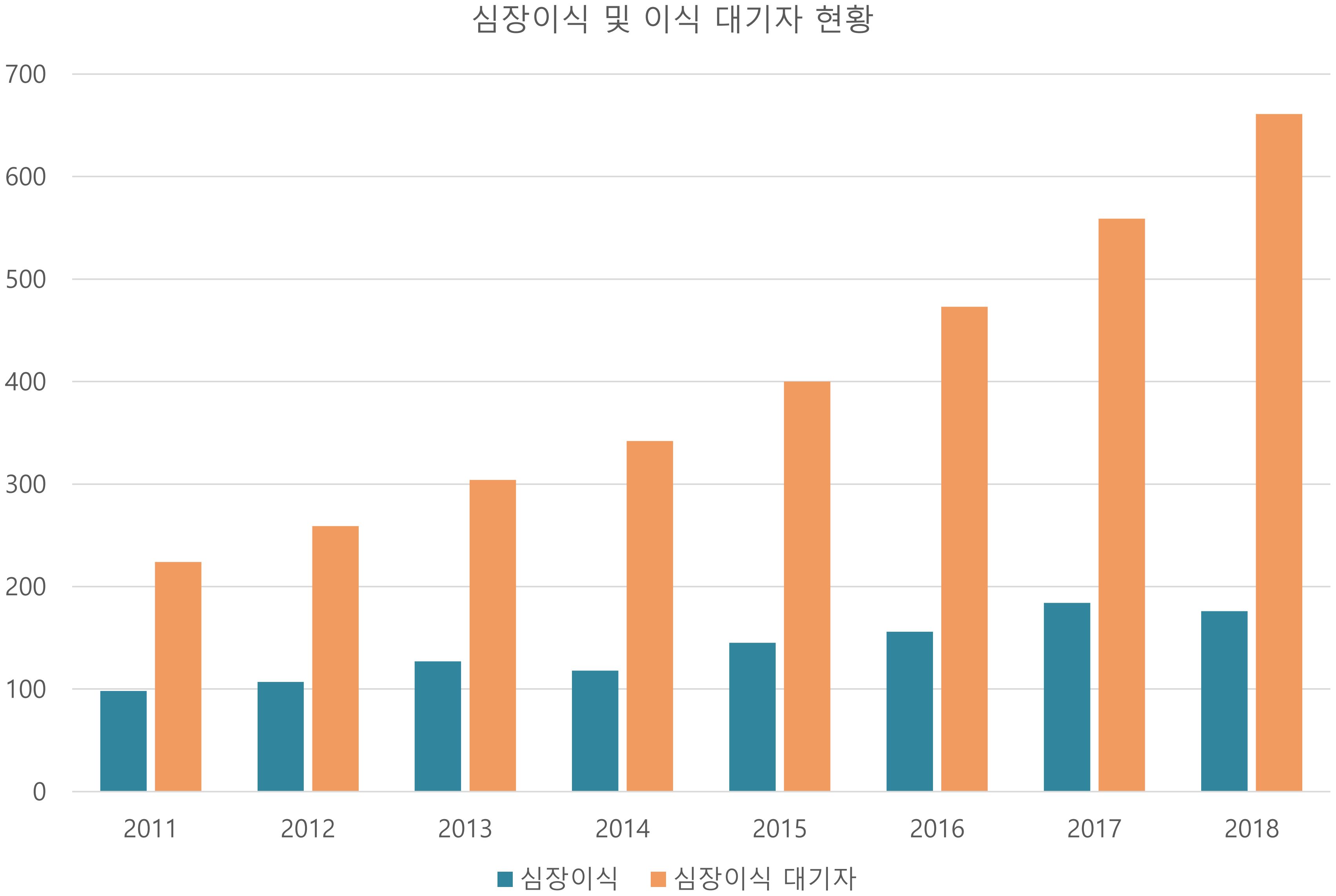
Bicaval technique


B Orthotopic Cardiac Transplantation with Bicaval Technique
Brachiocephalic trunk
Left common carotid artery
Left subclavian artery
Arch of aorta
Superior vena cava
Pulmonary artey trunk
Superior vena cava
Right atrium
Arch of aorta
Left atrium
Inferior vena cava
Completed transplantation
Right superior pulmonary vein
Right inferior pulmonary vein
Left atrium
Inferior vena cava

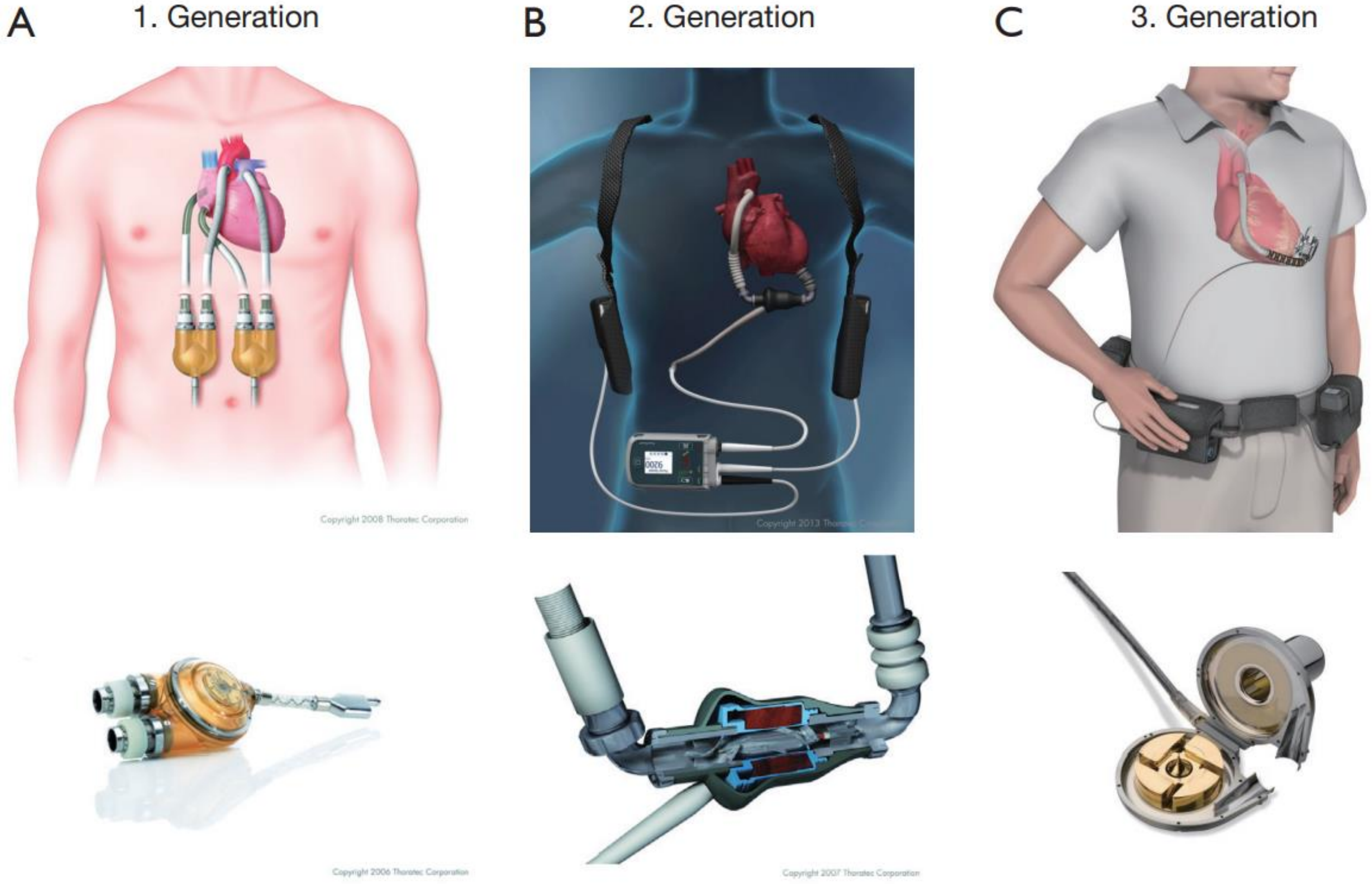
Sharon A. Hunt, N Engl J Med 2006;355:231-235

Left ventricular assist device

Heart transplantation and wait list

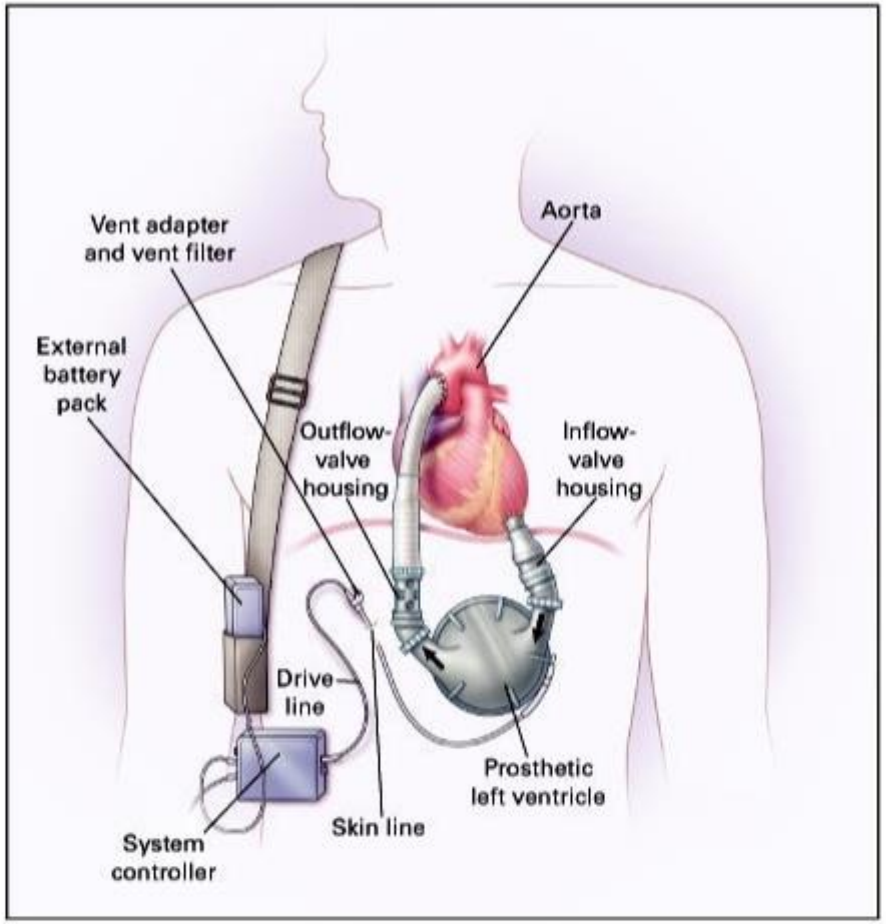


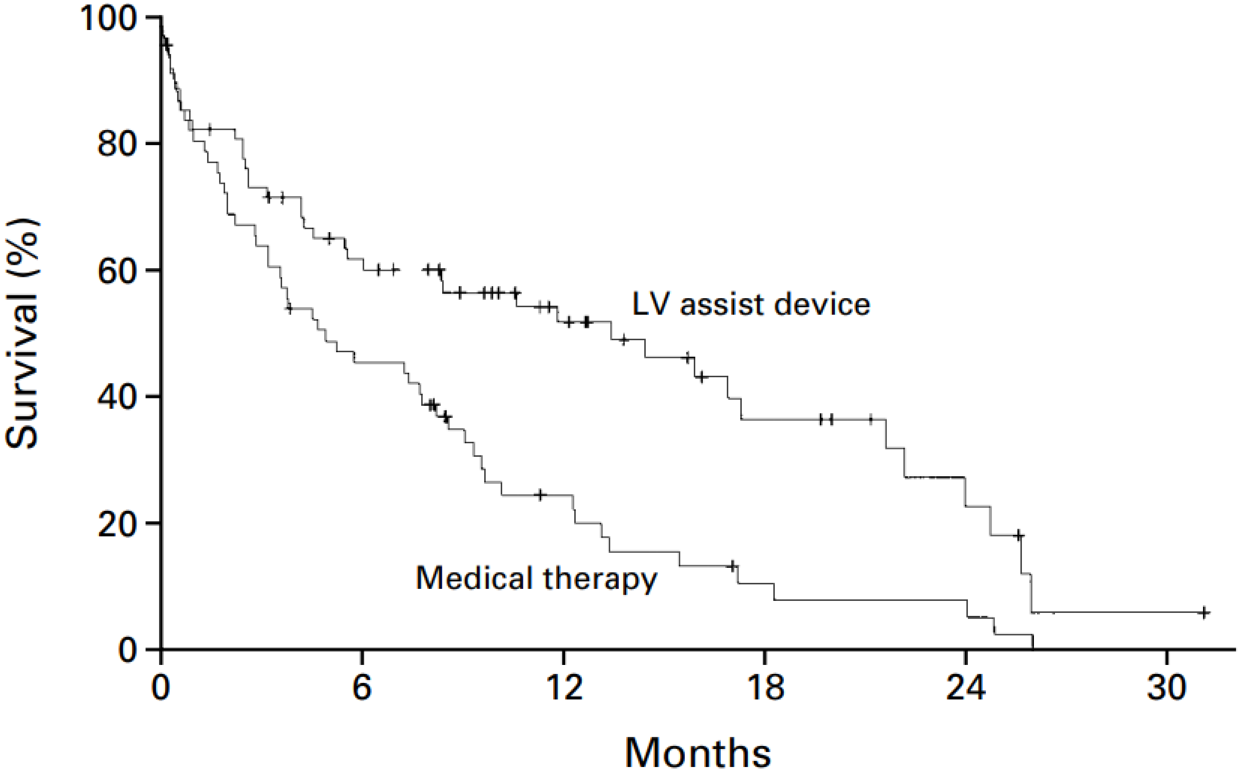
LVAD - generation


A
1. Generation
B
2. Generation
C
3. Generation
Copyright 2008 Thoratec Corporation
Copyright 2013 Thoratec Corporation
Copyright 2006 Thoratec Corporation
Copyright 2007 Thoratec Corporation

Prinzing et al. J Thorac Dis 2016

LVAD clinical trials – LVAD vs medical therapy


Vent adapter and vent filter
Aorta
External battery pack
Outflow-valve housing
Inflow-valve housing
Drive line
Prosthetic left ventricle
Skin line
System controller



Rose EA, et al. N Engl J Med. 2001 Nov 15;345(20):1435-43.

LVAD clinical trials – HM XVE vs HM II

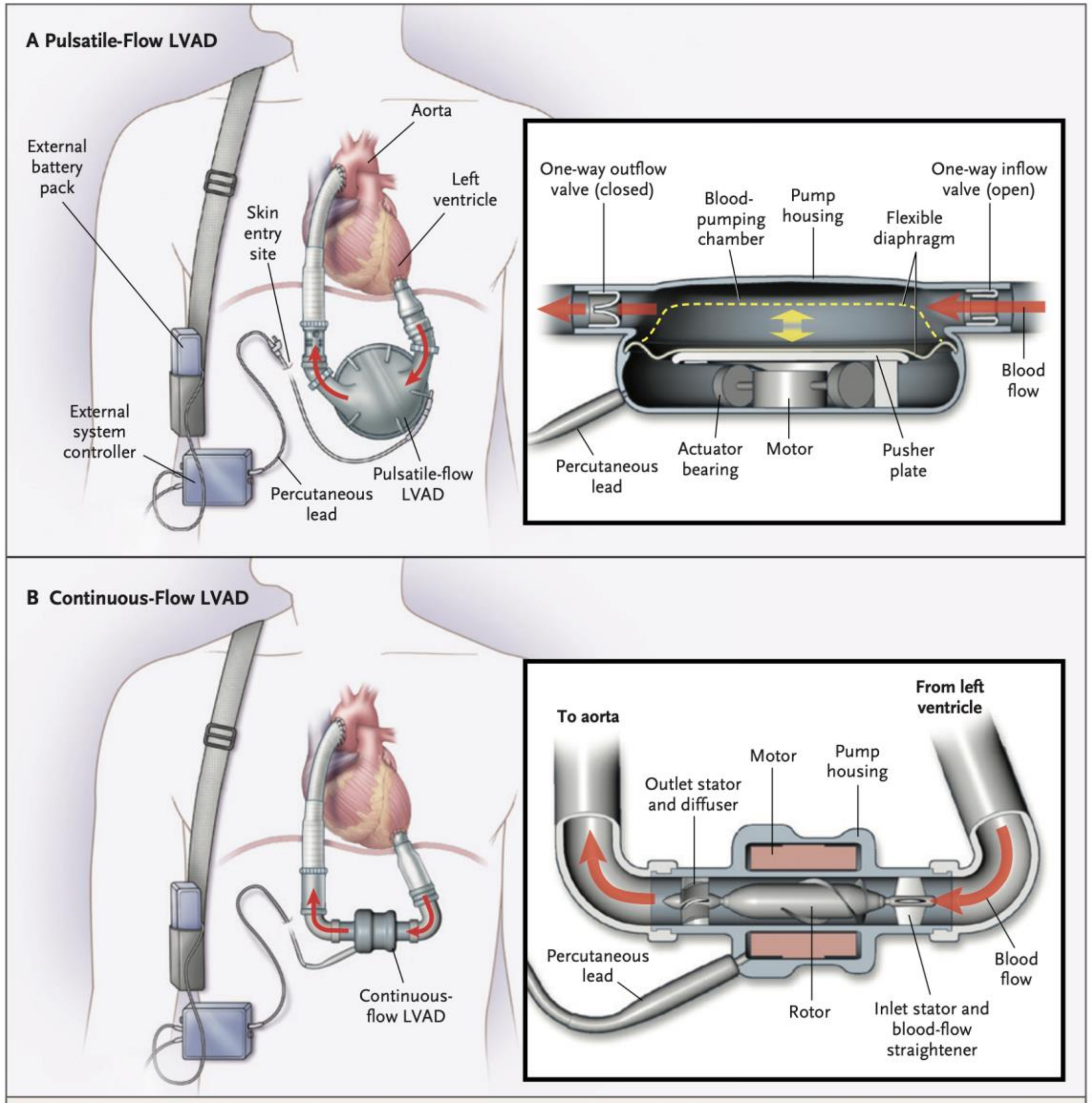
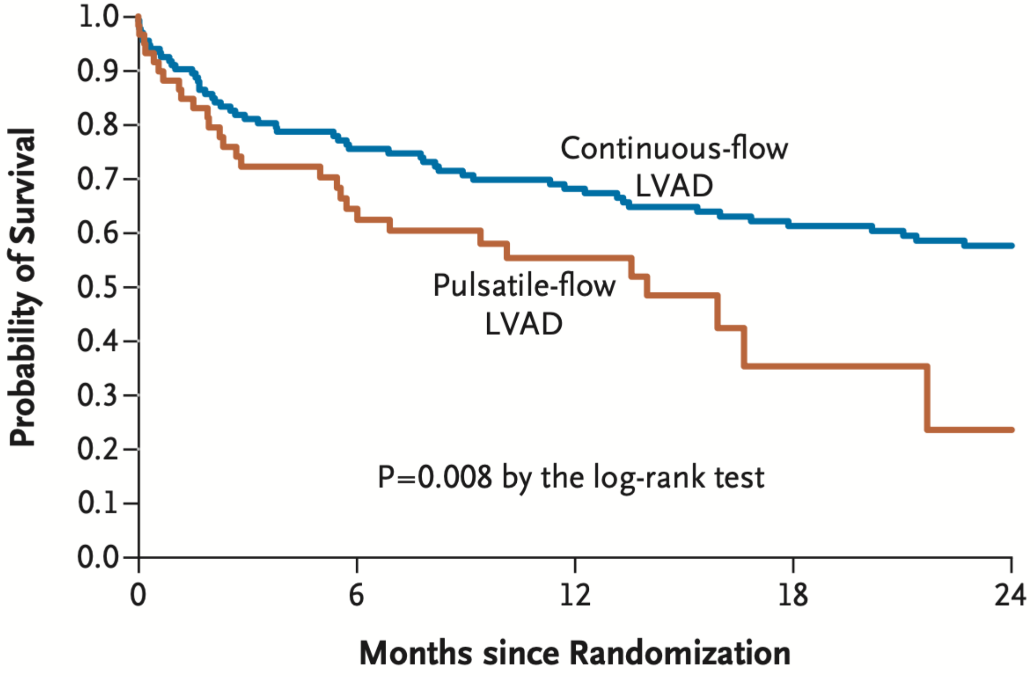

A Pulsatile-Flow LVAD
External battery pack
Aorta
Left ventricle
Skin entry site
External system controller
Percutaneous lead
Pulsatile-flow LVAD
One-way outflow valve (closed)
Blood-pumping chamber
Pump housing
Flexible diaphragm
One-way inflow valve (open)
Blood flow
Percutaneous lead
Actuator bearing
Motor
Pusher plate
B Continuous-Flow LVAD
Continuous-flow LVAD
To aorta
From left ventricle
Motor
Pump housing
Outlet stator and diffuser
Percutaneous lead
Rotor
Inlet stator and blood-flow straightener
Blood flow

Figure 1. **Pulsatile-Flow (Panel A) and Continuous-Flow (Panel B) Left Ventricular Assist Devices (LVADs).**

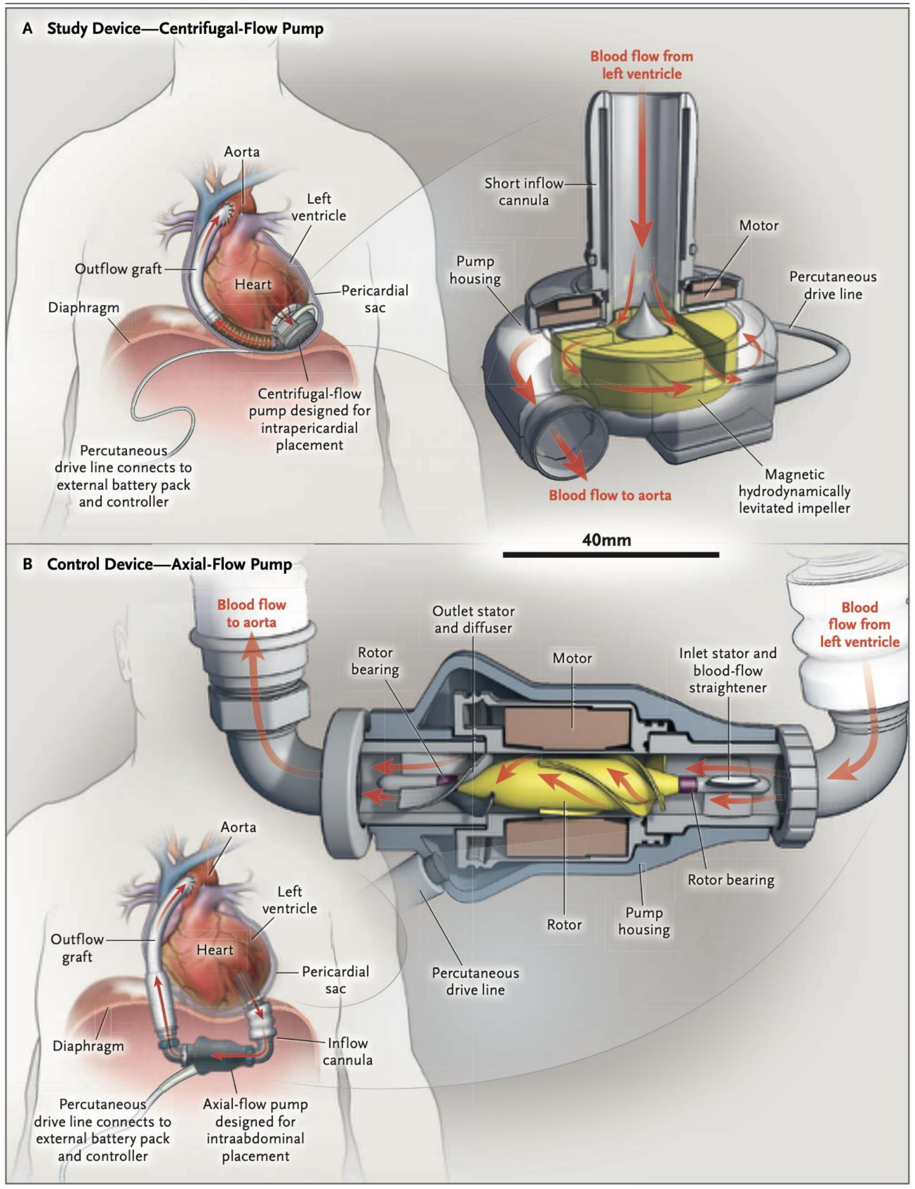


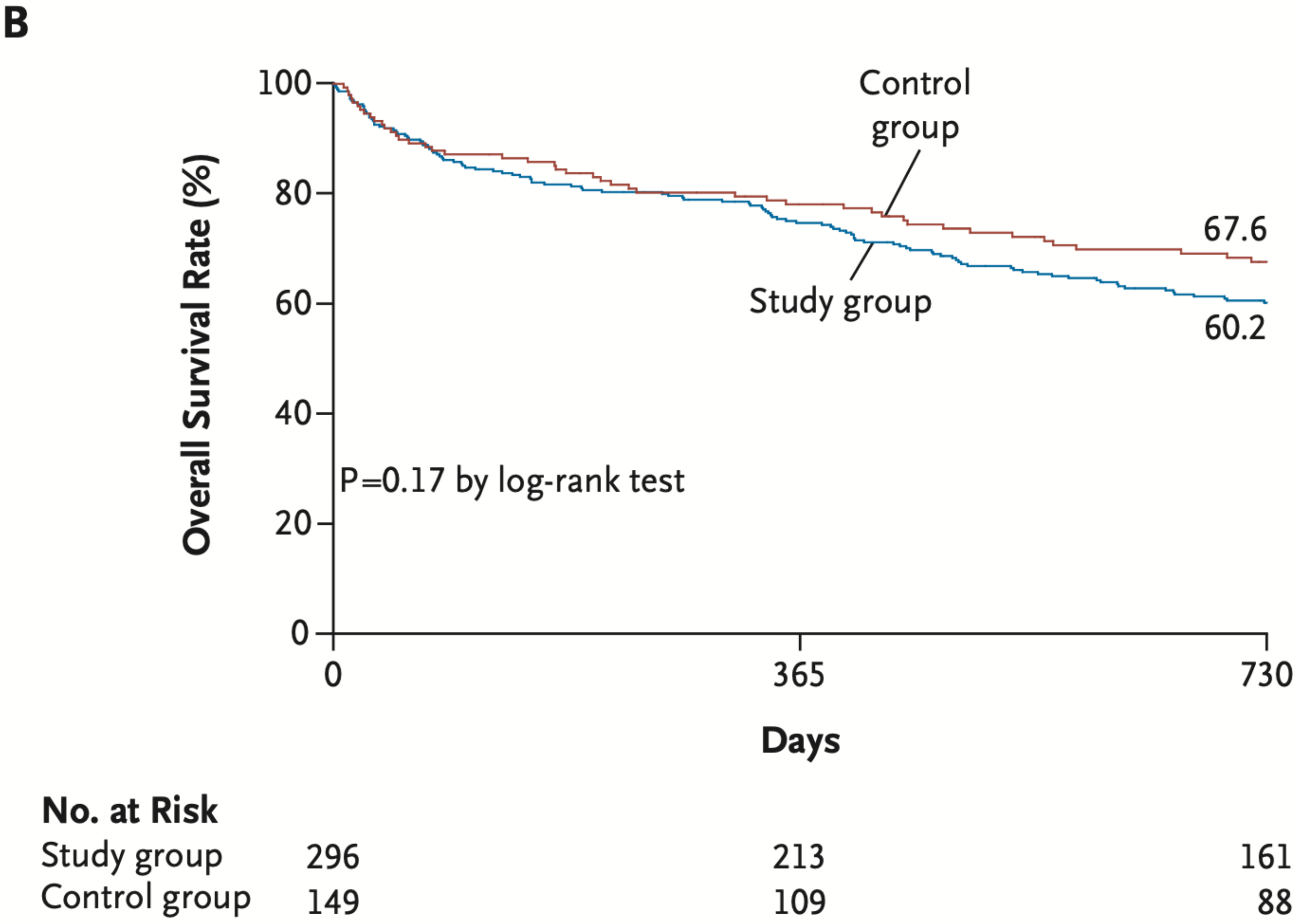
No. at Risk

Continuous-flow LVAD	133	95	82	69	62
Pulsatile-flow LVAD	59	32	19	5	2

Slaughter MS, et al. N Engl J Med. 2009 Dec 3;361(23):2241-51.

LVAD clinical trials – HM II vs Heartware


A Study Device—Centrifugal-Flow Pump
Blood flow from left ventricle
Aorta
Left ventricle
Short inflow cannula
Motor
Outflow graft
Heart
Pericardial sac
Pump housing
Percutaneous drive line
Diaphragm
Centrifugal-flow pump designed for intrapericardial placement
Percutaneous drive line connects to external battery pack and controller
Blood flow to aorta
Magnetic hydrodynamically levitated impeller
40mm
B Control Device—Axial-Flow Pump
Blood flow to aorta
Outlet stator and diffuser
Rotor bearing
Motor
Inlet stator and blood-flow straightener
Blood flow from left ventricle
Aorta
Left ventricle
Outflow graft
Heart
Pericardial sac
Rotor bearing
Rotor
Pump housing
Percutaneous drive line
Diaphragm
Inflow cannula
Percutaneous drive line connects to external battery pack and controller
Axial-flow pump designed for intraabdominal placement

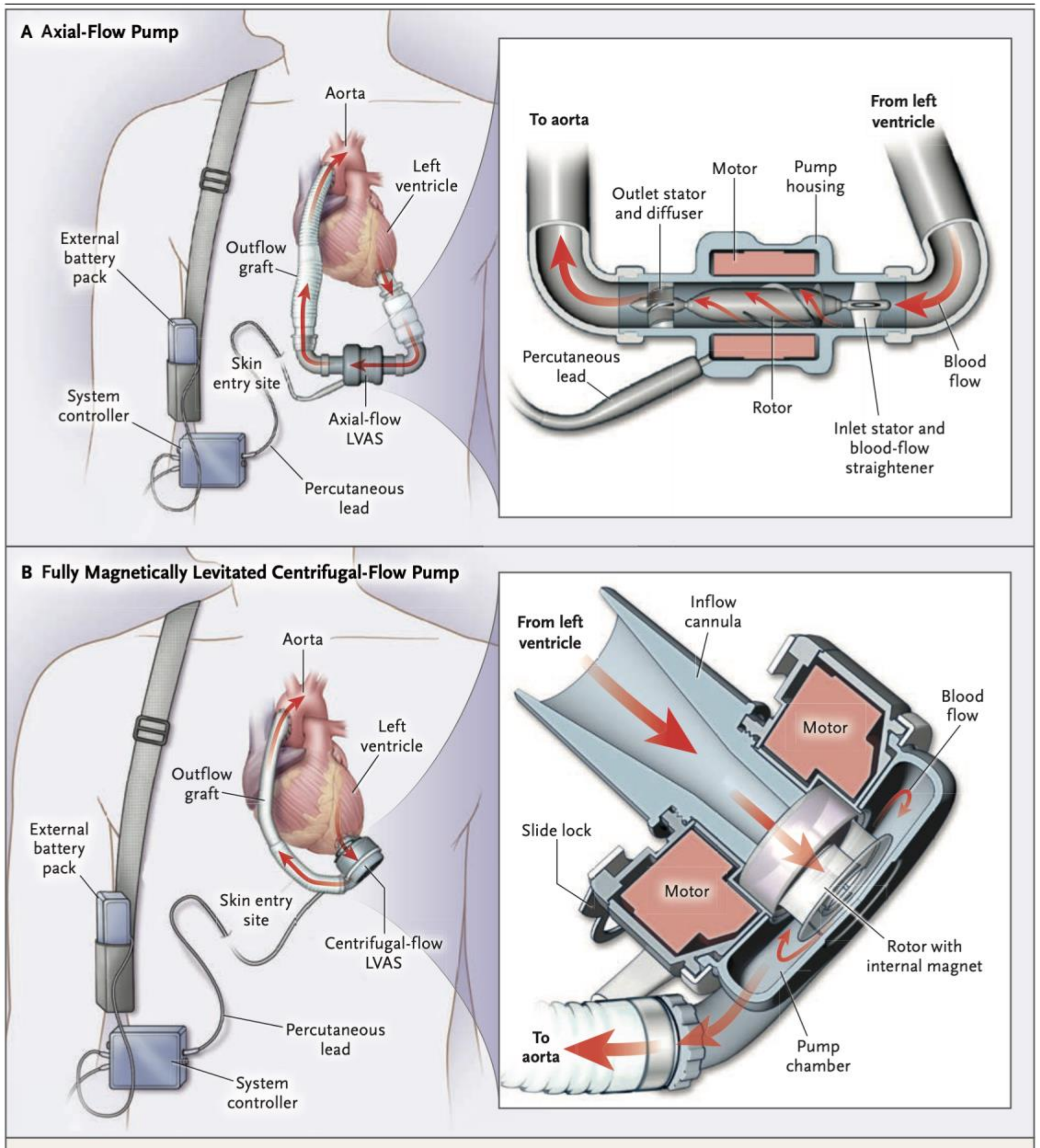


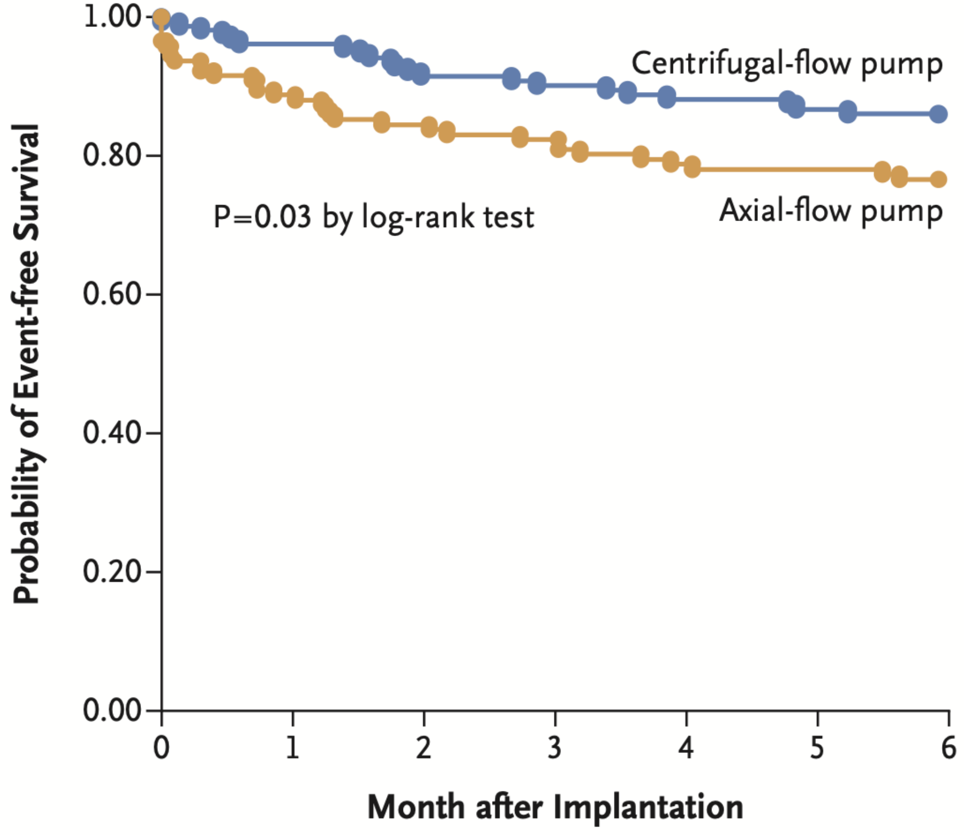
No. at Risk

	0	365	730
Study group	296	213	161
Control group	149	109	88

Rogers JG, et al. N Engl J Med. 2017 Feb 2;376(5):451-

LVAD clinical trials – HM II vs HM III


A Axial-Flow Pump
Aorta
Left ventricle
External battery pack
Outflow graft
Skin entry site
System controller
Axial-flow LVAS
Percutaneous lead
To aorta
From left ventricle
Motor
Pump housing
Outlet stator and diffuser
Percutaneous lead
Rotor
Blood flow
Inlet stator and blood-flow straightener
B Fully Magnetically Levitated Centrifugal-Flow Pump
Aorta
Left ventricle
Outflow graft
External battery pack
Skin entry site
Centrifugal-flow LVAS
Percutaneous lead
System controller
From left ventricle
Inflow cannula
Motor
Blood flow
Slide lock
Motor
Rotor with internal magnet
To aorta
Pump chamber

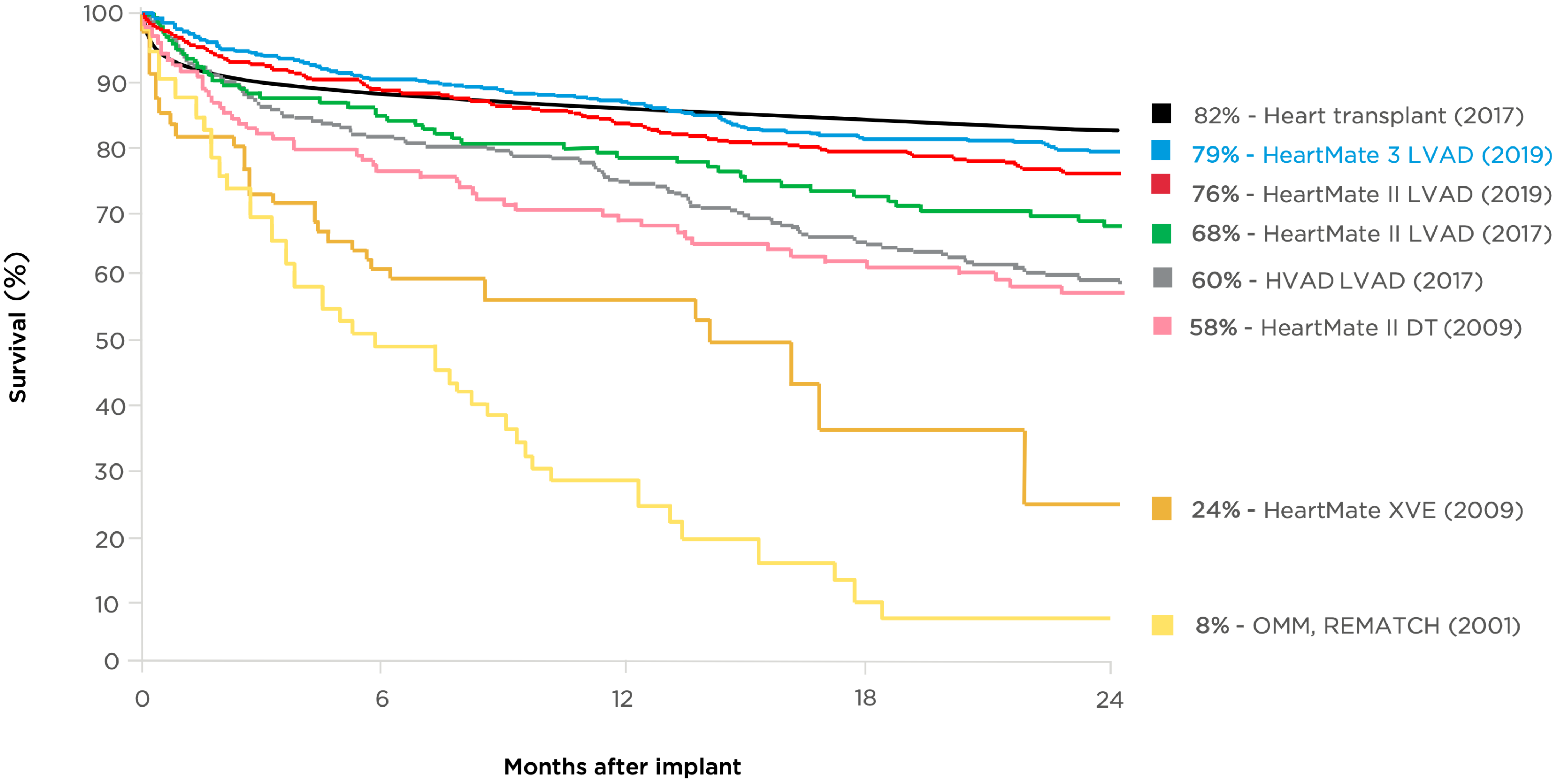


No. at Risk

	0	1	2	3	4	5	6
Centrifugal-flow pump	152	146	138	135	130	128	127
Axial-flow pump	142	125	119	116	110	106	103

Mehra MR, et al. N Engl J Med. 2017 Feb 2;376(5):440-

Heart failure treatment - Survival



Surrounding Advanced Heart Failure: The Role of the Latest Left Ventricular Assist Devices 2020 34th EACTS Annual meeting

LVAD clinical trials – Berlin Heart

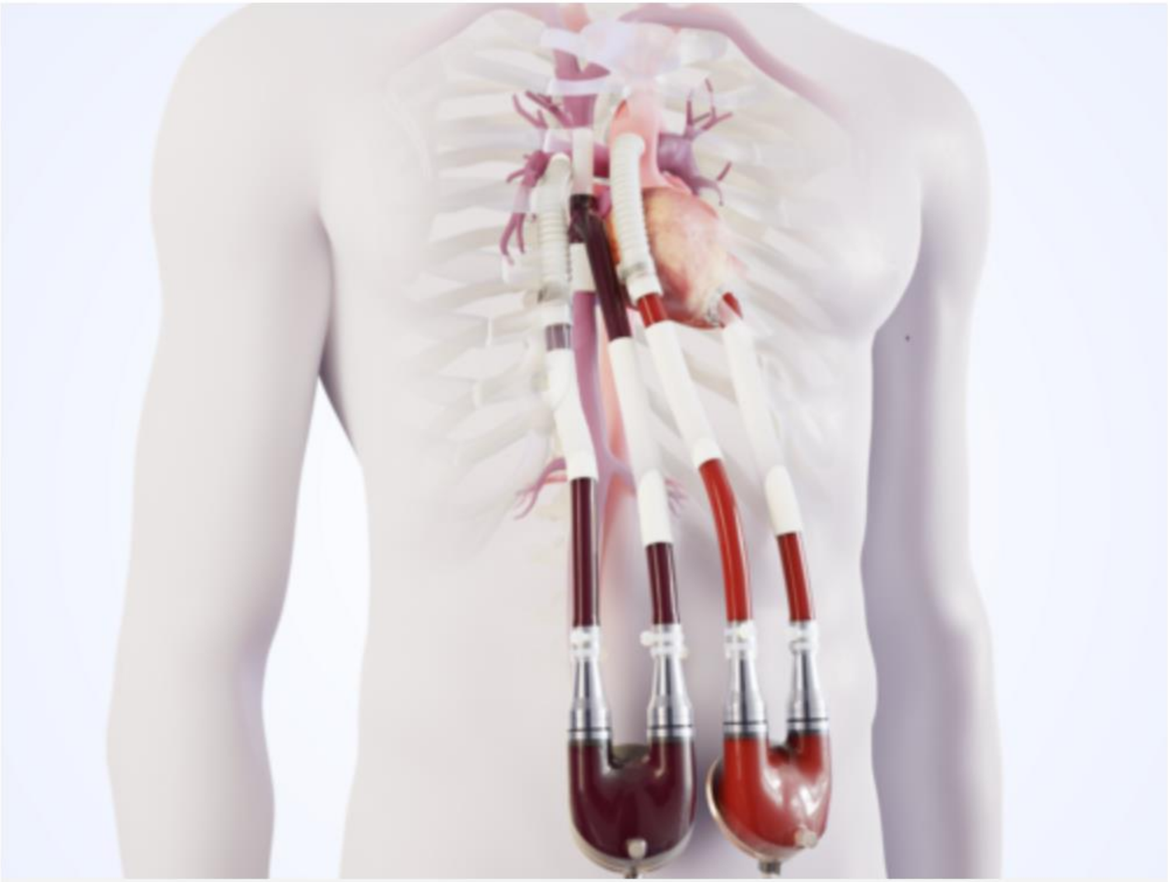
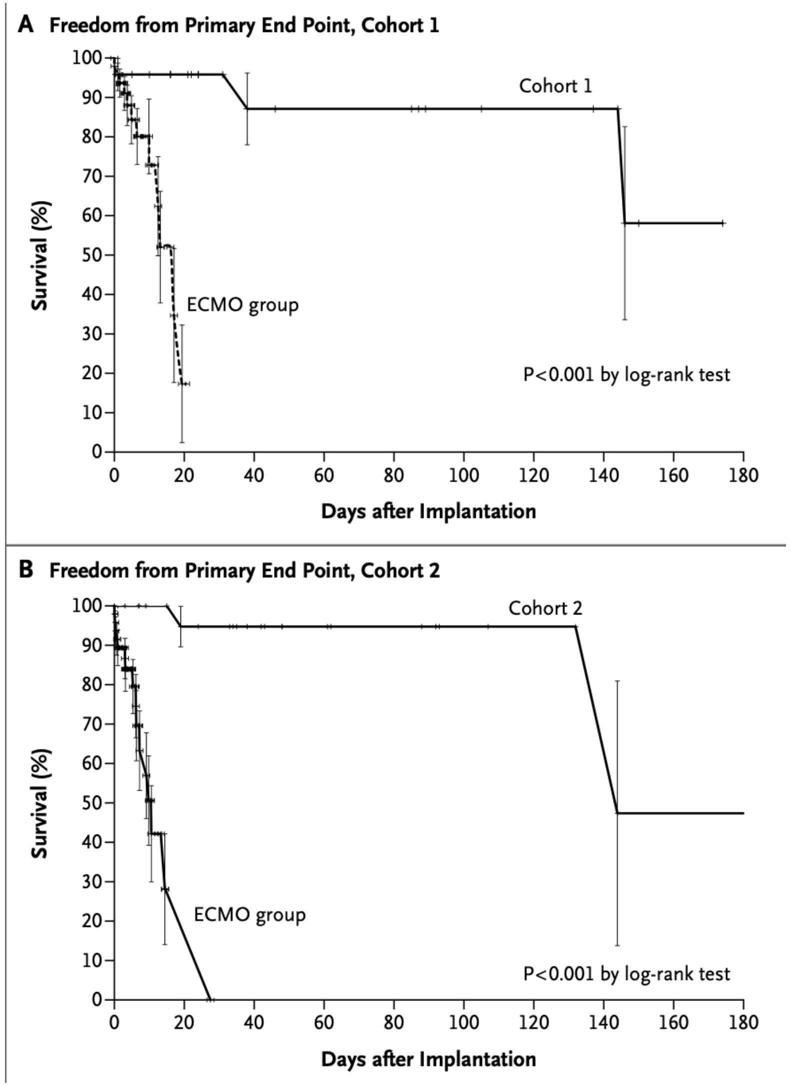


Figure 1



Fraser CD Jr, et al. N Engl J Med. 2012 Aug 9;367(6):532-41

LVAD – Indication and containdication

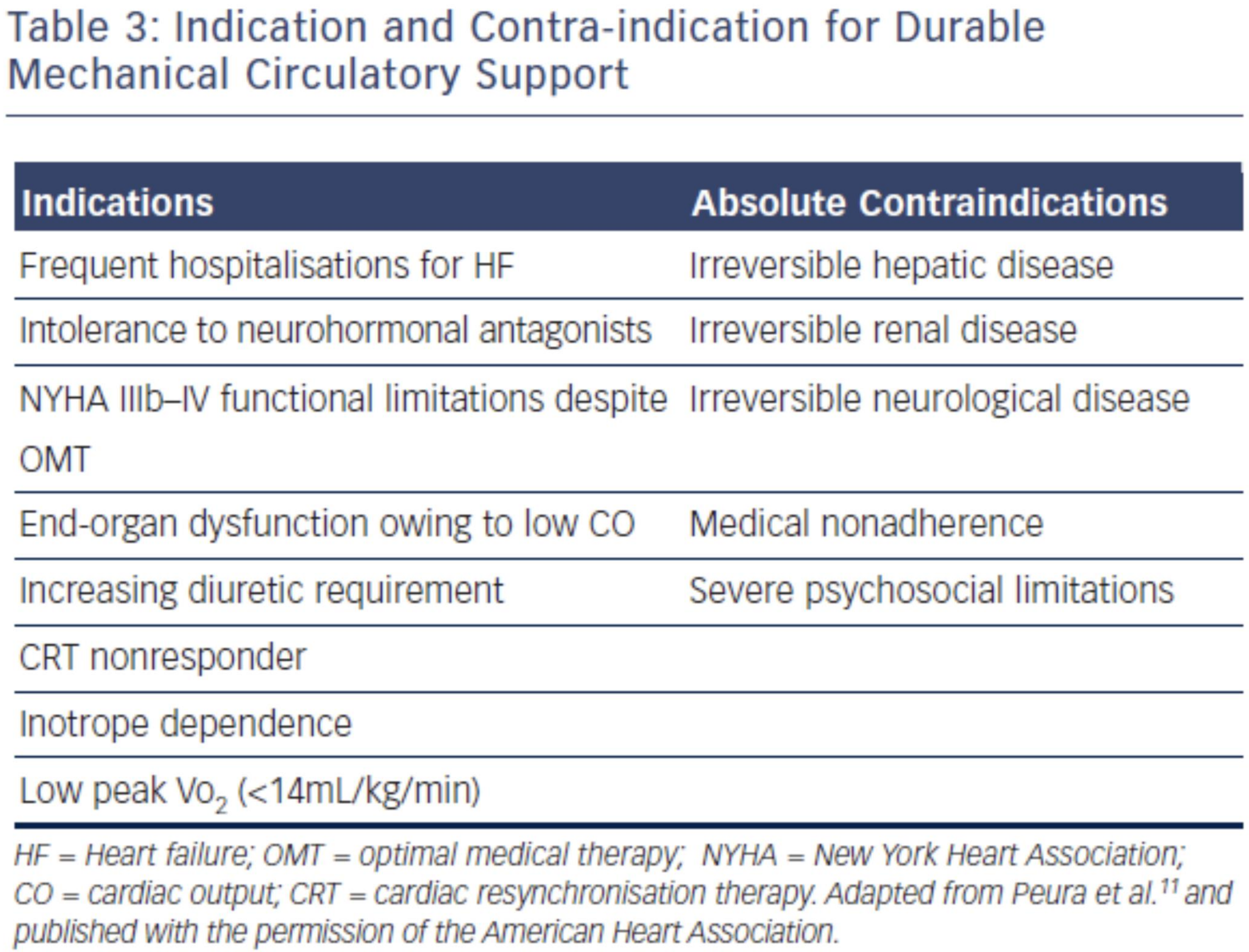


Table 3: Indication and Contra-indication for Durable Mechanical Circulatory Support

Indications	Absolute Contraindications
Frequent hospitalisations for HF	Irreversible hepatic disease
Intolerance to neurohormonal antagonists	Irreversible renal disease
NYHA IIIb–IV functional limitations despite OMT	Irreversible neurological disease
End-organ dysfunction owing to low CO	Medical nonadherence
Increasing diuretic requirement	Severe psychosocial limitations
CRT nonresponder	
Inotrope dependence	
Low peak Vo_2 (<14mL/kg/min)	

HF = Heart failure; OMT = optimal medical therapy; NYHA = New York Heart Association; CO = cardiac output; CRT = cardiac resynchronisation therapy. Adapted from Peura et al.[11] and published with the permission of the American Heart Association.

Edo Y Birati, & Mariell Jessup Cardiac Failure Review 2015;1(1):25–30

LVAD – 심평원 승인 기준

1. 적응증

① 이식형 좌심실 보조장치 치료술

비가역적 말기심부전 환자로서 약물치료 베타차단제 등 또는 기계순환보조 등 치료에도 불구하고 심각한 증상이 지속되고 다음 중 하나 이상을 충족하는 경우

다 음

1) LVEF <25% 이거나 이에 준하는 심실 기능부전의 증거가 있으면서, peak VO2 < 12mL/kg/min (단, 베타차단제 불응성인 경우는 peak VO2 < 14mL/kg/min) 혹은 동등한 운동능력 검사 결과가 있는 경우
2) 정맥 강심제에 의존적인 상태로 투여를 중단할 수 없는 경우
3) 점진적 신장 혹은 간장 부전이 있고 이의 원인이 심부전으로 증명된 경우 이상이면서 수축기혈압 90mmHg이하 혹은 Cardiac Index 가 2.0L/min/m2 이하)

LVAD – 심평원 승인 기준

1. 적응증

② 체외형 심실 보조장치 치료술

가 .재태연령 주 이상이고 체중 이상인 경우부터 세 미만의 심장 이식 대기자로 등록된 중증 심부전 환자로 다음 중 하나 이상을 충족하는 경우

1) 최대한의 심부전 치료에도 불구하고 수준의 심부전이 지속 IV 되고 강심제에 의존하며 전신 장기기능이 진행성으로 악화된 경우
2) 악성 심근염 등으로 보조순환기가 장착되어 중지가 어려운 경우
3) 치료 불가능한 치명적인 부정맥이 지속되는 경우

나. 18세 이상의 심장이식 대기자로 등록된 중증 심부전 환자로 이식형 좌심실 보조장치 치료술 급여기준에 부합하고 다음 중 하나 이상을 충족하는 경우

다 음

1) 해부학적으로 이식형 좌심실 보조장치 치료술이 불가능한 경우
2) 선천성 심장질환자로서 양심실부전으로 양심실 보조장치 치료술이 반드시 필요한 경우

LVAD – 심평원 승인 기준

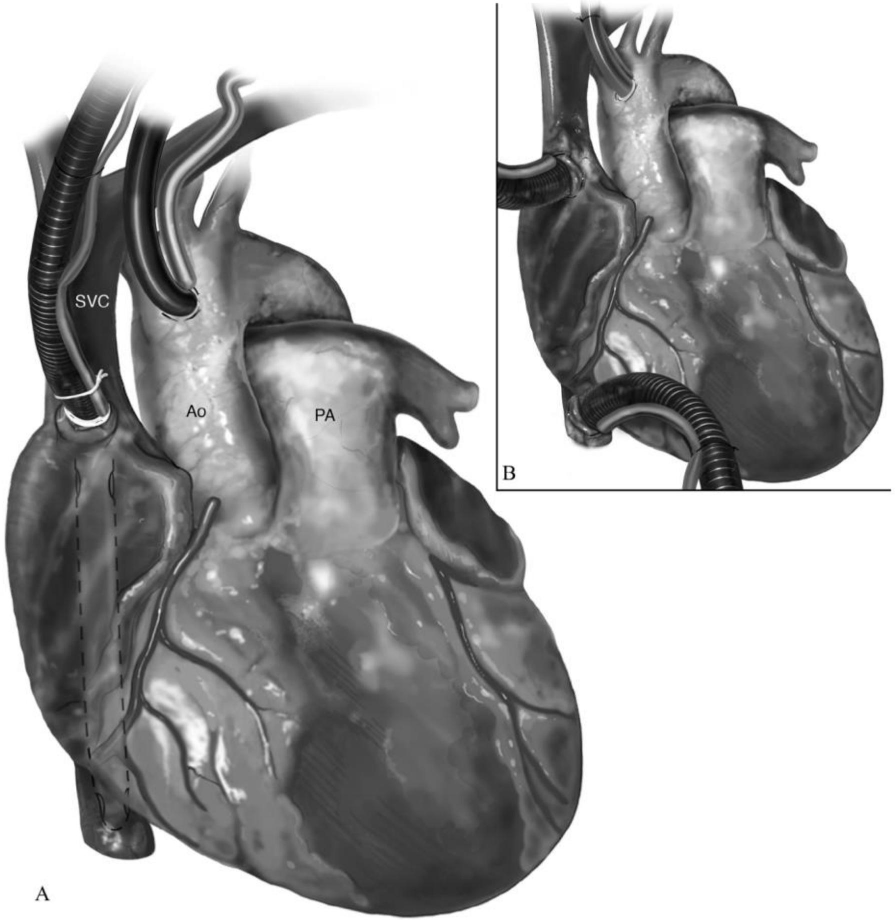
2. 금기증

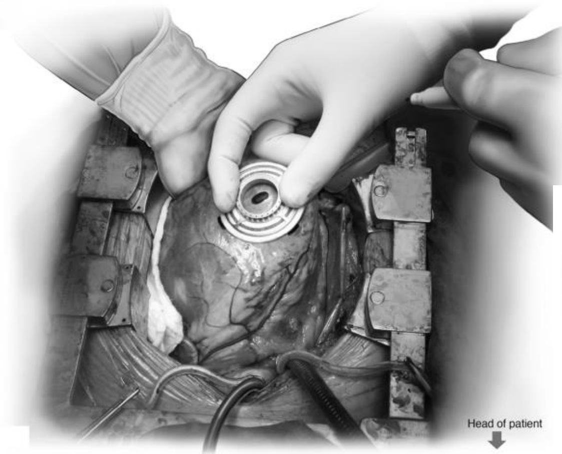
아래와 같은 경우 시술을 승인하지 않으며 대상자가 다음의 경우에 부합되는지 여부는 위원회의 결정에 따름

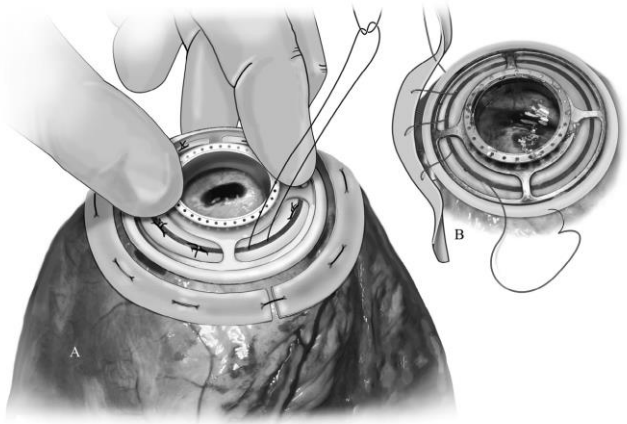
① 이식형 좌심실 보조장치 치료술
가. 지속적 혈액투석을 하는 말기신부전
나. 비가역적 장기부전(신장, 간, 폐 등)
다. 중증 뇌손상
라. 패혈증
마. 장기적 항응고 치료가 불가한 경우
바. 말기 암 등으로 인해 장기적 생존이 제한적인 경우

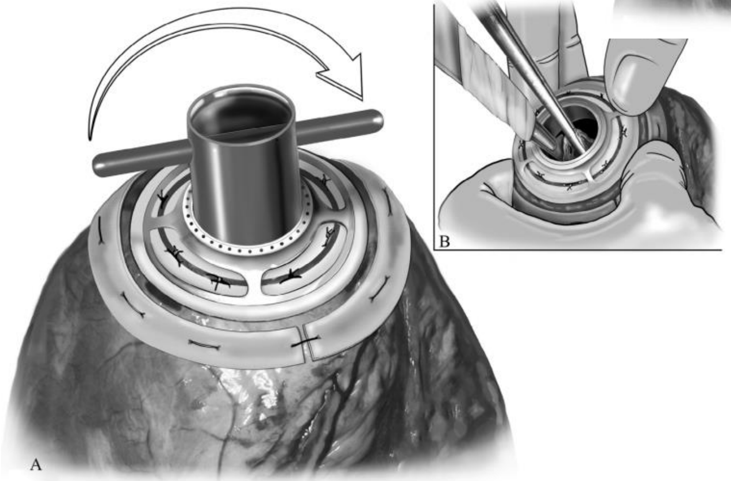
② 체외형 심실 보조장치 치료술
가. 추후 심장 단독 혹은 심장 포함 다중 장기 이식이 불가능한 경우
나. 심실보조장치 삽입 후에도 회복을 기대하기 어려운 비가역적 장기부전 (신장, 간, 폐 등)
다. 중증 뇌손상
라. 조절되지 않는 패혈증
마. 장기적 항응고 치료가 불가한 경우
바. 말기 암 등으로 인해 장기적 생존이 제한적인 경우

LVAD - Operation



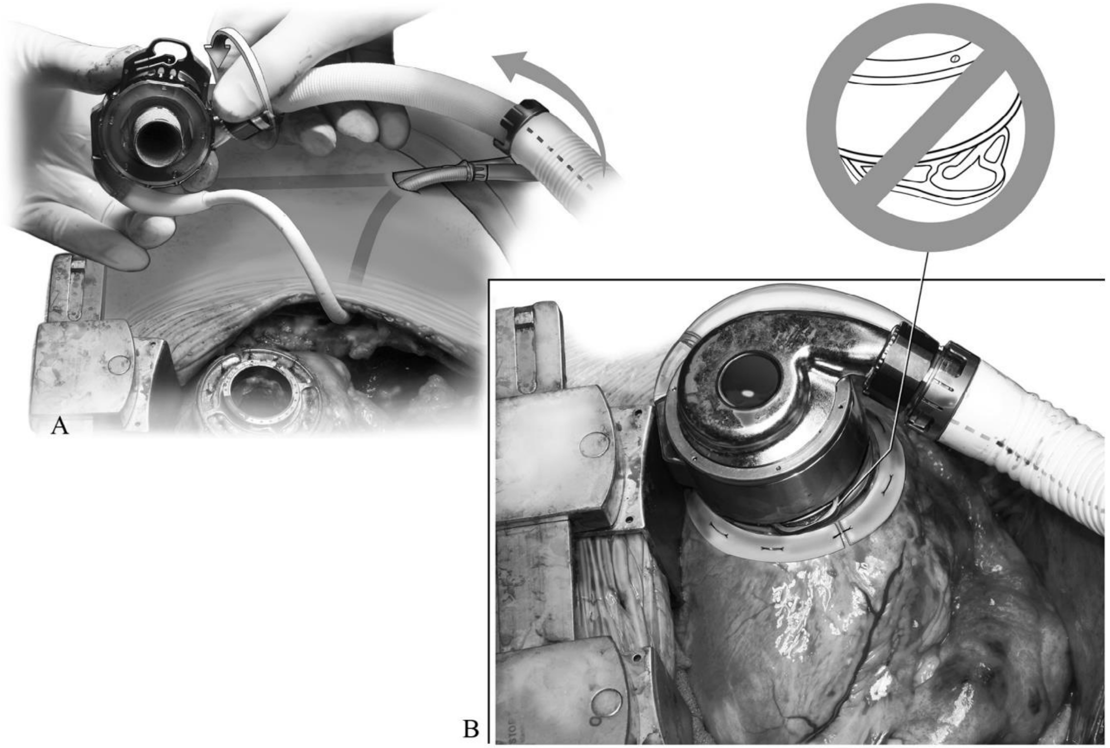

Head of patient

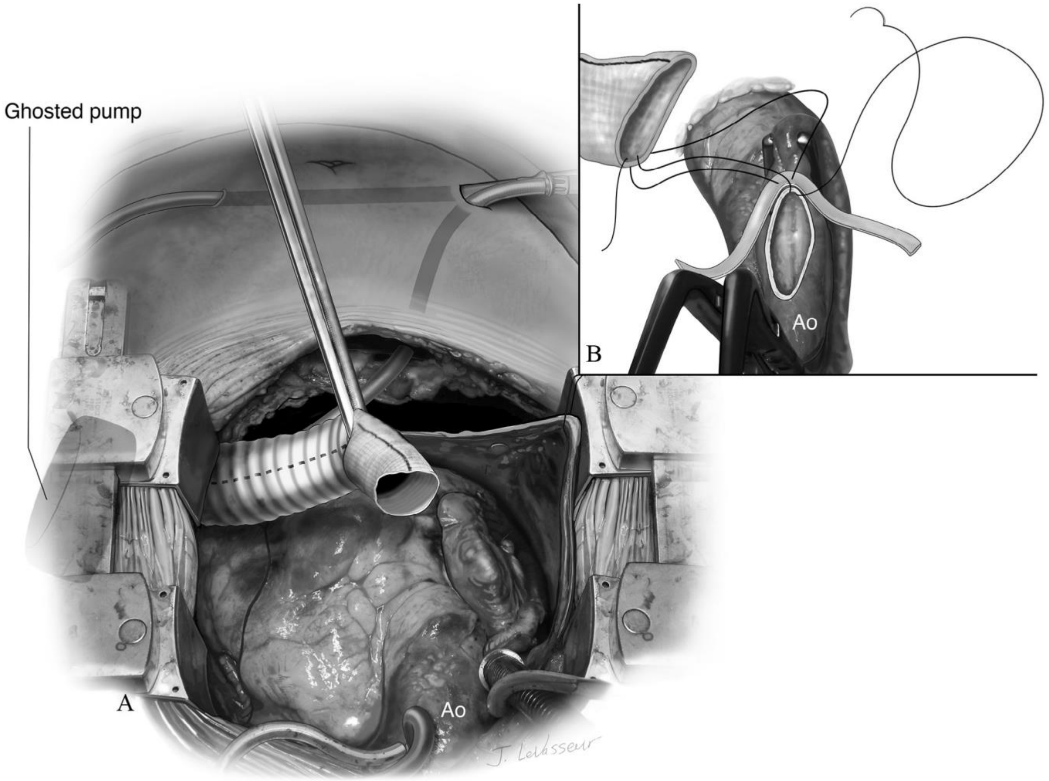




Beyersdorf et al. Operative techniques in thoracic and cardiovascular surgery 2018

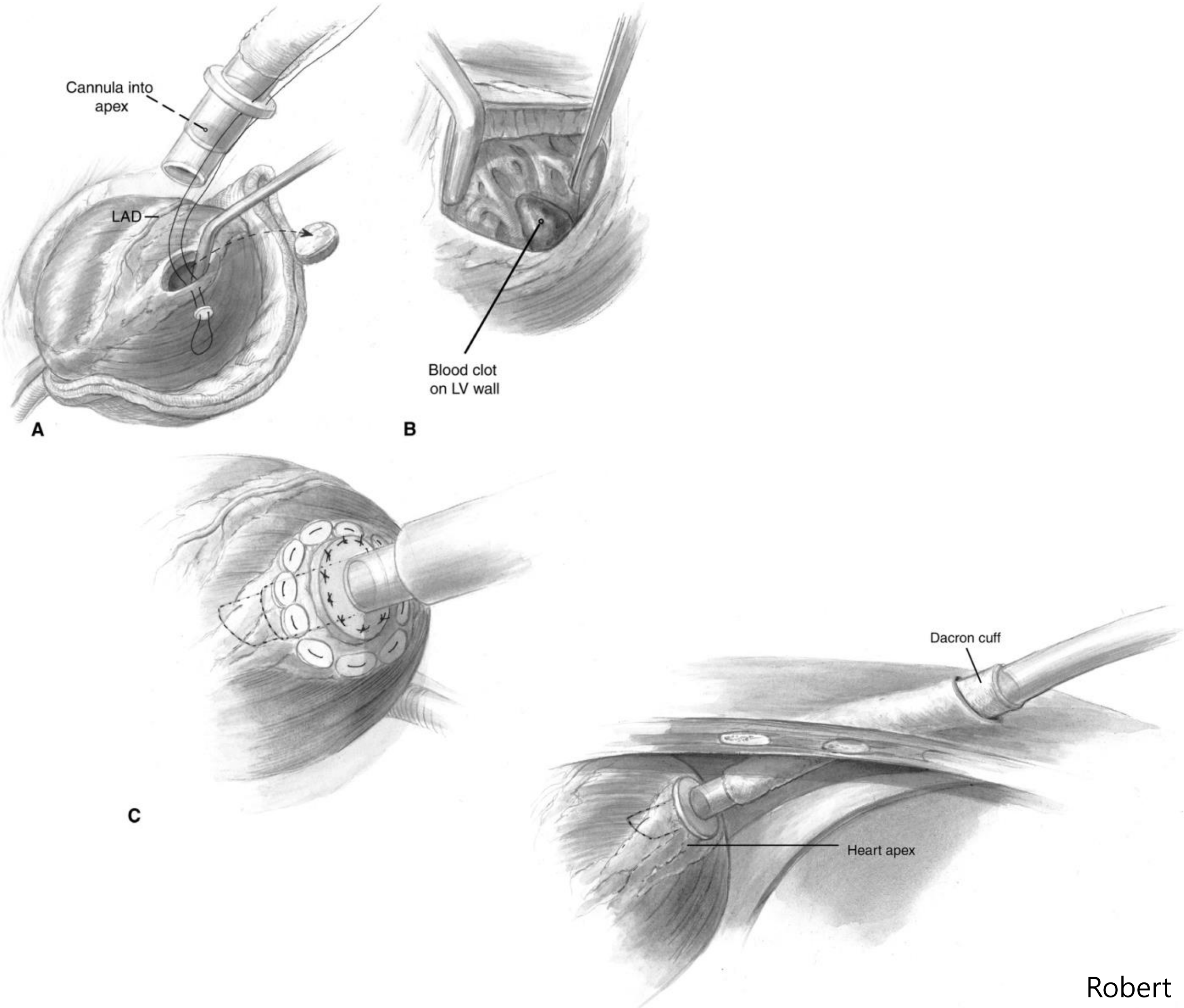
LVAD - Operation

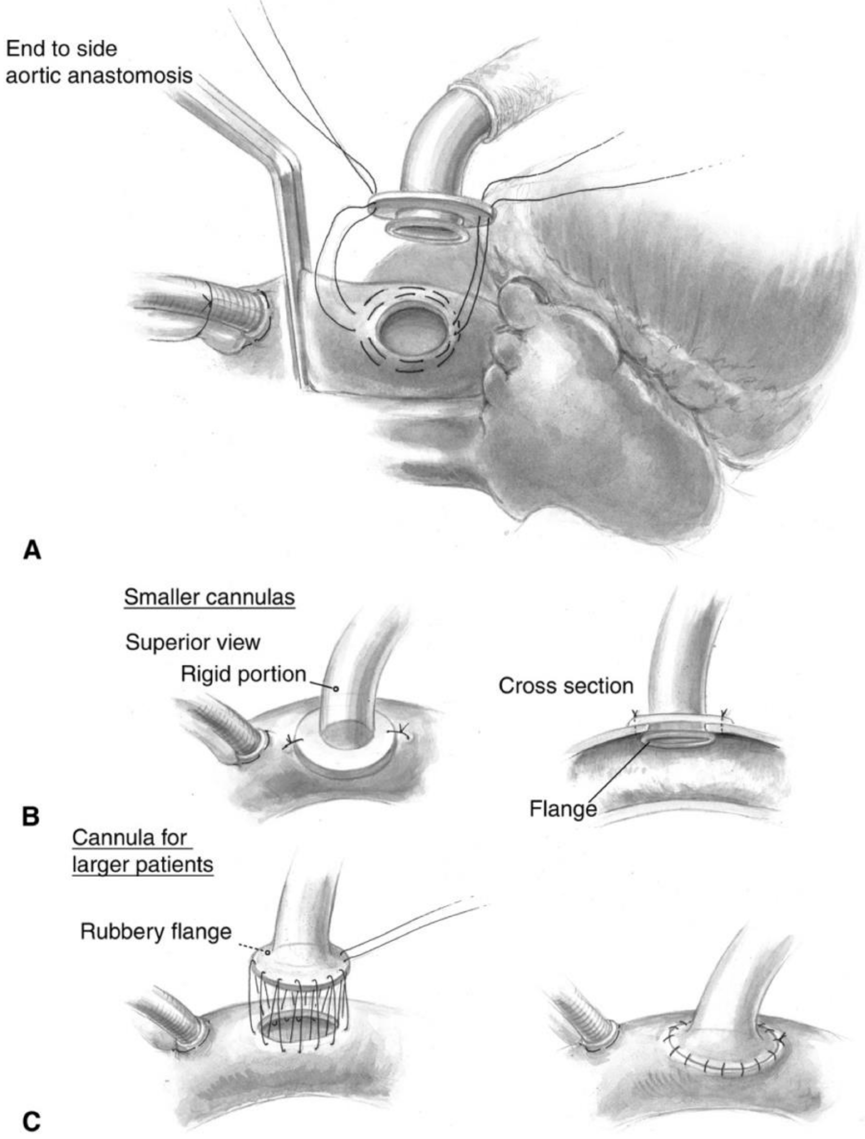



Ghosted pump
A
Ao
B
Ao

Beyersdorf et al. Operative techniques in thoracic and cardiovascular surgery 2018

Berlin Heart - Operation


Cannula into apex
LAD
A
Blood clot on LV wall
B
C
Dacron cuff
Heart apex


End to side aortic anastomosis
A
Smaller cannulas
Superior view
Rigid portion
Cross section
Flange
B
Cannula for larger patients
Rubbery flange
C

Robert D.B. et al. Operative techniques in thoracic and cardiovascular surgery 2010

Thank You

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