



HAL
open science

Transcatheter interventions for left-sided valvular heart disease complicated by cardiogenic shock: a consensus statement from the European Association of Percutaneous Cardiovascular Interventions (EAPCI) in collaboration with the Association for Acute Cardiovascular (ACVC) and the ESC Working Group on Cardiovascular Surgery.

Chiara Fraccaro, Nicole Karam, Helge Möllmann, Sabine Bleiziffer, Nikolaos Bonaros, Rui Campante Teles, Pedro Carrilho Ferreira, Alaide Chieffo, Martin Czerny, Erwan Donal, et al.

HAL Id: hal-04196088

<https://univ-rennes.hal.science/hal-04196088v1>

Submitted on 30 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

► **To cite this version:**

Chiara Fraccaro, Nicole Karam, Helge Möllmann, Sabine Bleiziffer, Nikolaos Bonaros, et al.. Transcatheter interventions for left-sided valvular heart disease complicated by cardiogenic shock: a consensus statement from the European Association of Percutaneous Cardiovascular Interventions (EAPCI) in collaboration with the Association for Acute Cardiovascular (ACVC) and the ESC Working Group on Cardiovascular Surgery.. *EuroIntervention : journal of EuroPCR in collaboration with the Working Group on Interventional Cardiology of the European Society of Cardiology*, 2023, 19 (8), pp.634-651. 10.4244/EIJ-D-23-00473 . hal-04196088

1 **TRANSCATHETER INTERVENTIONS FOR LEFT-SIDED VALVULAR HEART**
 2 **DISEASE COMPLICATED BY CARDIOGENIC SHOCK: A consensus statement**
 3 **from the European Association of Percutaneous Cardiovascular Interventions**
 4 **(EAPCI) in collaboration with the Association for Acute CardioVascular Care**
 5 **(ACVC) and the ESC Working Group on Cardiovascular Surgery**

6
 7 **Short title:** Left-sided structural intervention for cardiogenic shock

8
 9 Total word count: 4992

10
 11 **Authors:** Chiara Fraccaro^{1*}, MD PhD, Nicole Karam^{2*}, MD PhD, Helge Möllmann^{3*},
 12 MD PhD, Sabine Bleiziffer⁴, MD, Nikolaos Bonaros⁵, MD, PhD, MSc, Rui C. Teles⁶, MD,
 13 Pedro Carrilho Ferreira⁷, MD, Alaide Chieffo⁸, MD, Martin Czerny^{9,10}, MD, Erwan
 14 Donal¹¹, MD, Dariusz Dudek¹², MD, Nicolas Dumonteil¹³, MD, Giovanni Esposito¹⁴, MD
 15 PhD, Stephane Fournier¹⁵, MD PhD, Christian Hassager¹⁶, MD, DMSc, Won-Keun Kim¹⁷,
 16 MD PhD, Konstantin A. Krychtiuk^{18,19}, MD, Julinda Mehilli^{20,21}, MD, Jerzy Pręgowski²²,
 17 MD, Giulio G. Stefanini^{23,24}, MD PhD, Julien Ternacle^{25,26}, MD PhD, Holger Thiele²⁷, MD
 18 PhD, Matthias Thielmann²⁸, MD, Flavien Vincent²⁹, MD, Ralph Stephan von
 19 Bardeleben³⁰, MD, Giuseppe Tarantini¹, MD PhD.

20
 21 *These authors contributed equally to this work.

22
 23
 24
 25 **Affiliations:**

26 ¹*Department of Cardiac, Thoracic, Vascular Sciences and Public Health, University of*
 27 *Padua, Padua, Italy*

28 ²*European Hospital Georges Pompidou, Heart Valves Unit, University of Paris City,*
 29 *INSERM, Paris, France*

30 ³*Department of Cardiology, St. Johannes Hospital Dortmund, Germany*

31 ⁴*Heart and Diabetes Center NRW, Bad Oeynhausen, Germany*

32 ⁵*Cardiac Surgery, Medical University of Innsbruck, Innsbruck, AUT*

33 ⁶*Hospital de Santa Cruz, CHLO; Nova Medical School, CEDOC, Lisbon, Portugal*

34 ⁷*Cardiology Department, Santa Maria University Hospital, CHLN, CAML, CCUL, Faculty*
 35 *of Medicine, University of Lisbon, Lisbon, Portugal*

36 ⁸*Interventional Cardiology Unit, San Raffaele Scientific Institute, Milan, Italy*

37 ⁹*Department of Cardiovascular Surgery, University Heart Centre Freiburg University,*
 38 *Freiburg, Germany*

39 ¹⁰*University of Freiburg, Faculty of Medicine, Freiburg, Germany*

40 ¹¹*Service de Cardiologie CCPCHU de Rennes, University of Rennes, CHU Rennes,*
 41 *Inserm, LTSI-UMR 1099, Pontchaillou F-35000 Rennes, France*

42 ¹²*Institute of Cardiology, Jagiellonian University Medical College, Krakow, Poland*

43 ¹³*Clinique Pasteur, Toulouse, France*

44 ¹⁴*Divisions of Cardiology and Cardiothoracic Surgery, Department of Advanced*
 45 *Biomedical Sciences, Federico II University, Naples, Italy*

- 1 ¹⁵*Service of Cardiology, Lausanne University Hospital and University of Lausanne,*
2 *Lausanne, Switzerland*
3 ¹⁶*Department of Cardiology, Copenhagen University Hospital, Rigshospitalet, Denmark*
4 ¹⁷*Department of Cardiology, St. Johannes Hospital, Dortmund, Germany*
5 ¹⁸*Duke Clinical Research Institute, Durham, NC, USA*
6 ¹⁹*Department of Internal Medicine II, Division of Cardiology, Medical University of*
7 *Vienna, Vienna, Austria*
8 ²⁰*German Centre for Cardiovascular Research (DZHK), Department of Cardiology,*
9 *Ludwig Maximilian University of Munich, Partner Site Munich Heart Alliance, 80539*
10 *Munich, Germany*
11 ²¹*Medizinische Klinik I, Landshut-Achdorf Hospital, 84036 Landshut, Germany*
12 ²²*Department of Interventional Cardiology and Angiology, National Institute of*
13 *Cardiology, Warszawa, Poland*
14 ²³*Department of Biomedical Sciences Humanitas University Pieve Emanuele-Milan Italy*
15 ²⁴*Humanitas Research Hospital IRCCS Rozzano-Milan Italy*
16 ²⁵*Institut universitaire de cardiologie et de pneumologie de Québec, Université*
17 *Laval/Québec Heart and Lung Institute, Laval University, Canada*
18 ²⁶*Haut-Leveque Cardiology Hospital, Bordeaux University, Pessac, France*
19 ²⁷*Department of Internal Medicine/Cardiology, Heart Center Leipzig at the University of*
20 *Leipzig, Leipzig, Germany*
21 ²⁸*Department of Thoracic and Cardiovascular Surgery, West German Heart and Vascular*
22 *Center, University Hospital Essen, 45147 Essen, Germany*
23 ²⁹*Centre Hospitalier Universitaire de Lille-Cardiologie, France*
24 ³⁰*Heart Valve Center, Heart and Vascular Center, Universitätsmedizin Mainz, Mainz,*
25 *Germany*

26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42

Corresponding author:

Chiara Fraccaro, MD PhD

Interventional Cardiology Unit,

Department of Cardiac, Thoracic, Vascular Sciences and Public Health, University of

Padua, Padua, Italy

2, Via Giustiniani

35100 Padova (Italy)

e-mail: chiarafraccaro980@gmail.com

Mobile: +39 328 3850343

Twitter handle: @ChiaraFraccaro

1 **Abstract**

2 Valvular heart disease (VHD) is one of the most frequent causes of heart failure (HF) and
3 is associated with poor prognosis particularly among patients with conservative
4 management. Development and improvement of catheter-based VHD interventions have
5 broadened the indications for transcatheter valve interventions from inoperable-high risk
6 patients to younger/lower risk patients. Cardiogenic shock (CS) associated with severe
7 VHD is a clinical condition at very high risk of mortality where surgical treatment is often
8 deemed prohibitive risk. Transcatheter valve interventions might be a promising alternative
9 in this setting given their less invasiveness. However, supportive scientific evidence is
10 scarce, and often limited to small case series. Current guidelines on VHD do not contain
11 specific recommendations on how to manage patients with VHD and CS. The purpose of
12 this clinical consensus statement, developed by a group of international experts invited by
13 the European Association of Percutaneous Cardiovascular Interventions (EAPCI)
14 Scientific Documents and Initiatives Committee, is to perform a revision of available
15 scientific evidences on the management of CS associated with left-sided VHD, and to
16 provide a rationale and practical approach for the application of transcatheter valve
17 interventions in this specific clinical setting.

18
19 **Classification: Expert Consensus**

20
21 **Keywords.** Valvular heart disease; cardiogenic shock; transcatheter valve interventions;
22 aortic valve disease; mitral valve disease; structural heart disease.
23

1 Abbreviation list

AMI	Acute myocardial infarction
AR	aortic regurgitation
AS	aortic stenosis
BAV	balloon aortic valvuloplasty
BVF	bioprosthetic valve failure
CAD	coronary artery disease
CO	cardiac output
CS	cardiogenic shock
EACTS	European Association for Cardio-Thoracic Surgery
EAPCI	European Association of Percutaneous Cardiovascular Interventions
ESC	European Society of Cardiology
HF	heart failure
HVD	haemodynamic valve deterioration
IABP	intra-aortic balloon pump
ICA	invasive coronary angiography
LA	Left atrium/atrial
LV	left ventricular
LVEF	left ventricular ejection fraction
MCS	mechanical circulatory support
MR	mitral regurgitation
MS	mitral stenosis
MSCT	multislice computed tomography
PVL	paravalvular leak
PCI	percutaneous coronary intervention
PMBV	percutaneous mitral balloon valvuloplasty
RCT	randomized controlled trial
SCAI	Society for Cardiovascular Angiography and Interventions
SVD	structural valve deterioration
TAVI	transcatheter aortic valve implantation
TEER	transcatheter edge-to-edge repair
TMVI	transcatheter mitral valve implantation
TEE	transoesophageal echocardiography
TTE	trans-thoracic echocardiography
VA-ECMO	venous-arterial extracorporeal membrane oxygenation
VHD	valvular heart disease

2

3

4

5

1 **INTRODUCTION**

2 Valvular heart disease (VHD) is among the most frequent causes of heart failure (HF),
3 associated with poor prognosis, particularly when managed conservatively.^{1,2} Acute
4 valvular emergencies comprise approximately 8% of coronary care unit admissions,³ but it
5 is unclear how many turn from acute HF to cardiogenic shock (CS).⁴⁻⁷ Transcatheter valve
6 interventions provided treatment options for a subset of patients with VHD at prohibitive
7 or very high surgical risk. Moreover, technological advances broadened their indication to
8 younger or lower risk patients, or even to less symptomatic or moderate VHD.⁸
9 Conversely, patients with VHD and CS are generally excluded from randomized controlled
10 trials (RCT) exploring these technologies, and less evidence is available in this setting.
11 Therefore, the 2021 European Society of Cardiology (ESC) and European Association for
12 Cardio-Thoracic Surgery (EACTS) Guidelines for VHD⁹ did not include specific sections
13 for VHD presenting with CS. Treatment strategies are left to the discretion of
14 multidisciplinary Heart Teams in a case-by-case fashion, weighing risks and benefits to
15 identify those likely to benefit from interventions and avoid futility.

16 The purpose of this consensus statement, developed by international experts invited
17 by the European Association of Percutaneous Cardiovascular Interventions (EAPCI)
18 Scientific Documents and Initiatives Committee, is to provide a practical approach to
19 transcatheter valve interventions use in patients with left-sided VHD and CS, based on
20 available scientific evidences.

21

22 **DEFINITION OF CARIOGENIC SHOCK**

1 Cardiogenic shock (CS) is a clinical syndrome characterized by life-threatening
2 organ hypoperfusion, caused by low cardiac output (CO) due to primary cardiac pump
3 failure despite adequate volume preload.¹⁰⁻¹⁴ Variable definitions of CS exist
4 (Supplemental Table 1). Consistent part of CS evidence stems from patients with acute
5 myocardial infarction (AMI), while other aetiologies are increasing.¹⁵ The Society for
6 Cardiovascular Angiography and Interventions (SCAI) recently published a disease
7 severity classification in an effort to make CS patients more comparable for clinical and
8 research purposes.^{16,17}

9 We defined CS associated with VHD as significant VHD combined with systolic blood
10 pressure <90 mmHg for >30 min OR need of vasopressors to maintain systolic blood
11 pressure >90 mmHg, elevated serum lactate levels and clinical signs of end-organ
12 hypoperfusion (including cool, sweated extremities, altered mental status, oliguria),
13 corresponding to SCAI stage \geq C.

14

15 **CLINICAL SCENARIOS OF CS AND VHD**

16 **Acute onset of new severe VHD**

17 CS may be due to acute onset of severe VHD such as ischaemic mitral regurgitation (MR),
18 often related to AMI. Functional MR due to left ventricular (LV) global or regional
19 remodelling or ischaemic papillary muscle dysfunction, may resolve after revascularization
20 and recovery of LV function, or persist and require treatment. Acute MR may also be
21 related to chord rupture. Acute severe AR, commonly leads to CS,^{18,19} and is caused by
22 type A aortic dissection, rupture of fenestrated aortic valve or endocarditis, typically
23 requiring surgical correction¹⁹. Other rare situations are iatrogenic or traumatic aortic valve

1 injury, or AR in LV assist device patients. Acute severe VHD may also be related to
2 bioprosthetic valve failure (BVF).^{19,20}

3

4 **Deterioration of chronic VHD**

5 Pre-existing moderate to severe clinically stable VHD (can turn into acute decompensated
6 HF and CS with various cardiac or non-cardiac triggers.

7 In BVF, patients in CS should have at least severe haemodynamic valve deterioration (HVD)
8 (i.e. stage 3)²¹ for valve-related haemodynamic instability. All causes of BVF may lead to
9 severe HVD, including 1) structural valve deterioration (SVD) (i.e., cusp tear); 2) non-
10 structural valve dysfunction (i.e., paravalvular leak); 3) thrombosis; or 4) endocarditis
11 (figure 1).

12 Primary approach should address the triggering condition. However, transcatheter
13 interventions can be used as bailout in complex cases or when the trigger, such as pregnancy,
14 persists.

15

16 Cardiovascular triggers

17 a. *Atrial fibrillation and other (supra-)ventricular arrhythmias:* While left-sided VHD
18 precipitate atrial fibrillation occurrence, the latter complicates moderate to severe left-sided
19 valvular stenosis. In the SEAS trial, at 4-year follow-up, 6% of patients with mild to
20 moderate aortic stenosis (AS) developed atrial fibrillation.²² In AS and mitral stenosis
21 (MS), rapid heart rate and loss of the atrial contraction limit the filling time of the LV.
22 Restoration of sinus rhythm is crucial, though difficult to achieve, particularly in MS.

1 b. *AMI*: AS is not uncommon in AMI patients, and this combination is independently
2 associated with short and long-term mortality.²³ Impaired ischaemic LV contractility
3 further reduces CO, and AS increases afterload creating a vicious circle, leading to CS.
4 Treatment is challenging because inotropic drugs and diuretics increase intraventricular
5 pressure increasing haemodynamic impairment and gradient.

6 c. *Hypertensive crisis* and rapid *volume overload* (intravascular intravenous fluid
7 infusion or blood transfusion) can also cause CS in severe VHD but can generally be
8 treated medically.

9 d. *Takotsubo syndrome* has been associated with pulmonary oedema in AS²⁴.
10 Moreover, dynamic LV outflow tract obstruction typical of apical ballooning may be
11 create severe MR through systolic anterior motion of the anterior mitral leaflet, which may
12 result in CS.²⁵ As with AMI, medical treatment is challenging and may aggravate
13 haemodynamic impairment and CS in AS. Conversely, cautious use of beta-blockers
14 (ideally starting with intravenous, short acting beta-blockers like esmolol) with fluid
15 resuscitation, reduces LV outflow tract obstruction by decreasing basal hypercontractility,
16 increasing LV filling and size, and reducing heart rate, all potentially leading to MR
17 reduction and haemodynamic stabilization.²⁶

18

19 *Non-cardiovascular triggers*

20 a. *Pregnancy* carries high risk of cardiac decompensation in VHD due to pregnancy-
21 related haemodynamic changes. Stenotic VHD, particularly MS, are generally less
22 tolerated during pregnancy than regurgitant lesions, as increased heart rate, stroke volume
23 and CO increase transvalvular gradient by approximately 50%, mainly between the first

1 and second trimesters, worsening patient's and foetus' prognosis.²⁷⁻³¹ Accordingly, MS
2 should be treated pre-conceptionally when diagnosed. Otherwise, transcatheter valve
3 interventions provide minimally invasive options for acutely decompensated condition not
4 responsive to medical treatment³².

5 b. *Severe infection/sepsis* can lead to decreased systemic vascular resistance and
6 hypovolemia, causing compensatory increase in heart rate and hypotension despite
7 increased CO, poorly tolerated in severe MS or AS. Besides, decreased preload increases
8 valvular gradients, aggravating pre-existing stenosis. Cardiovascular comorbidities are risk
9 factors for septic shock,³³ while infection is the main non-cardiac deaths cause (up to 31%)
10 in AS.³⁴⁻³⁶

11 In most patients with septic non-CS, VHD is a bystander and won't require specific urgent
12 intervention. However, valvular intervention might be advisable for selected patients when
13 standard medical therapy fails or weaning and recovery seem challenging. Emergency
14 percutaneous mitral balloon valvuloplasty (PMBV) has been effective in this context.³⁷
15 Balloon valvuloplasty avoids prosthetic valve implantation in infected patients at
16 endocarditis risk. However, it carries an acute MR or AR risk. Weighing the risk-benefit is
17 challenging, and decision should be tailored to patient's condition.

18 a. *Other precipitating factors* include severe anaemia, acute renal failure,
19 hyperthyroidism and hypoalbuminemia, all usually improving after treatment and not
20 requiring emergent valve intervention.

21

22 **EMERGENT DIAGNOSTIC WORKUP**

23 **Non-invasive diagnostic tools**

1 Transthoracic echocardiography (TTE). TTE is the optimal modality in CS,³⁸ determining
2 the cause and severity of underlying VHD and their potential accountability. Limited
3 point-of-care cardiac ultrasound focusing on 2-dimensional assessment of LV function,
4 such as LVEF, may miss important VHD lesions³⁹. Discrimination of the severity of VHD
5 using TTE requires high image quality, precise measurement, complex calculations, and
6 integration of multiple criteria. Moreover, the low flow status of CS should be accounted
7 for, as it might underestimate transvalvular gradients. Conversely, medications used in CS,
8 such as dobutamine, might increase transvalvular gradient, over-estimating VHD. We
9 herein propose an echocardiographic assessment workflow in CS (Figure 2, Table 1).

10

11 Transoesophageal echocardiography (TEE). TEE may increase diagnostic accuracy,
12 especially in case of poor acoustic TTE window, and is relatively straightforward to
13 perform in patients under mechanical ventilation. TEE may identify BVF aetiology,
14 differentiate PVL from valvular regurgitation, and help in suspected endocarditis. It is
15 mandatory for transcatheter mitral valve therapies to evaluate eligibility and guide
16 intervention. It may be used for aortic valve sizing, if CT scan is not available (Table 1).

17

18 Multislice computed tomography (MSCT). MSCT is complementary to TTE. Calcium
19 scoring using non-contrast MSCT can confirm AS severity (likely if >2000 AU in men and
20 >1200 AU in women) in discordant AS grading (aortic valve area <1cm² and mean
21 gradient <40mmHg) related to low CO. MSCT with contrast injection is the gold standard
22 for feasibility study and planning of valvular interventions, such as transcatheter aortic
23 valve implantation (TAVI). MSCT acquisition protocol should include contrast enhanced

1 ECG-gated or triggered heart and aortic root scan, and non-ECG gated vascular bed scan
2 from subclavian arteries to superficial femoral arteries, reconstructed at 1.0mm or less slice
3 thickness for accurate multiplanar evaluations (at least 64-detector technology).
4 High spatial resolution of MSCT by multiplanar and 3D-volume reconstructions, provide
5 accurate analysis of valve morphology (tricuspid, vs bicuspid, calcium distribution), aortic
6 root anatomy, vascular access route, and coronary arteries, the latter being challenging in
7 CS due to tachycardia and low CO. Contrast-enhanced MSCT is also useful in BVF to
8 discriminate SVD, thrombosis, pannus and infective endocarditis, and in planning valve-
9 in-valve procedures (Table 1).

10

11 **Invasive diagnostic tools**

12 Invasive coronary angiography (ICA), CAD is diagnosed in 20 to 80% of symptomatic
13 severe AS according to age group, and increases operative risk⁴⁰ Besides, among patients
14 with CS undergoing TAVI, 10% and 20% present significant left main CAD and proximal
15 left anterior descending artery stenosis, respectively.⁴¹ The coexistence of CAD and
16 secondary MR is much more frequent. More than two thirds of patients undergoing
17 transcatheter edge-to-edge repair (TEER) have relevant CAD.⁴² Therefore, ICA is
18 mandatory to rule out CAD. The objectives of ICA are to 1) identify treatable CAD,
19 aggravating the CS; 2) perform myocardial revascularization when needed; 3) obtain safe
20 and adequate arterial access for percutaneous mechanical circulatory support (MCS).
21 Except for CS in AMI, in case of coexisting CAD requiring revascularization and
22 significant VHD, due to lack of RCT, time-sequence of events – placement of MCS,

1 revascularization and emergency balloon valvuloplasty/TAVI or TEER – depend on team
2 experience, patient clinical status and VHD (Table 1).

3 *Invasive right heart catheterization.* Alongside diagnosing pulmonary hypertension, it was
4 previously broadly used for haemodynamic monitoring and treatment adjustment.

5 However, several registries reported considerable complications related to its routine use
6 for treatment monitoring, and, despite conflicting registry-evidences^{43,44}, the only RCT

7 demonstrated no additional benefit compared to TTE.^{45,46} Therefore, right heart

8 catheterization is not recommended for daily monitoring. It can be useful, alone or in

9 combination with left catheterization, for decision making or in selected cases during the

10 peri-interventional phase in experienced hands (Table 1). Moreover, selective use of

11 pulmonary artery catheters can be considered to guide medical decision in CS, particularly

12 in patients considered for or supported by MCS.^{47,48}

13

14

15 **THERAPEUTIC STRATEGIES: GENERAL CONCEPTS**

16 Both 2021 ESC/EACTS Guidelines for VHD management⁹ and 2021 ESC Guidelines for

17 diagnosis and treatment of acute and chronic HF¹¹ contain few recommendations on VHD

18 management in CS. CS is time-sensitive with rapidly increasing mortality, which diagnosis

19 and management should start as early as possible. Early identification and treatment of

20 underlying cause, along with haemodynamic stabilization and management of organ

21 dysfunction, are key.

22

23 **Medical treatment and ancillary procedures**

1 After initial fluid challenge (if appropriate), pharmacological management of CS consists
2 of intravenous (I.V.) vasoactive agents to improve organ perfusion by increasing CO and
3 blood pressure.^{11,54} Pharmacological agents selection is largely empirical, and they must be
4 used with caution, starting at low doses and up-titrating with close monitoring.^{19,54,55}
5 Norepinephrine is the vasopressor of choice, despite potentially harmful increase in stroke
6 volume and transvalvular gradient in case of AS and increase LV afterload.¹¹ Accordingly,
7 medical stabilization is often difficult in presence of VHD and a rapid escalation to other
8 strategies (mechanical support and/or intervention) is strongly advisable.

9 Triggering factors must be recognized and treated immediately. In case of acute
10 coronary syndrome, urgent revascularization is required regardless of VHD. Nishino et al.
11 showed that shorter symptoms onset-to-reperfusion time was an independent predictor of
12 early MR improvement in AMI.⁴⁹ Out of 51 patients from TAVI-SHOCK Registry, 33%
13 had CAD but only one (2%) presented AMI.⁵⁰

14 Other causative factors include valve thrombosis especially within 12 months of prosthetic
15 valve implantation, when it is the most common valve dysfunction cause.^{51,52}

16 Anticoagulation using VKA and/or UFH is the first-line treatment of biological valve
17 thrombosis. Fibrinolysis is an option (streptokinase was most commonly used fibrinolytic
18 agent, followed by t-PA and urokinase at standard recommended doses of each agent) in
19 obstructive, especially mechanical, valve thrombosis,⁵³. However, considering the risks of
20 bleeding, systemic embolism and recurrent thrombosis, emergency surgical valve
21 replacement is recommended over fibrinolysis if immediately available and not
22 contraindicated⁹.

23

1

2 Mechanical circulatory support devices

3 Evidence regarding outcomes of MCS in CS with VHD remains scarce, deriving mainly
4 from small case series or registries,^{50,56-60} and there are no published guidelines for short-
5 term MCS in this setting. Hence, unselected use of MCS is not supported and requires
6 multidisciplinary expertise for device selection, implantation, and management. In
7 persisting severe haemodynamic deterioration and CS despite medical support and
8 triggering factor removal, early MCS could increase CO and end-organ perfusion, as a
9 bridge-to-recovery, bridge-to-destination or bridge-to-bridge.^{11,19,47} Different temporary
10 MCS are currently available, including: intra-aortic balloon pump (IABP), veno-arterial
11 extracorporeal membrane oxygenation (VA-ECMO), the Impella (Abiomed Europe
12 GmbH, Aachen, Germany), the Tandem-Heart percutaneous system (Cardiac Assist, Inc,
13 Pittsburgh, PA, USA) and percutaneous LV assist devices. Device selection requires in-
14 depth understanding of anatomy, physiology, and pathology of VHD.^{19,47,48}
15 In severe AS, most MCS options may be used.⁴⁸ VA-ECMO may increase LV afterload
16 and, in some cases, concomitant LV unloading is mandatory, requiring unloading devices
17 such as a microaxial flow pump device if not contraindicated, or through atrial septostomy.
18 In MS, where LV end diastolic pressure is generally low, the optimal device would be
19 TandemHeart (with direct LA drainage). However, especially in RV failure and
20 hypoxemia, VA-ECMO would be best, with the preferred use of LA VA-ECMO modality.
21 In patients with CS due to AMI with papillary muscle rupture and acute MR, intra-aortic
22 balloon pump (IABP) may be considered according to ESC guidelines^{11,61}, to decrease
23 afterload, supporting adequate mean arterial pressure and potentially decreasing MR,

1 despite minimal CO augmentation. ECMO can better support CO, but is less commonly
2 used alone, since it may increase total peripheral vascular resistance, potentially worsening
3 MR. More frequently, in MR, physicians should consider LA VA-ECMO modality to
4 unload the LA or Impella device, alone or with ECMO (ie, ECPELLA), to directly unload
5 the LV (caution needed in papillary muscle rupture-related MR).^{19,47,62}

6 Given AR pathophysiology, most (if not all) MCS are relatively contraindicated, especially
7 in presence of concomitant aortic dissection.⁴⁸ In fact, elevated diastolic blood pressure
8 during IABP inflation, and increased afterload due to VA-ECMO, may both increase AR
9 and contribute to LV distention. Similarly, LVAD and Impella (precluding aortic valve
10 coaptation) may worsen AR and recirculation, reducing device' forward flow. If MCS is
11 absolutely necessary in severe AR, TandemHeart or LA VA-ECMO could be considered
12 due to concomitant LA unloading.^{19,47,48}

13 MCS including ECMO, IABP, Impella® and TandemHeart have also been used in high-
14 risk transcatheter valve procedures during CS.⁶³⁻⁶⁵ This use vary widely depending on
15 institutional practice and expertise but, it was demonstrated that a 'standardized team-
16 based approach' with predefined algorithms for early MCS implant and close monitoring
17 of clinical signs, invasive haemodynamics and biochemical markers, may translate into
18 improved survival.⁶⁶⁻⁶⁸

19

20 **Valvular intervention**

21 On top of pharmacological and organ-specific support, valvular intervention can be
22 considered when VHD is the primary cause or an aggravating factor in CS (*Central*

1 *Illustration*). Significant VHD is associated with increased in-hospital mortality in CS,⁶⁹
2 and early treatment is advocated because delay between CS onset and valvular intervention
3 predicted poor outcomes in patients with AS and CS.^{41,70} Interestingly, in the IREMMI
4 registry, time between shock onset and TEER for acute MR was around 30 days.⁷¹ Prior to
5 TEER, 66% of patients were stabilized with IABP or Impella® and 12% with VA-ECMO.
6 However, the authors advocated for early MR correction irrespective of LVEF and
7 development of CS.⁷¹
8 The Heart Team must decide the indication, timing and mode of intervention (surgical vs.
9 transcatheter), taking into account patients' clinical status and risk profile, anatomical
10 considerations (i.e., type of VHD, presence of combined VHD, aortic disease or CAD),
11 role of VHD in the CS, as well as institutional expertise and patients' values and
12 preferences. Contraindications for intervention in patients with CS, include:

- 13 1. Severe frailty, limiting life expectancy (< 6-12 months), or refusal of life-saving
14 treatment.
- 15 2. Non-severe VHD.
- 16 3. End-stage CS with severe end organ failure (the “point of no return” was crossed).
- 17 4. CS complicated by resuscitated cardiac arrest with unfortunate neurological
18 outcome.
- 19 5. Possibility and indication for urgent heart transplantation with or without previous
20 MCS as bridge therapy (i.e., end-stage HF patients with functional MR).

21 Some of these contraindications are relative and dynamic; hence, patients should be closely
22 monitored and the decision adjusted according to the patient's clinical status. Regarding

1 the mode of intervention (surgical vs transcatheter), very few data are available to support
2 either choice. Urgent/emergent cardiac surgery in VHD and CS is at high morbidity and
3 mortality risk,⁷²⁻⁷⁴ and a less invasive approach with at least equal results might be
4 preferable. This can be more intuitive with TAVI, but less evident with other transcatheter
5 valve interventions. RCTs are needed to confirm this hypothesis, but hard to carry out in
6 this setting. Regardless of the strategy, acute correction of VHD in CS can potentially
7 reverse fatal process, allowing for recovery, and improving long-term patient outcomes.
8 Emergent or urgent surgical treatment of VHD leading to CS is advisable as a first-line
9 therapy (particularly in young patients and those with low comorbidity), or as the only
10 therapeutic option in some setting (i.e. active endocarditis or acute AR associated to type A
11 aortic dissection), if surgical risk allows it. Benefit of early surgery in infective
12 endocarditis is uncertain due to high recurrence rate, and its timing must be carefully
13 selected. Therefore, surgery in the acute setting is restricted to specific clinical situations
14 (HF, uncontrolled infection and prevention of embolic events) and eligible patients.⁷⁵ In
15 other cases, and in the absence of haemodynamic refractory instability, surgery is
16 postponed to allow 1 or 2 weeks of antibiotic treatment under careful clinical and
17 echocardiographic observation.^{75,76}

18 Few surgical reports indicate that immediate surgical aortic valve replacement is feasible in
19 critically ill and decompensated patients with AS, with an in-hospital mortality of 25-
20 30%.⁷⁷⁻⁷⁹ In MR with CS, primary and secondary MR should be distinguished. In MR
21 caused by AMI, standard of care is acute surgical revascularization with simultaneous
22 mitral valve repair or replacement, despite high risk in CS (early mortality up to 20-
23 30%)⁸⁰. Peri-operative short-term MCS may be beneficial. In acute ischaemic MR, only

1 papillary muscle and chordal ruptures usually need immediate intervention. Accordingly,
2 of $\approx 8\%$ of patients with CS due to severe MR complicating AMI in the SHOCK Trial
3 Registry, only 46% underwent mitral valve surgery.⁸¹ Surgery of papillary muscle rupture
4 carries higher mortality rate compared to regular mitral surgery owing to acute setting.⁸¹
5 As rapid deterioration after papillary muscle rupture is unpredictable, early intervention is
6 mandatory, even though intravenous diuretic and vasodilator/inotropic support may
7 initially stabilize patients.⁸²
8 Emergency transcatheter valve treatments across different structural VHD complicated by
9 CS are described below, in dedicated sections.

10 In general, specific contraindications for transcatheter intervention include:

- 11 1. Unfavourable valve or vascular anatomy;
- 12 2. Percutaneous intervention not achievable (i.e., intra-chamber thrombus, valvular
13 thrombosis, mitral valve anatomy not suitable for TEER - same contraindications as
14 in stable patients).
- 15 3. Active endocarditis (for transcatheter implantation of devices and valvular
16 replacement);
- 17 4. Feasible and potentially more beneficial valvular surgery despite increased surgical
18 risk according to Heart Team consensus.

19

20 **URGENT/EMERGENT TRANSCATHETER VALVE TREATMENTS ACROSS**

21 **DIFFERENT VHD**

22 **Native AS and CS**

1 TAVI has a class I indication in symptomatic severe AS at high or prohibitive
2 surgical risk.⁹ CS represents a high-risk surgical condition, but RCTs of TAVI in this
3 setting is not available as CS was an exclusion criterion in most RCTs evaluating therapies
4 targeting both AS and HF. Therefore, current guidelines still recommend balloon aortic
5 valvuloplasty (BAV) in AS with decompensated HF and/or CS for stabilization as bridge
6 to TAVI or surgical aortic valve replacement (Class IIb, level of evidence C).⁹ However,
7 despite initial success of urgent BAV, early mortality of these patients remains high (up to
8 71%).⁸³⁻⁹² Recently, urgent/emergent TAVI has been suggested as an alternative when
9 available^{41,50,70,89,93,94} (Table 2). Theoretical advantages of TAVI over BAV in this setting
10 may be a better and sustained haemodynamic improvement with complete relief of
11 afterload mismatch and low residual AR risk, potentially translating into better outcomes
12 and lower rates of early readmission.⁹⁶ Notwithstanding, TAVI may be more challenging
13 due to larger vascular access, higher vascular complications risk and the inconstant
14 availability and feasibility of pre-procedural MSCT.⁸⁹ Moreover, urgent TAVI is not
15 feasible in all hospitals and transfer might be needed. Finally, even in hospitals with TAVI
16 availability, urgent TAVI may not be rapidly feasible for logistic reasons. (Table 3).
17 Masha et al. reported the TAVI largest series in CS (4.1% of the U.S. TAVI population),⁴¹
18 comparing 2,220 emergent TAVI for CS to 12,851 high-risk patients without CS (median
19 STS score 10.2) included in the STS/ACC TVT registry between 2014 and 2017. Despite
20 similar optimal gradient relief, CS population had higher complications rates and 30-day
21 mortality (19.1% vs. 4.9%), primarily driven by pre-procedural shock severity rather than
22 procedural complications. Impact of CS duration prior to treatment is well known, and
23 available evidence suggests that AS should be promptly corrected (BAV or TAVI) -

1 ideally within 48 hours from CS onset, as >48 hours delay was linked to worse
2 prognosis.^{86,89,90} However, ideal time window and accurate criteria for intervention remain
3 unknown. Given procedural risks, it should be undertaken after Heart Team discussion in
4 experienced centres. Decision-making should consider feasibility, efficacy and utility of
5 emergent TAVI over other treatments, including medical management, BAV, durable LV
6 assist devices, and palliative care (Figure 3). There is no uniform definition of futility;
7 however, in TAVI, it can be described as death and/or absence of functional improvement
8 6 to 12 months post-procedure.⁹⁷

9 Considerable knowledge gaps also exist regarding specific technical considerations, such
10 as 1) timing of coronary revascularization of concomitant CAD; 2) valve choice; 3)
11 usefulness of intraprocedural MCS (i.e., “protected TAVI”).^{98,99} Regarding valve choice,
12 there is no RCT and interventionalists should rather use the device they are most familiar
13 with. Furthermore, devices anticipating best outcomes with least hemodynamic
14 compromise during deployment should be preferred.

15 *Bicuspid aortic valve disease.* In the specific and not uncommon setting of bicuspid severe
16 AS, especially in the youth, cardiac surgery should be considered. BAV can be undertaken
17 in non-calcified valves with minimal AR (for example during pregnancy), as a bridge-to-
18 surgery. In older patients with calcified valves, TAVI remains an option, provided accurate
19 valve evaluation, sizing and preprocedural planning by MSCT.

20

21 **Native AR and CS**

22 Given the high surgical risk, TAVI may be an alternative for pure (non-calcified) AR^{100–106}
23 also in CS, as reported in case reports or small series (Table 4).^{107–110} It is generally

1 contraindicated in endocarditis and aortic dissection. The Endo-Bentall procedure for
2 transcatheter treatment of acute aortic dissection complicated by acute AR is promising.¹¹¹
3 Concerning AR in LV assist device patients, casuistics and meta-analyses demonstrate
4 challenges and potentials of transcatheter treatment.^{109,112}
5 There is currently only one CE-marked device for pure AR.¹⁰⁰ Procedural challenges with
6 TAVI in pure AR include 1)lack of calcification for annulus visualization and valve
7 anchoring; 2)large annular size exceeding the manufacturer's recommendations for
8 available transcatheter heart valves sizes. Future devices' iterations may overcome these
9 limitations.

10

11 **Native MS and CS**

12 PMBV in rheumatic MS has revolutionized the treatment of rheumatic MS since its
13 introduction in 1984.^{113,114} It is recommended for severe symptomatic MS without
14 unfavourable anatomic characteristics for mitral commissurotomy according to the 2021
15 ESC/EACTS Guidelines VHD management.⁹
16 This is particularly appealing in CS, as the procedure is less invasive than surgery and can
17 be performed quickly, on an emergency basis, and under local anaesthesia. Several case
18 reports described its use in this setting.¹¹⁵⁻¹¹⁸ In patients who are not good candidates for
19 PMBV, transcatheter mitral valve implantation (TMVI) could offer a minimally invasive
20 alternative, even though most techniques are much more challenging, require general
21 anaesthesia and thorough pre-procedural planning. Besides, widespread availability and
22 longer-term follow-up is lacking.

1 In the specific case of pregnant women with severe HF, use of PMBV has been described
2 with substantial improvement in clinical outcomes and acceptable safety.¹¹⁹ Its yield in CS
3 has been described in a case report.¹²⁰ Radiation exposure during PMBV carries a foetal
4 risk, especially during organogenesis. Every effort should be made to postpone the
5 procedure to second trimester, after the fourth month, when organogenesis is complete and
6 thyroid is still inactive.¹²¹ However, when CS occurs, postponing the procedure may not be
7 possible. In this case, radiation doses should be kept as low as reasonably achievable
8 (ALARA) and dedicated protocols are warranted to minimize foetal radiation and iodine-
9 based contrast medium due to the risk of neonatal hypothyroidism (Supplemental Table 2).

10

11 **Native MR and CS**

12 Postoperative outcome of emergency surgery (repair or replacement) for acute severe MR,
13 regardless of aetiology is poor with an overall 30-day mortality of 22.5%, even higher in
14 AMI-related MR complicated by CS (up to 26.9%).¹²² Role of transcatheter interventions
15 in patients with MR and CS has not been fully demonstrated. There are no specific RCTs
16 completed to date (The “Transcatheter Mitral Valve Repair for Inotrope Dependent
17 Cardiogenic Shock (MINOS)” - NCT05298124 - is ongoing) and patients in CS were
18 excluded from landmark trials of transcatheter mitral valve repair .^{123–125} However, several
19 case reports and recent observational studies described good results (Table 5).^{59,62,71,126–132}
20 Available evidence concerns almost exclusively one TEER device; use of TMVI in this
21 setting has not been reported. Of note, most data pertain to secondary, especially
22 ischaemic, MR.

1 Comparison among studies is limited by differences in population, methods and outcomes
2 assessment. Still, available evidence suggests that MitraClip® (Abbott Vascular, Abbott
3 Park, Illinois, USA) is associated with high procedural success (72.7-100%), and
4 acceptable short and mid-term outcomes (30-day or in-hospital mortality 0-27.3%, with a
5 single-center study reporting a 30-day mortality of 60%; 6-month or follow-up mortality
6 16.7-63.0%).^{59,62,71,126-132} In the largest study published to date, Jung et al. pooled data
7 from several observational studies, and performed a patient-level analysis of 141 patients
8 with CS and moderate to severe acute ischaemic MR; 78.7% of patients required inotropes
9 and about half were on MCS. Most had secondary MR (75.2%). Procedural success was
10 high (88.7%), with a relatively low overall mortality (in-hospital mortality 15.6%, 90-days
11 mortality 29.5%, and one-year mortality 42.6%). Successful TEER was associated with
12 74% relative reduction in both in-hospital and 90-day mortality.¹²⁶ Tang et al. compared
13 the outcome of patients receiving MitraClip® during the index hospitalization to those who
14 did not using propensity-matched data from the Centers for Medicare and Medicaid
15 Services in the United States. They showed increasing device use throughout the study,
16 and significantly lower in-hospital (24.8% versus 35.4%; odds ratio 0.6; 95% confidence
17 interval (CI) 0.47-0.77; $p < 0.001$) and one-year mortality (hazard ratio 0.76; 95% CI 0.65-
18 0.88; $p < 0.001$) in patients undergoing TEER. This benefit was consistent in all subgroups,
19 except for patients requiring acute MCS or haemodialysis at the time of intervention.¹³³
20 These preliminary results, even if encouraging, should be considered with caution. More
21 robust data should be obtained and the role of other techniques including TMVI must be

1 assessed. In the meantime, TEER in CS should be considered in experienced hands and
2 after careful feasibility evaluation.

3

4 **BVF and CS**

5 According to EAPCI consensus and VARC-3 definition,²⁰ BVF is defined by 1) clinically
6 expressive bioprosthetic valve dysfunction or irreversible severe HVD, 2) valve
7 reintervention, and 3) valve-related death.^{134–136}

8 Transcatheter treatment for Stage 3 HVD and CS depends on underlying pathology and
9 time from index procedure.

10 Short interval (<12 months): Valve thrombosis is the most common cause of
11 dysfunction.^{51,52} Its treatment has previously been described (see *Medical treatment and*
12 *ancillary procedures*). New valve regurgitation is related to valve migration, PVL, or
13 endocarditis.¹³⁷ Plug implantation is gold-standard for non-surgical patients with PVL.^{138–}
14 ¹⁴⁰ Valve-in-valve can restore valve function and haemodynamics in unstable patients with
15 migrated transcatheter or sutureless valves, and inoperable patients with subacute
16 endocarditis.^{141,142}

17 Long interval (>12 months): Most common causes are degeneration and endocarditis, even
18 if endocarditis decreases one year after valve implantation (approximately 1% per person-
19 year vs 0.5% per person-year afterwards).¹⁴³ In case of valve-in-valve, characteristics of
20 the bioprosthesis should be taken into account (Table 6). CS context would require fast and
21 effective transcatheter procedure. However, some anatomical conditions like small internal
22 diameter of degenerated bioprosthesis and high coronary obstruction risk, or outflow tract
23 obstruction risks, will require sophisticated techniques to achieve optimal procedural

1 outcome^{145,146} (Table 7). Those situations will require general anaesthesia to allow TEE
2 guidance, and potentially MCS to stabilize haemodynamics during longer procedures.

3

4 **CONCLUSIONS**

5 CS is a clinical condition of extremely high morbidity and mortality where severe VHD is
6 associated with increased mortality.⁶⁹ Acute onset of severe VHD may be the cause of CS,
7 or triggering factors acting on pre-existing stable severe VHD can cause CS. In both
8 situations, pharmacological support is the first line therapy, including removal and
9 treatment of triggering factors. However, if haemodynamic status is not quickly reverted,
10 rapid escalation to other non-pharmacological treatment, particularly correction of
11 concomitant VHD, may be required. Treatment decision should consider procedural utility
12 and futility. Given the extremely high mortality risk, less invasive transcatheter valve
13 interventions can be used as an alternative to surgery in several situations. Heart Teams
14 must guide decision-making regarding indications, timing and mode of intervention,
15 according to patients' clinical status and risk profile, anatomical considerations, VHD role,
16 institutional expertise, and patients' values and preferences. As outlined above, to date,
17 most evidence stems from case series and registries. The very high mortality risk warrants
18 dedicated, well-designed and adequately powered RCTs to further elucidate the role of
19 transcatheter valvular interventions and could, if positive, have significant public health
20 implications. While CS RCTs are complicated by time pressures and patients'
21 heterogeneity, clear inclusion criteria render such trials feasible and effective.¹⁴⁷ We
22 believe that in the meantime, all CS patients, if not eligible for ongoing RCTs, should be
23 included in registries embedded in network of networks, or a hub-and-spoke registry, that

1 will allow high-quality retrospective analyses in large, worldwide dataset, and may assist
2 in future registry-based RCTs.¹⁴⁸

3

4 **FUNDING STATEMENT:** This research received no specific grant from any funding
5 agency in the public, commercial or not-for-profit sectors.

6

7 **CONFLICT OF INTEREST:**

8 Nikolaos Bonaros reports grants from Edwards Lifesciences and Corcym and lecture fees
9 from Edwards Lifesciences and Medtronic. Pedro Carrilho-Ferreira reports lecture fees
10 from Astra Zeneca, A. Menarini, Bayer, Biotronik, Medinfar, Medtronic and Advisory
11 Board for Medtronic. Martin Czerny is Consultant for Terumo Aortic, Medtronic,
12 Endospan and NEOS and Shareholder TEVAR Ltd and Ascense Medical. Chiara Fraccaro
13 reports Support for attending meetings from Medtronic. Christian Hassager reports
14 Research grants from Novo Nordisk Foundation and Lundbeck Foundation and Lecture
15 honorarium from Abiomed. Nicole Karam reports consulting and lecture fees from
16 Medtronic, Edwards and Abbott Vascular. Won-Keun Kim reports lecture fees and
17 honoraria from Abbott, Boston, Meril, Edwards, Medtronic, Shockwave. Konstantin A.
18 Krychtiuk reports lecture and/or consulting fees from Amgen, Novartis, Sanofi. Helge
19 Möllmann received speaker honraria/proctor fees from Abbott, Boston Scientific, Edwards
20 Lifesciences, Medtronic. Jerzy Pręgowski reports lecture fees from Abbott and Edwards
21 and contracts from Abbott. Giuseppe Tarantini reports lecture fees from Medtronic,
22 Edwards Lifesciences, Abbott Vascular, Boston Scientific, GADA, Abiomed. Julien
23 Ternacle reports consulting fees from Abbott, General Electric and Philips Healthcare and
24 lecture fees from Edwards. All other authors have nothing to disclose.

25

26

1 REFERENCES

- 2 1. Tabata N, Sinning J-M, Kaikita K, Tsujita K, Nickenig G, Werner N. Current status
3 and future perspective of structural heart disease intervention. *J Cardiol* 2019;74:1–12.
- 4 2. Nieminen MS, Brutsaert D, Dickstein K, Drexler H, Follath F, Harjola V-P,
5 Hochadel M, Komajda M, Lassus J, Lopez-Sendon JL, Ponikowski P, Tavazzi L, on behalf
6 of the EuroHeart Survey Investigators. EuroHeart Failure Survey II (EHFS II): a survey on
7 hospitalized acute heart failure patients: description of population. *European Heart*
8 *Journal* 2006;27:2725–2736.
- 9 3. Bohula EA, Katz JN, Diepen S van, Alviar CL, Baird-Zars VM, Park J-G, Barnett
10 CF, Bhattal G, Barsness GW, Burke JA, Cremer PC, Cruz J, Daniels LB, DeFilippis A,
11 Granger CB, Hollenberg S, Horowitz JM, Keller N, Kontos MC, Lawler PR, Menon V,
12 Metkus TS, Ng J, Orgel R, Overgaard CB, Phreaner N, Roswell RO, Schulman SP, Snell
13 RJ, Solomon MA, Ternus B, Tymchak W, Vikram F, Morrow DA, Critical Care
14 Cardiology Trials Network. Demographics, Care Patterns, and Outcomes of Patients
15 Admitted to Cardiac Intensive Care Units: The Critical Care Cardiology Trials Network
16 Prospective North American Multicenter Registry of Cardiac Critical Illness. *JAMA*
17 *Cardiol* 2019;4:928–935.
- 18 4. Tavazzi G, Rossello X, Grand J, Gierlotka M, Sionis A, Ahrens I, Hassager C,
19 Price S. Epidemiology, monitoring, and treatment strategy in cardiogenic shock. A
20 multinational cross-sectional survey of ESC-acute cardiovascular care association research
21 section. *Eur Heart J Acute Cardiovasc Care* 2022:zuac087.
- 22 5. Bhatt AS, Berg DD, Bohula EA, Alviar CL, Baird-Zars VM, Barnett CF, Burke JA,
23 Carnicelli AP, Chaudhry S-P, Daniels LB, Fang JC, Fordyce CB, Gerber DA, Guo J,

- 1 Jentzer JC, Katz JN, Keller N, Kontos MC, Lawler PR, Menon V, Metkus TS, Nativi-
2 Nicolau J, Phreaner N, Roswell RO, Sinha SS, Jeffrey Snell R, Solomon MA, Van Diepen
3 S, Morrow DA. De Novo vs Acute-on-Chronic Presentations of Heart Failure-Related
4 Cardiogenic Shock: Insights from the Critical Care Cardiology Trials Network Registry.
5 *Journal of Cardiac Failure* 2021;27:1073–1081.
- 6 6. Berg DD, Bohula EA, Morrow DA. Epidemiology and causes of cardiogenic
7 shock. *Current Opinion in Critical Care* 2021;27:401–408.
- 8 7. Harjola V-P, Lassus J, Sionis A, Køber L, Tarvasmäki T, Spinar J, Parissis J,
9 Banaszewski M, Silva-Cardoso J, Carubelli V, Di Somma S, Tolppanen H, Zeymer U,
10 Thiele H, Nieminen MS, Mebazaa A, CardShock Study Investigators, GREAT network.
11 Clinical picture and risk prediction of short-term mortality in cardiogenic shock. *Eur J*
12 *Heart Fail* 2015;17:501–509.
- 13 8. Prendergast BD, Baumgartner H, Delgado V, Gérard O, Haude M, Himmelmann
14 A, Iung B, Leafstedt M, Lennartz J, Maisano F, Marinelli EA, Modine T, Mueller M,
15 Redwood SR, Rörick O, Sahyoun C, Saillant E, Søndergaard L, Thoenes M, Thomitzek K,
16 Tschernich M, Vahanian A, Wendler O, Zemke EJ, Bax JJ. Transcatheter heart valve
17 interventions: where are we? Where are we going? *Eur Heart J* 2019;40:422–440.
- 18 9. Vahanian A, Beyersdorf F, Praz F, Milojevic M, Baldus S, Bauersachs J,
19 Capodanno D, Conradi L, De Bonis M, De Paulis R, Delgado V, Freemantle N, Gilard M,
20 Haugaa KH, Jeppsson A, Jüni P, Pierard L, Prendergast BD, Sádaba JR, Tribouilloy C,
21 Wojakowski W, ESC/EACTS Scientific Document Group, Neumann F-J, Myers P,
22 Abdelhamid M, Achenbach S, Asteggiano R, Barili F, Borger MA, Carrel T, Collet J-P,
23 Foldager D, Habib G, Hassager C, Irs A, Iung B, Jahangiri M, Katus HA, Koskinas KC,

- 1 Massberg S, Mueller CE, Nielsen JC, Pibarot P, Rakisheva A, Roffi M, Rubboli A,
2 Shlyakhto E, Siepe M, Sitges M, Sondergaard L, Sousa-Uva M, Tarantini G, Zamorano JL,
3 Praz F, Milojevic M, Baldus S, Bauersachs J, Capodanno D, Conradi L, De Bonis M, De
4 Paulis R, Delgado V, Freemantle N, Gilard M, Haugaa KH, Jeppsson A, Jüni P, Pierard L,
5 Prendergast BD, Sádaba JR, Tribouilloy C, Wojakowski W. 2021 ESC/EACTS Guidelines
6 for the management of valvular heart disease. *European Heart Journal* 2021;ehab395.
- 7 10. Zeymer U, Bueno H, Granger CB, Hochman J, Huber K, Lettino M, Price S,
8 Schiele F, Tubaro M, Vranckx P, Zahger D, Thiele H. Acute Cardiovascular Care
9 Association position statement for the diagnosis and treatment of patients with acute
10 myocardial infarction complicated by cardiogenic shock: A document of the Acute
11 Cardiovascular Care Association of the European Society of Cardiology. *Eur Heart J*
12 *Acute Cardiovasc Care* 2020;9:183–197.
- 13 11. McDonagh TA, Metra M, Adamo M, Gardner RS, Baumbach A, Böhm M, Burri H,
14 Butler J, Čelutkienė J, Chioncel O, Cleland JGF, Coats AJS, Crespo-Leiro MG, Farmakis
15 D, Gilard M, Heymans S, Hoes AW, Jaarsma T, Jankowska EA, Lainscak M, Lam CSP,
16 Lyon AR, McMurray JJV, Mebazaa A, Mindham R, Muneretto C, Francesco Piepoli M,
17 Price S, Rosano GMC, Ruschitzka F, Kathrine Skibelund A, ESC Scientific Document
18 Group. 2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart
19 failure. *Eur Heart J* 2021;42:3599–3726.
- 20 12. Josiassen J, Frydland M, Hassager C, Møller JE, Perner A, Grand J. Randomized
21 clinical trials of patients with acute myocardial infarction-related cardiogenic shock: a
22 systematic review of used cardiogenic shock definitions and outcomes. *Kardiol Pol*
23 2021;79:1003–1015.

- 1 13. Califf RM, Bengtson JR. Cardiogenic shock. *N Engl J Med* 1994;330:1724–1730.
- 2 14. Menon V, Slater JN, White HD, Sleeper LA, Cocke T, Hochman JS. Acute
3 myocardial infarction complicated by systemic hypoperfusion without hypotension: report
4 of the SHOCK trial registry. *Am J Med* 2000;108:374–380.
- 5 15. Shah M, Patnaik S, Patel B, Ram P, Garg L, Agarwal M, Agrawal S, Arora S, Patel
6 N, Wald J, Jorde UP. Trends in mechanical circulatory support use and hospital mortality
7 among patients with acute myocardial infarction and non-infarction related cardiogenic
8 shock in the United States. *Clin Res Cardiol* 2018;107:287–303.
- 9 16. Baran DA, Grines CL, Bailey S, Burkhoff D, Hall SA, Henry TD, Hollenberg SM,
10 Kapur NK, O’Neill W, Ornato JP, Stelling K, Thiele H, Diepen S van, Naidu SS. SCAI
11 clinical expert consensus statement on the classification of cardiogenic shock: This
12 document was endorsed by the American College of Cardiology (ACC), the American
13 Heart Association (AHA), the Society of Critical Care Medicine (SCCM), and the Society
14 of Thoracic Surgeons (STS) in April 2019. *Catheter Cardiovasc Interv* 2019;94:29–37.
- 15 17. Naidu SS, Baran DA, Jentzer JC, Hollenberg SM, Diepen S van, Basir MB, Grines
16 CL, Diercks DB, Hall S, Kapur NK, Kent W, Rao SV, Samsky MD, Thiele H, Truesdell
17 AG, Henry TD. SCAI SHOCK Stage Classification Expert Consensus Update: A Review
18 and Incorporation of Validation Studies: This statement was endorsed by the American
19 College of Cardiology (ACC), American College of Emergency Physicians (ACEP),
20 American Heart Association (AHA), European Society of Cardiology (ESC) Association
21 for Acute Cardiovascular Care (ACVC), International Society for Heart and Lung
22 Transplantation (ISHLT), Society of Critical Care Medicine (SCCM), and Society of
23 Thoracic Surgeons (STS) in December 2021. *J Am Coll Cardiol* 2022:S0735-

- 1 1097(22)00180-2.
- 2 18. Zipes, Libby, Bonow, Mann, Tomaselli, Braunwald. Aortic Regurgitation.
- 3 *Braunwald's Heart Disease: A textbook of Cardiovascular Medicine*. Elsevier/Saunders,
- 4 Philadelphia, PA e 2019.
- 5 19. Bernard S, Deferm S, Bertrand PB. Acute valvular emergencies. *European Heart*
- 6 *Journal Acute Cardiovascular Care* 2022;11:653–665.
- 7 20. VARC-3 WRITING COMMITTEE:, G n reux P, Piazza N, Alu MC, Nazif T,
- 8 Hahn RT, Pibarot P, Bax JJ, Leipsic JA, Blanke P, Blackstone EH, Finn MT, Kapadia S,
- 9 Linke A, Mack MJ, Makkar R, Mehran R, Popma JJ, Reardon M, Rodes-Cabau J, Van
- 10 Mieghem NM, Webb JG, Cohen DJ, Leon MB. Valve Academic Research Consortium 3:
- 11 Updated Endpoint Definitions for Aortic Valve Clinical Research. *J Am Coll Cardiol*
- 12 2021;77:2717–2746.
- 13 21. VARC-3 WRITING COMMITTEE, G n reux P, Piazza N, Alu MC, Nazif T,
- 14 Hahn RT, Pibarot P, Bax JJ, Leipsic JA, Blanke P, Blackstone EH, Finn MT, Kapadia S,
- 15 Linke A, Mack MJ, Makkar R, Mehran R, Popma JJ, Reardon M, Rodes-Cabau J, Van
- 16 Mieghem NM, Webb JG, Cohen DJ, Leon MB. Valve Academic Research Consortium 3:
- 17 updated endpoint definitions for aortic valve clinical research. *European Heart Journal*
- 18 2021;42:1825–1857.
- 19 22. Bang CN, Greve AM, Boman K, Egstrup K, Gohlke-Baerwolf C, K ber L,
- 20 Nienaber CA, Ray S, Rosseb  AB, Wachtell K. Effect of lipid lowering on new-onset
- 21 atrial fibrillation in patients with asymptomatic aortic stenosis: the Simvastatin and
- 22 Ezetimibe in Aortic Stenosis (SEAS) study. *Am Heart J* 2012;163:690–696.
- 23 23. Singh GK, Bijl P van der, Goedemans L, Vollema EM, Abou R, Ajmone Marsan

- 1 N, Bax JJ, Delgado V. Prevalence of Aortic Valve Stenosis in Patients With ST-Segment
2 Elevation Myocardial Infarction and Effect on Long-Term Outcome. *Am J Cardiol*
3 2021;153:30–35.
- 4 24. Bayer MF. Acute pulmonary edema due to stress cardiomyopathy in a patient with
5 aortic stenosis: a case report. *Cases J* 2009;2:9128.
- 6 25. Conradi PM, Loon RB van, Handoko ML. Dynamic left ventricular outflow tract
7 obstruction in Takotsubo cardiomyopathy resulting in cardiogenic shock. *BMJ Case Rep*
8 2021;14:e240010.
- 9 26. Migliore F, Bilato C, Isabella G, Iliceto S, Tarantini G. Haemodynamic effects of
10 acute intravenous metoprolol in apical ballooning syndrome with dynamic left ventricular
11 outflow tract obstruction. *Eur J Heart Fail* 2010;12:305–308.
- 12 27. Elkayam U, Goland S, Pieper PG, Silverside CK. High-Risk Cardiac Disease in
13 Pregnancy: Part I. *J Am Coll Cardiol* 2016;68:396–410.
- 14 28. Silversides CK, Colman JM, Sermer M, Siu SC. Cardiac risk in pregnant women
15 with rheumatic mitral stenosis. *Am J Cardiol* 2003;91:1382–1385.
- 16 29. Hameed A, Karaalp IS, Tummala PP, Wani OR, Canetti M, Akhter MW, Goodwin
17 I, Zapadinsky N, Elkayam U. The effect of valvular heart disease on maternal and fetal
18 outcome of pregnancy. *J Am Coll Cardiol* 2001;37:893–899.
- 19 30. Samiei N, Amirsardari M, Rezaei Y, Parsaee M, Kashfi F, Hantoosh Zadeh S,
20 Beikmohamadi S, Fouladi M, Hosseini S, Peighambari MM, Mohebbi A.
21 Echocardiographic Evaluation of Hemodynamic Changes in Left-Sided Heart Valves in
22 Pregnant Women With Valvular Heart Disease. *Am J Cardiol* 2016;118:1046–1052.
- 23 31. Hagen IM van, Thorne SA, Taha N, Youssef G, Elnagar A, Gabriel H, ElRakshy Y,

- 1 Iung B, Johnson MR, Hall R, Roos-Hesselink JW, ROPAC Investigators and EORP Team.
2 Pregnancy Outcomes in Women With Rheumatic Mitral Valve Disease: Results From the
3 Registry of Pregnancy and Cardiac Disease. *Circulation* 2018;137:806–816.
- 4 32. Fraccaro C, Tence N, Masiero G, Karam N. Management of Valvular Disease
5 During Pregnancy: Evolving Role of Percutaneous Treatment. *Interv Cardiol* 2020;15:e10.
- 6 33. Cecconi M, Evans L, Levy M, Rhodes A. Sepsis and septic shock. *Lancet*
7 2018;392:75–87.
- 8 34. Minamino-Muta E, Kato T, Morimoto T, Taniguchi T, Shiomi H, Nakatsuma K,
9 Shirai S, Ando K, Kanamori N, Murata K, Kitai T, Kawase Y, Miyake M, Izumi C,
10 Mitsuoka H, Kato M, Hirano Y, Matsuda S, Nagao K, Inada T, Murakami T, Takeuchi Y,
11 Yamane K, Toyofuku M, Ishii M, Inoko M, Ikeda T, Komasa A, Tada E, Ishii K, Hotta K,
12 Higashitani N, Jinnai T, Kato Y, Inuzuka Y, Maeda C, Morikami Y, Saito N, Sakata R,
13 Minatoya K, Kimura T. Causes of Death in Patients with Severe Aortic Stenosis: An
14 Observational study. *Sci Rep* 2017;7:14723.
- 15 35. Banovic M, Putnik S, Penicka M, Doros G, Deja MA, Kockova R, Kotrc M,
16 Glaveckaite S, Gasparovic H, Pavlovic N, Velicki L, Salizzoni S, Wojakowski W, Van
17 Camp G, Nikolic SD, Iung B, Bartunek J, AVATAR-trial investigators. Aortic Valve
18 ReplAcemenT versus Conservative Treatment in Asymptomatic SeveRe Aortic Stenosis:
19 The AVATAR Trial. *Circulation* 2021.
- 20 36. Kang D-H, Park S-J, Lee S-A, Lee S, Kim D-H, Kim H-K, Yun S-C, Hong G-R,
21 Song J-M, Chung C-H, Song J-K, Lee J-W, Park S-W. Early Surgery or Conservative Care
22 for Asymptomatic Aortic Stenosis. *N Engl J Med* 2020;382:111–119.
- 23 37. Litmanovitch M, Joynt GM, Skoularigis J, Lipman J. Emergency percutaneous

- 1 balloon mitral valvotomy in a patient with septic shock. *Chest* 1995;108:570–572.
- 2 38. Okutucu S, Fatihoglu SG, Lacoste MO, Oto A. Echocardiographic assessment in
3 cardiogenic shock. *Herz* 2021;46:467–475.
- 4 39. Sannino A, Gargiulo G, Schiattarella GG, Brevetti L, Perrino C, Stabile E, Losi
5 MA, Toscano E, Giugliano G, Scudiero F, Chiacchio E, Trimarco B, Esposito G. Increased
6 mortality after transcatheter aortic valve implantation (TAVI) in patients with severe aortic
7 stenosis and low ejection fraction: a meta-analysis of 6898 patients. *Int J Cardiol*
8 2014;176:32–39.
- 9 40. Faroux L, Guimaraes L, Wintzer-Wehekind J, Junquera L, Ferreira-Neto AN, Del
10 Val D, Muntané-Carol G, Mohammadi S, Paradis J-M, Rodés-Cabau J. Coronary Artery
11 Disease and Transcatheter Aortic Valve Replacement: JACC State-of-the-Art Review. *J*
12 *Am Coll Cardiol* 2019;74:362–372.
- 13 41. Masha L, Vemulapalli S, Manandhar P, Balan P, Shah P, Kosinski AS, Stewart G.
14 Demographics, Procedural Characteristics, and Clinical Outcomes When Cardiogenic
15 Shock Precedes TAVR in the United States. *JACC: Cardiovascular Interventions*
16 2020;13:1314–1325.
- 17 42. Shamekhi J, Weber M, Sugiura A, Öztürk C, Treede H, Grube E, Werner N,
18 Nickenig G, Sinning J-M. Impact of Coronary Artery Disease on Outcomes in Patients
19 Undergoing Percutaneous Edge-to-Edge Repair. *JACC Cardiovasc Interv* 2020;13:2137–
20 2145.
- 21 43. Ranka S, Mastoris I, Kapur NK, Tedford RJ, Rali A, Acharya P, Weidling R, Goyal
22 A, Sauer AJ, Gupta B, Haglund N, Gupta K, Fang JC, Lindenfeld J, Shah Z. Right Heart
23 Catheterization in Cardiogenic Shock Is Associated With Improved Outcomes: Insights

- 1 From the Nationwide Readmissions Database. *JAHA* 2021;10:e019843.
- 2 44. Garan AR, Kanwar M, Thayer KL, Whitehead E, Zweck E, Hernandez-Montfort J,
3 Mahr C, Haywood JL, Harwani NM, Wencker D, Sinha SS, Vorovich E, Abraham J,
4 O'Neill W, Burkhoff D, Kapur NK. Complete Hemodynamic Profiling With Pulmonary
5 Artery Catheters in Cardiogenic Shock Is Associated With Lower In-Hospital Mortality.
6 *JACC: Heart Failure* 2020;8:903–913.
- 7 45. Chen Y, Shlofmitz E, Khalid N, Bernardo NL, Ben-Dor I, Weintraub WS,
8 Waksman R. Right Heart Catheterization-Related Complications: A Review of the
9 Literature and Best Practices. *Cardiol Rev* 2020;28:36–41.
- 10 46. Binanay C, Califf RM, Hasselblad V, O'Connor CM, Shah MR, Sopko G,
11 Stevenson LW, Francis GS, Leier CV, Miller LW, ESCAPE Investigators and ESCAPE
12 Study Coordinators. Evaluation study of congestive heart failure and pulmonary artery
13 catheterization effectiveness: the ESCAPE trial. *JAMA* 2005;294:1625–1633.
- 14 47. Villablanca P, Nona P, Lemor A, Qintar M, O'Neill B, Lee J, Frisoli T, Wang DD,
15 Eng MH, O'Neill WW. Mechanical Circulatory Support in Cardiogenic Shock due to
16 Structural Heart Disease. *Interventional Cardiology Clinics* 2021;10:221–234.
- 17 48. Santana JM, Dalia AA, Newton M, Pisano DV, Eapen S, Kawabori M, Ortoleva J.
18 Mechanical Circulatory Support Options in Patients With Aortic Valve Pathology. *J*
19 *Cardiothorac Vasc Anesth* 2022;36:3318–3326.
- 20 49. Nishino S, Watanabe N, Kimura T, Enriquez-Sarano M, Nakama T, Furugen M,
21 Koiwaya H, Ashikaga K, Kuriyama N, Shibata Y. The Course of Ischemic Mitral
22 Regurgitation in Acute Myocardial Infarction After Primary Percutaneous Coronary
23 Intervention: From Emergency Room to Long-Term Follow-Up. *Circ Cardiovasc Imaging*

- 1 2016;9:e004841.
- 2 50. Fraccaro C, Campante Teles R, Tchétché D, Saia F, Bedogni F, Montorfano M,
3 Fiorina C, Meucci F, De Benedictis M, Leonzi O, Barbierato M, Dumonteil N, Stolcova
4 M, Maffeo D, Compagnone M, Brito J, Chieffo A, Tarantini G. Transcatheter aortic valve
5 implantation (TAVI) in cardiogenic shock: TAVI-shock registry results. *Catheter*
6 *Cardiovasc Interv* 2020;96:1128–1135.
- 7 51. Egbe AC, Pislaru SV, Pellikka PA, Poterucha JT, Schaff HV, Maleszewski JJ,
8 Connolly HM. Bioprosthetic Valve Thrombosis Versus Structural Failure: Clinical and
9 Echocardiographic Predictors. *J Am Coll Cardiol* 2015;66:2285–2294.
- 10 52. Dangas GD, Weitz JI, Giustino G, Makkar R, Mehran R. Prosthetic Heart Valve
11 Thrombosis. *J Am Coll Cardiol* 2016;68:2670–2689.
- 12 53. Karthikeyan G, Senguttuvan NB, Joseph J, Devasenapathy N, Bahl VK, Airan B.
13 Urgent surgery compared with fibrinolytic therapy for the treatment of left-sided prosthetic
14 heart valve thrombosis: a systematic review and meta-analysis of observational studies.
15 *European Heart Journal* 2013;34:1557–1566.
- 16 54. Maack C, Eschenhagen T, Hamdani N, Heinzl FR, Lyon AR, Manstein DJ,
17 Metzger J, Papp Z, Tocchetti CG, Yilmaz MB, Anker SD, Balligand J-L, Bauersachs J,
18 Brutsaert D, Carrier L, Chlopicki S, Cleland JG, Boer RA de, Dietl A, Fischmeister R,
19 Harjola V-P, Heymans S, Hilfiker-Kleiner D, Holzmeister J, Keulenaer G de, Limongelli
20 G, Linke WA, Lund LH, Masip J, Metra M, Mueller C, Pieske B, Ponikowski P, Ristić A,
21 Ruschitzka F, Seferović PM, Skouri H, Zimmermann WH, Mebazaa A. Treatments
22 targeting inotropy. *Eur Heart J* 2019;40:3626–3644.
- 23 55. Ahmad T, Miller PE, McCullough M, Desai NR, Riello R, Psocka M, Böhm M,

- 1 Allen LA, Teerlink JR, Rosano GMC, Lindenfeld J. Why has positive inotropy failed in
2 chronic heart failure? Lessons from prior inotrope trials. *Eur J Heart Fail* 2019;21:1064–
3 1078.
- 4 56. Higuchi R, Tobaru T, Hagiya K, Saji M, Takamisawa I, Shimizu J, Iguchi N,
5 Takanashi S, Takayama M, Isobe M. Outcomes of patients requiring extracorporeal
6 membrane oxygenation in transcatheter aortic valve implantation: a clinical case series.
7 *Heart Vessels* 2018;33:1343–1349.
- 8 57. Seco M, Forrest P, Jackson SA, Martinez G, Andvik S, Bannon PG, Ng M, Fraser
9 JF, Wilson MK, Vallely MP. Extracorporeal membrane oxygenation for very high-risk
10 transcatheter aortic valve implantation. *Heart Lung Circ* 2014;23:957–962.
- 11 58. Singh V, Patel SV, Savani C, Patel NJ, Patel N, Arora S, Panaich SS, Deshmukh A,
12 Cleman M, Mangi A, Forrest JK, Badheka AO. Mechanical circulatory support devices
13 and transcatheter aortic valve implantation (from the National Inpatient Sample). *Am J*
14 *Cardiol* 2015;116:1574–1580.
- 15 59. Cheng R, Dawkins S, Hamilton MA, Makar M, Hussaini A, Azarbal B, Patel JK,
16 Kobashigawa JA, Trento A, Makkar RR, Kar S. Percutaneous Mitral Repair for Patients in
17 Cardiogenic Shock Requiring Inotropes and Temporary Mechanical Circulatory Support.
18 *JACC Cardiovasc Interv* 2019;12:2440–2441.
- 19 60. Alkhalil A, Hajjar R, Ibrahim H, Ruiz CE. Mechanical Circulatory Support in
20 Transcatheter Aortic Valve Implantation in the United States (from the National Inpatient
21 Sample). *Am J Cardiol* 2019;124:1615–1620.
- 22 61. Folland ED, Kemper AJ, Khuri SF, Josa M, Parisi AF. Intraaortic balloon
23 counterpulsation as a temporary support measure in decompensated critical aortic stenosis.

- 1 *J Am Coll Cardiol* 1985;5:711–716.
- 2 62. Vandembrielle C, Balthazar T, Wilson J, Adriaenssens T, Davies S, Droogne W,
3 Dubois C, Caetano AF, Goetschalckx K, Jacobs S, Janssens S, Ledot S, Meyns B,
4 Soliman-Aboumarie H, Verbrugge P, Price S. Left Impella®-device as bridge from
5 cardiogenic shock with acute, severe mitral regurgitation to MitraClip®-procedure: a new
6 option for critically ill patients. *Eur Heart J Acute Cardiovasc Care* 2021;10:415–421.
- 7 63. Johnson DW, Erwin III JP. Use of Impella 5.0 Prior to Transcatheter Aortic Valve
8 Replacement in a Patient with Severe Aortic Stenosis and Cardiogenic Shock. *J Heart
9 Valve Dis* 2017;26:485–487.
- 10 64. Muraca I, Pennesi M, Carrabba N, Scudiero F, Migliorini A, Marchionni N,
11 Stefano P, Valenti R. Percutaneous left ventricular advanced support for ‘protected’
12 complex high-risk transcatheter mitral valve repair: a case series. *Eur Heart J Case Rep*
13 2020;4:1–7.
- 14 65. Abraham J, Wang L, Kumar V, Kirker EB, Spinelli KJ. Axillary transvalvular
15 microaxial pump as extended bridge to transcatheter aortic valve replacement in
16 cardiogenic shock with severe aortic stenosis. *J Heart Lung Transplant* 2022;41:434–437.
- 17 66. Tehrani BN, Truesdell AG, Sherwood MW, Desai S, Tran HA, Epps KC, Singh R,
18 Psotka M, Shah P, Cooper LB, Rosner C, Raja A, Barnett SD, Saulino P, deFilippi CR,
19 Gurbel PA, Murphy CE, O’Connor CM. Standardized Team-Based Care for Cardiogenic
20 Shock. *J Am Coll Cardiol* 2019;73:1659–1669.
- 21 67. Basir MB, Kapur NK, Patel K, Salam MA, Schreiber T, Kaki A, Hanson I, Almany
22 S, Timmis S, Dixon S, Kolski B, Todd J, Senter S, Marso S, Lasorda D, Wilkins C,
23 Lalonde T, Attallah A, Larkin T, Dupont A, Marshall J, Patel N, Overly T, Green M,

- 1 Tehrani B, Truesdell AG, Sharma R, Akhtar Y, McRae T, O'Neill B, Finley J, Rahman A,
2 Foster M, Askari R, Goldsweig A, Martin S, Bharadwaj A, Khuddus M, Caputo C, Korpas
3 D, Cawich I, McAllister D, Blank N, Alraies MC, Fisher R, Khandelwal A, Alaswad K,
4 Lemor A, Johnson T, Hacala M, O'Neill WW, National Cardiogenic Shock Initiative
5 Investigators. Improved Outcomes Associated with the use of Shock Protocols: Updates
6 from the National Cardiogenic Shock Initiative. *Catheter Cardiovasc Interv*
7 2019;93:1173–1183.
- 8 68. Tehrani BN, Truesdell AG, Psotka MA, Rosner C, Singh R, Sinha SS, Damluji AA,
9 Batchelor WB. A Standardized and Comprehensive Approach to the Management of
10 Cardiogenic Shock. *JACC Heart Fail* 2020;8:879–891.
- 11 69. Parlow S, Weng W, Di Santo P, Jung RG, Lepage-Ratte MF, Motazedian P,
12 Prosperi-Porta G, Abdel-Razek O, Simard T, Chan V, Labinaz M, Froeschl M, Mathew R,
13 Hibbert B, CAPITAL DOREMI investigators. Significant valvular dysfunction and
14 outcomes in cardiogenic shock: insights from the randomized DOREMI trial. *Can J*
15 *Cardiol* 2022:S0828-282X(22)00220-3.
- 16 70. Frerker C, Schewel J, Schlüter M, Schewel D, Ramadan H, Schmidt T, Thielsen T,
17 Kreidel F, Schlingloff F, Bader R, Wohlmuth P, Schäfer U, Kuck K-H. Emergency
18 transcatheter aortic valve replacement in patients with cardiogenic shock due to acutely
19 decompensated aortic stenosis. *EuroIntervention* 2016;11:1530–1536.
- 20 71. Estévez-Loureiro R, Shuvy M, Taramasso M, Benito-Gonzalez T, Denti P,
21 Arzamendi D, Adamo M, Freixa X, Villablanca P, Krivoshei L, Fam N, Spargias K,
22 Czarnecki A, Haberman D, Agmon Y, Sudarsky D, Pascual I, Ninios V, Scianna S, Moaraf
23 I, Schiavi D, Chrissoheris M, Beeri R, Kerner A, Fernández-Peregrina E, Di Pasquale M,

- 1 Regueiro A, Poles L, Iñiguez-Romo A, Fernández-Vázquez F, Maisano F. Use of
2 MitraClip for mitral valve repair in patients with acute mitral regurgitation following acute
3 myocardial infarction: Effect of cardiogenic shock on outcomes (IREMMI Registry).
4 *Catheter Cardiovasc Interv* 2021;97:1259–1267.
- 5 72. Maheshwari V, Barr B, Srivastava M. Acute Valvular Heart Disease. *Cardiol Clin*
6 2018;36:115–127.
- 7 73. Jentzer JC, Ternus B, Eleid M, Rihal C. Structural Heart Disease Emergencies. *J*
8 *Intensive Care Med* 2021;36:975–988.
- 9 74. Akodad M, Schurtz G, Adda J, Leclercq F, Roubille F. Management of
10 valvulopathies with acute severe heart failure and cardiogenic shock. *Archives of*
11 *Cardiovascular Diseases* 2019;112:773–780.
- 12 75. Habib G, Lancellotti P, Antunes MJ, Bongiorni MG, Casalta J-P, Del Zotti F,
13 Dulgheru R, El Khoury G, Erba PA, Iung B, Miro JM, Mulder BJ, Plonska-Gosciniak E,
14 Price S, Roos-Hesselink J, Snygg-Martin U, Thuny F, Tornos Mas P, Vilacosta I,
15 Zamorano JL, ESC Scientific Document Group. 2015 ESC Guidelines for the management
16 of infective endocarditis: The Task Force for the Management of Infective Endocarditis of
17 the European Society of Cardiology (ESC). Endorsed by: European Association for
18 Cardio-Thoracic Surgery (EACTS), the European Association of Nuclear Medicine
19 (EANM). *Eur Heart J* 2015;36:3075–3128.
- 20 76. Habib G, Avierinos J-F, Thuny F. Aortic valve endocarditis: is there an optimal
21 surgical timing? *Current Opinion in Cardiology* 2007;22:77–83.
- 22 77. Hutter AM, De Sanctis RW, Nathan MJ, Buckley MJ, Mundth ED, Daggett WM,
23 Austen WG. Aortic valve surgery as an emergency procedure. *Circulation* 1970;41:623–

- 1 627.
- 2 78. Carabello BA, Green LH, Grossman W, Cohn LH, Koster JK, Collins JJ.
3 Hemodynamic determinants of prognosis of aortic valve replacement in critical aortic
4 stenosis and advanced congestive heart failure. *Circulation* 1980;62:42–48.
- 5 79. Oettinger V, Kaier K, Mühlen C von zur, Zehender M, Bode C, Beyersdorf F,
6 Stachon P, Bothe W. Impact of Procedure Volume on the Outcomes of Surgical Aortic
7 Valve Replacement. *Thorac Cardiovasc Surg* 2022;s-0042-1754352.
- 8 80. Gelsomino S, Maessen JG, Veen F van der, Livi U, Renzulli A, Lucà F, Carella R,
9 Crudeli E, Rubino A, Rostagno C, Russo C, Borghetti V, Beghi C, De Bonis M, Gensini
10 GF, Lorusso R. Emergency surgery for native mitral valve endocarditis: the impact of
11 septic and cardiogenic shock. *Ann Thorac Surg* 2012;93:1469–1476.
- 12 81. Thompson CR, Buller CE, Sleeper LA, Antonelli TA, Webb JG, Jaber WA, Abel
13 JG, Hochman JS. Cardiogenic shock due to acute severe mitral regurgitation complicating
14 acute myocardial infarction: a report from the SHOCK Trial Registry. SHould we use
15 emergently revascularize Occluded Coronaries in cardiogenic shock? *J Am Coll Cardiol*
16 2000;36:1104–1109.
- 17 82. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, Caforio
18 ALP, Crea F, Goudevenos JA, Halvorsen S, Hindricks G, Kastrati A, Lenzen MJ, Prescott
19 E, Roffi M, Valgimigli M, Varenhorst C, Vranckx P, Widimský P, ESC Scientific
20 Document Group. 2017 ESC Guidelines for the management of acute myocardial
21 infarction in patients presenting with ST-segment elevation: The Task Force for the
22 management of acute myocardial infarction in patients presenting with ST-segment
23 elevation of the European Society of Cardiology (ESC). *Eur Heart J* 2018;39:119–177.

- 1 83. Percutaneous balloon aortic valvuloplasty. Acute and 30-day follow-up results in
2 674 patients from the NHLBI Balloon Valvuloplasty Registry. *Circulation* 1991;84:2383–
3 2397.
- 4 84. Emergency Balloon Valvuloplasty as Initial Treatment of Patients with Aortic
5 Stenosis and Cardiogenic Shock. *N Engl J Med* 1992;326:646–646.
- 6 85. Moreno PR, Jang I-K, Newell JB, Block PC, Palacios IF. The role of percutaneous
7 aortic balloon valvuloplasty in patients with cardiogenic shock and critical aortic stenosis.
8 *Journal of the American College of Cardiology* 1994;23:1071–1075.
- 9 86. Buchwald AB, Meyer T, Scholz K, Unterberg C, Schorn B. Efficacy of balloon
10 valvuloplasty in patients with critical aortic stenosis and cardiogenic shock-the role of
11 shock duration. *Clin Cardiol* 2001;24:214–218.
- 12 87. Saia F, Marrozzini C, Ciuca C, Guastaroba P, Taglieri N, Palmerini T, Bordoni B,
13 Moretti C, Dall’Ara G, Branzi A, Marzocchi A. Emerging indications, in-hospital and
14 long-term outcome of balloon aortic valvuloplasty in the transcatheter aortic valve
15 implantation era. *EuroIntervention* 2013;8:1388–1397.
- 16 88. Theiss HD, Greif M, Steinbeck G, Kupatt C, Franz WM. Balloon valvuloplasty for
17 treatment of cardiogenic shock in the era of surgical valve replacement and TAVI. *Intern
18 Emerg Med* 2014;9:345–347.
- 19 89. Bongiovanni D, Kühl C, Bleiziffer S, Stecher L, Poch F, Greif M, Mehilli J,
20 Massberg S, Frey N, Lange R, Laugwitz K-L, Schymik G, Frank D, Kupatt C. Emergency
21 treatment of decompensated aortic stenosis. *Heart* 2018;104:23–29.
- 22 90. Debry N, Kone P, Vincent F, Lemesle G, Delhay C, Schurtz G, Spillemaeker H,
23 Porouchani S, Coisne A, Auffray J-L, Sudre A, Lamblin N, Bonello L, Van Belle E.

- 1 Urgent balloon aortic valvuloplasty in patients with cardiogenic shock related to severe
2 aortic stenosis: time matters. *EuroIntervention* 2018;14:e519–e525.
- 3 91. Eugène M, Urena M, Abtan J, Carrasco J-L, Ghodbane W, Nataf P, Vahanian A,
4 Himbert D. Effectiveness of Rescue Percutaneous Balloon Aortic Valvuloplasty in Patients
5 With Severe Aortic Stenosis and Acute Heart Failure. *The American Journal of Cardiology*
6 2018;121:746–750.
- 7 92. Varela ML, Teixeira P, Ponte M, Caeiro D, Dias A, Rodrigues A, Braga P. Balloon
8 Aortic Valvuloplasty in Patients Admitted for Cardiogenic Shock with Severe Aortic
9 Stenosis: A Retrospective Analysis of 14 Cases. *Cureus* 2019.
- 10 93. D’Ancona G, Pasic M, Buz S, Drews T, Dreysse S, Kukucka M, Hetzer R,
11 Unbehaun A. Transapical transcatheter aortic valve replacement in patients with
12 cardiogenic shock. *Interactive CardioVascular and Thoracic Surgery* 2012;14:426–430.
- 13 94. Huang H, Kovach CP, Bell S, Reisman M, Aldea G, McCabe JM, Dvir D, Don C.
14 Outcomes of Emergency Transcatheter Aortic Valve Replacement. *Journal of*
15 *Interventional Cardiology* 2019;2019:1–7.
- 16 95. Steffen J, Stocker A, Scherer C, Haum M, Fischer J, Doldi PM, Theiss H, Braun D,
17 Rizas K, Peterß S, Hausleiter J, Massberg S, Orban M, Deseive S. Emergency TAVI for
18 acute heart failure due to severe aortic stenosis in critically ill patients with or without
19 cardiogenic shock. *Eur Heart J Acute Cardiovasc Care* 2022:zuac131.
- 20 96. Chakraborty S, Patel N, Bandyopadhyay D, Hajra A, Amgai B, Zaid S, Sharedalal
21 P, Ahmad H, Cohen MB, Abbott JD, Naidu SS. Readmission following urgent
22 transcatheter aortic valve implantation versus urgent balloon aortic valvuloplasty in
23 patients with decompensated heart failure or cardiogenic shock. *Catheter Cardiovasc*

- 1 *Interv* 2021;98:607–612.
- 2 97. Puri R, Iung B, Cohen DJ, Rodés-Cabau J. TAVI or No TAVI: identifying patients
3 unlikely to benefit from transcatheter aortic valve implantation. *Eur Heart J*
4 2016;37:2217–2225.
- 5 98. Vallabhajosyula S, Patlolla SH, Sandhyavenu H, Vallabhajosyula S, Barsness GW,
6 Dunlay SM, Greason KL, Holmes DR, Eleid MF. Periprocedural Cardiopulmonary Bypass
7 or Venoarterial Extracorporeal Membrane Oxygenation During Transcatheter Aortic Valve
8 Replacement: A Systematic Review. *JAHA* 2018;7.
- 9 99. Burzotta F, Nerla R, Trani C. Bail-Out Use of Impella CP as a Bridge to TAVI in a
10 Cardiogenic Shock Patient: The ‘Pump-Rewiring’ Technique. *J Invasive Cardiol*
11 2016;28:E1-5.
- 12 100. Hamid N, Ranard LS, Khalique OK, Hahn RT, Nazif TM, George I, Ng V, Leon
13 MB, Kodali SK, Vahl TP. Commissural Alignment After Transfemoral Transcatheter
14 Aortic Valve Replacement With the JenaValve Trilogy System. *JACC Cardiovasc Interv*
15 2021;14:2079–2081.
- 16 101. Arora S, Lahewala S, Zuzek Z, Thakkar S, Jani C, Jaswaney R, Singh A, Bhyan P,
17 Arora N, Main A, Osman MN, Hoit BD, Attizzani GF, Panaich SS. Transcatheter aortic
18 valve replacement in aortic regurgitation: The U.S. experience. *Catheter Cardiovasc Interv*
19 2021;98:E153–E162.
- 20 102. Purita PAM, Tahoces LS, Fraccaro C, Nai Fovino L, Kim W-K, Espada-Guerreiro
21 C, De Backer O, Seiffert M, Nombela-Franco L, Gomez RM, Mangieri A, Franzone A,
22 Bedogni F, Castriota F, Attisano T, Søndergaard L, Antolin RH, Tarantini G. Transcatheter
23 treatment of native aortic valve regurgitation: Results from an international registry using

- 1 the transfemoral ACURATE neo valve. *Int J Cardiol Heart Vasc* 2020;27:100480.
- 2 103. Jiang J, Liu X, He Y, Xu Q, Zhu Q, Jaiswal S, Wang L, Hu P, Gao F, Sun Y, Liu C,
3 Lin X, Liang J, Ren K, Wang JAA. Transcatheter Aortic Valve Replacement for Pure
4 Native Aortic Valve Regurgitation: A Systematic Review. *Cardiology* 2018;141:132–140.
- 5 104. Pesarini G, Lunardi M, Piccoli A, Gottin L, Prati D, Ferrero V, Scarsini R, Milano
6 A, Forni A, Faggian G, Ribichini F. Effectiveness and Safety of Transcatheter Aortic
7 Valve Implantation in Patients With Pure Aortic Regurgitation and Advanced Heart
8 Failure. *Am J Cardiol* 2018;121:642–648.
- 9 105. Roy DA, Schaefer U, Guetta V, Hildick-Smith D, Möllmann H, Dumonteil N,
10 Modine T, Bosmans J, Petronio AS, Moat N, Linke A, Moris C, Champagnac D, Parma R,
11 Ochala A, Medvedofsky D, Patterson T, Woitek F, Jahangiri M, Laborde J-C, Brecker SJ.
12 Transcatheter aortic valve implantation for pure severe native aortic valve regurgitation. *J*
13 *Am Coll Cardiol* 2013;61:1577–1584.
- 14 106. Yin W-H, Lee Y-T, Tsao T-P, Lee K-C, Hsiung M-C, Wei J. Outcomes of
15 transcatheter aortic valve replacement for pure native aortic regurgitation with the use of
16 newer- vs. early-generation devices. *Ann Transl Med* 2022;10:24.
- 17 107. Spina R, Khalique O, Kodali S, Bapat VN. Urgent transcatheter aortic valve
18 replacement for severe acute aortic regurgitation following open mitral valve surgery.
19 *Catheter Cardiovasc Interv* 2019;93:996–1001.
- 20 108. M Herrmann FE, Wellmann P, Dossow V von, Massberg S, Hagl C, Schramm R,
21 Pichlmaier M. Rescue TAVI for Aortic Regurgitation after Left Ventricular Assist Device
22 Implantation Following Preoperative Impella® Support. *J Heart Valve Dis* 2017;26:603–
23 605.

- 1 109. Werf HW van der, Schurer RA, Vonck TE, Poelman JE, Klungel AA, Cernak V,
2 Heuvel AF van den, Harst P van der. Emergency transcatheter aortic valve implantation in
3 patients with severe aortic regurgitation and a left ventricle assist device: A case report and
4 systematic review. *Eur Heart J Acute Cardiovasc Care* 2017;6:719–727.
- 5 110. Abdelaziz HK, Wiper A, More RS, Bittar MN, Roberts DH. Successful
6 Transcatheter Aortic Valve Replacement Using Balloon-Expandable Valve for Pure Native
7 Aortic Valve Regurgitation in the Presence of Ascending Aortic Dissection. *J Invasive*
8 *Cardiol* 2018;30:E62–E63.
- 9 111. Kreibich M, Rylski B, Beyersdorf F, Siepe M, Czerny M. Endo-Bentall for
10 proximal aortic dissection: from conception to application. *Asian Cardiovasc Thorac Ann*
11 2021;29:697–700.
- 12 112. Phan K, Haswell JM, Xu J, Assem Y, Mick SL, Kapadia SR, Cheung A, Ling FS,
13 Yan TD, Tchanchaleishvili V. Percutaneous Transcatheter Interventions for Aortic
14 Insufficiency in Continuous-Flow Left Ventricular Assist Device Patients: A Systematic
15 Review and Meta-Analysis. *ASAIO J* 2017;63:117–122.
- 16 113. Inoue K, Owaki T, Nakamura T, Kitamura F, Miyamoto N. Clinical application of
17 transvenous mitral commissurotomy by a new balloon catheter. *J Thorac Cardiovasc Surg*
18 1984;87:394–402.
- 19 114. Lock JE, Khalilullah M, Shrivastava S, Bahl V, Keane JF. Percutaneous catheter
20 commissurotomy in rheumatic mitral stenosis. *N Engl J Med* 1985;313:1515–1518.
- 21 115. Dugal JS, Jetley V, Sabharwal JS, Sofat S, Singh C. Life-saving PTMC for critical
22 calcific mitral stenosis in cardiogenic shock with balloon impasse. *Int J Cardiovasc*
23 *Intervent* 2003;5:172–174.

- 1 116. Endrys J, Habashy AG, Hayat N. Life-saving balloon mitral valvuloplasty in
2 patient with cardiogenic shock after cardiac arrest. *J Invasive Cardiol* 2001;13:752–754.
- 3 117. Kapoor MC, Dugal JS, Sharma S, Singh S. Percutaneous transvenous mitral
4 commissurotomy--a life saving option in severe mitral stenosis with cardiogenic shock.
5 *Ann Card Anaesth* 2004;7:158–161.
- 6 118. Lokhandwala YY, Banker D, Vora AM, Kerkar PG, Deshpande JR, Kulkarni HL,
7 Dalvi BV. Emergent balloon mitral valvotomy in patients presenting with cardiac arrest,
8 cardiogenic shock or refractory pulmonary edema. *J Am Coll Cardiol* 1998;32:154–158.
- 9 119. Ananthakrishna Pillai A, Ramasamy C, V SG, Kottyath H. Outcomes following
10 balloon mitral valvuloplasty in pregnant females with mitral stenosis and significant sub
11 valve disease with severe decompensated heart failure. *J Interv Cardiol* 2018;31:525–531.
- 12 120. Notrica M, Wisner J, Villagra L, Rossini A, Gonzalia D, Adaro M, Zillo A,
13 Izcovich E, Albertal M. Life-saving percutaneous mitral valvuloplasty on a pregnant
14 woman with refractory cardiogenic shock. *Heart Lung Circ* 2009;18:301–304.
- 15 121. Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J, Blomström-Lundqvist C,
16 Cífková R, De Bonis M, Iung B, Johnson MR, Kintscher U, Kranke P, Lang IM, Morais J,
17 Pieper PG, Presbitero P, Price S, Rosano GMC, Seeland U, Simoncini T, Swan L, Warnes
18 CA, ESC Scientific Document Group. 2018 ESC Guidelines for the management of
19 cardiovascular diseases during pregnancy. *Eur Heart J* 2018;39:3165–3241.
- 20 122. Lorusso R, Gelsomino S, De Cicco G, Beghi C, Russo C, De Bonis M, Colli A,
21 Sala A. Mitral valve surgery in emergency for severe acute regurgitation: analysis of
22 postoperative results from a multicentre study☆. *European Journal of Cardio-Thoracic*

- 1 *Surgery* 2008;33:573–582.
- 2 123. Feldman T, Foster E, Glower DD, Glower DG, Kar S, Rinaldi MJ, Fail PS,
3 Smalling RW, Siegel R, Rose GA, Engeron E, Loghin C, Trento A, Skipper ER, Fudge T,
4 Letsou GV, Massaro JM, Mauri L, EVEREST II Investigators. Percutaneous repair or
5 surgery for mitral regurgitation. *N Engl J Med* 2011;364:1395–1406.
- 6 124. Obadia J-F, Messika-Zeitoun D, Leurent G, Iung B, Bonnet G, Piriou N, Lefèvre T,
7 Piot C, Rouleau F, Carrié D, Nejjari M, Ohlmann P, Leclercq F, Saint Etienne C, Teiger E,
8 Leroux L, Karam N, Michel N, Gilard M, Donal E, Trochu J-N, Cormier B, Armoiry X,
9 Boutitie F, Maucort-Boulch D, Barnel C, Samson G, Guerin P, Vahanian A, Mewton N,
10 MITRA-FR Investigators. Percutaneous Repair or Medical Treatment for Secondary Mitral
11 Regurgitation. *N Engl J Med* 2018;379:2297–2306.
- 12 125. Stone GW, Lindenfeld J, Abraham WT, Kar S, Lim DS, Mishell JM, Whisenant B,
13 Grayburn PA, Rinaldi M, Kapadia SR, Rajagopal V, Sarembock IJ, Brieke A, Marx SO,
14 Cohen DJ, Weissman NJ, Mack MJ, COAPT Investigators. Transcatheter Mitral-Valve
15 Repair in Patients with Heart Failure. *N Engl J Med* 2018;379:2307–2318.
- 16 126. Jung RG, Simard T, Kovach C, Flint K, Don C, Di Santo P, Adamo M, Branca L,
17 Valentini F, Benito-González T, Fernández-Vázquez F, Estévez-Loureiro R, Berardini A,
18 Conti N, Rapezzi C, Biagini E, Parlow S, Shorr R, Levi A, Manovel A, Cardenal-Piris R,
19 Diaz Fernandez J, Shuvy M, Haberman D, Sala A, Alkhouli MA, Marini C, Bargagna M,
20 Schiavi D, Denti P, Markovic S, Buzzatti N, Chan V, Hynes M, Mesana T, Labinaz M,
21 Pappalardo F, Taramasso M, Hibbert B. Transcatheter Mitral Valve Repair in Cardiogenic
22 Shock and Mitral Regurgitation: A Patient-Level, Multicenter Analysis. *JACC Cardiovasc*
23 *Interv* 2021;14:1–11.

- 1 127. Adamo M, Curello S, Chiari E, Fiorina C, Chizzola G, Magatelli M, Locantore E,
2 Cuminetti G, Lombardi C, Manzato A, Metra M, Etori F. Percutaneous edge-to-edge
3 mitral valve repair for the treatment of acute mitral regurgitation complicating myocardial
4 infarction: A single centre experience. *Int J Cardiol* 2017;234:53–57.
- 5 128. Seizer P, Schibilsky D, Sauter R, Schrieck J, Lausberg H, Walker T, Gawaz M,
6 Langer HF, Schlensak C. Percutaneous Mitral Valve Edge-to-Edge Repair Assisted by
7 Hemodynamic Support Devices: A Case Series of Bailout Procedures. *Circ Heart Fail*
8 2017;10:e004051.
- 9 129. Flint K, Brieke A, Wiktor D, Carroll J. Percutaneous edge-to-edge mitral valve
10 repair may rescue select patients in cardiogenic shock: Findings from a single center case
11 series. *Catheter Cardiovasc Interv* 2019;94:E82–E87.
- 12 130. Chan V, Messika-Zeitoun D, Labinaz M, Hynes M, Nicholson D, Dryden A,
13 Mesana T, Hibbert B. Percutaneous Mitral Repair as Salvage Therapy in Patients With
14 Mitral Regurgitation and Refractory Cardiogenic Shock. *Circ Cardiovasc Interv*
15 2019;12:e008435.
- 16 131. Garcia S, Alsidawi S, Bae R, Cavalcante J, Eckman P, Gössl M, Steffen R, Sun B,
17 Schmidt CW, Sorajja P. Percutaneous Mitral Valve Repair With MitraClip in Inoperable
18 Patients With Severe Mitral Regurgitation Complicated by Cardiogenic Shock. *J Invasive*
19 *Cardiol* 2020;32:228–231.
- 20 132. Falasconi G, Melillo F, Pannone L, Adamo M, Ronco F, Latib A, Rahgozar K,
21 Carrabba N, Valenti R, Citro R, Stella S, Ingallina G, Capogrosso C, Scandroglio M,
22 Ancona F, Godino C, Denti P, Castiglioni A, De Bonis M, Colombo A, Lupi L, Branca L,
23 Montorfano M, Agricola E. Use of edge-to-edge percutaneous mitral valve repair for

- 1 severe mitral regurgitation in cardiogenic shock: A multicenter observational experience
2 (MITRA-SHOCK study). *Catheter Cardiovasc Interv* 2021;98:E163–E170.
- 3 133. Tang GHL, Estevez-Loureiro R, Yu Y, Prillinger JB, Zaid S, Psołka MA. Survival
4 Following Edge-to-Edge Transcatheter Mitral Valve Repair in Patients With Cardiogenic
5 Shock: A Nationwide Analysis. *J Am Heart Assoc* 2021;10:e019882.
- 6 134. Makkar RR, Thourani VH, Mack MJ, Kodali SK, Kapadia S, Webb JG, Yoon S-H,
7 Trento A, Svensson LG, Herrmann HC, Szeto WY, Miller DC, Satler L, Cohen DJ, Dewey
8 TM, Babaliaros V, Williams MR, Kereiakes DJ, Zajarias A, Greason KL, Whisenant BK,
9 Hodson RW, Brown DL, Fearon WF, Russo MJ, Pibarot P, Hahn RT, Jaber WA, Rogers
10 E, Xu K, Wheeler J, Alu MC, Smith CR, Leon MB, PARTNER 2 Investigators. Five-Year
11 Outcomes of Transcatheter or Surgical Aortic-Valve Replacement. *N Engl J Med*
12 2020;382:799–809.
- 13 135. Capodanno D, Petronio AS, Prendergast B, Eltchaninoff H, Vahanian A, Modine T,
14 Lancellotti P, Sondergaard L, Ludman PF, Tamburino C, Piazza N, Hancock J, Mehilli J,
15 Byrne RA, Baumbach A, Kappetein AP, Windecker S, Bax J, Haude M. Standardized
16 definitions of structural deterioration and valve failure in assessing long-term durability of
17 transcatheter and surgical aortic bioprosthetic valves: a consensus statement from the
18 European Association of Percutaneous Cardiovascular Interventions (EAPCI) endorsed by
19 the European Society of Cardiology (ESC) and the European Association for Cardio-
20 Thoracic Surgery (EACTS). *Eur J Cardiothorac Surg* 2017;52:408–417.
- 21 136. Gallo M, Fovino LN, Blitzer D, Doulamis IP, Guariento A, Salvador L, Tagliari
22 AP, Ferrari E. Transcatheter aortic valve replacement for structural degeneration of
23 previously implanted transcatheter valves (TAVR-in-TAVR): a systematic review. *Eur J*

- 1 *Cardiothorac Surg* 2021:ezab443.
- 2 137. Cahill TJ, Khaliq OK, George I, Kodali S. Valve thrombosis after transcatheter
3 and surgical aortic valve replacement: Incidence and outcomes. *The Journal of thoracic*
4 *and cardiovascular surgery*.
- 5 138. Sorajja P, Bae R, Lesser JA, Pedersen WA. Percutaneous repair of paravalvular
6 prosthetic regurgitation: patient selection, techniques and outcomes. *Heart* 2015;101:665–
7 673.
- 8 139. Ruiz CE, Hahn RT, Berrebi A, Borer JS, Cutlip DE, Fontana G, Gerosa G, Ibrahim
9 R, Jelnin V, Jilaihawi H, Jolicoeur EM, Kliger C, Kronzon I, Leipsic J, Maisano F, Millan
10 X, Nataf P, O’Gara PT, Pibarot P, Ramee SR, Rihal CS, Rodes-Cabau J, Sorajja P, Suri R,
11 Swain JA, Turi ZG, Tuzcu EM, Weissman NJ, Zamorano JL, Serruys PW, Leon MB,
12 Paravalvular Leak Academic Research Consortium. Clinical Trial Principles and Endpoint
13 Definitions for Paravalvular Leaks in Surgical Prosthesis. *Eur Heart J* 2018;39:1224–1245.
- 14 140. Saia F, Martinez C, Gafoor S, Singh V, Ciuca C, Hofmann I, Marrozzini C, Tan J,
15 Webb J, Sievert H, Marzocchi A, O’Neill WW. Long-term outcomes of percutaneous
16 paravalvular regurgitation closure after transcatheter aortic valve replacement: a
17 multicenter experience. *JACC Cardiovasc Interv* 2015;8:681–688.
- 18 141. Kamde SP, Anjankar A. Pathogenesis, Diagnosis, Antimicrobial Therapy, and
19 Management of Infective Endocarditis, and Its Complications. *Cureus* 2022.
- 20 142. Brankovic M, Hashemi A, Ansari J, Sharma A. Transcatheter Aortic Valve
21 Replacement for Aortic Valve Infective Endocarditis: A Systematic Review and Call for
22 Action. *Cardiol Ther* 2023.
- 23 143. Glaser N, Jackson V, Holzmann MJ, Franco-Cereceda A, Sartipy U. Prosthetic

- 1 Valve Endocarditis After Surgical Aortic Valve Replacement. *Circulation* 2017;136:329–
2 331.
- 3 144. Butala NM, Makkar R, Secemsky EA, Gallup D, Marquis-Gravel G, Kosinski AS,
4 Vemulapalli S, Valle JA, Bradley SM, Chakravarty T, Yeh RW, Cohen DJ. Cerebral
5 Embolic Protection and Outcomes of Transcatheter Aortic Valve Replacement: Results
6 From the Transcatheter Valve Therapy Registry. *Circulation* 2021;143:2229–2240.
- 7 145. Dvir D, Khan J, Kornowski R, Komatsu I, Chatriwalla A, Mackenson GB,
8 Simonato M, Ribeiro H, Wood D, Leipsic J, Webb J, Mylotte D. Novel strategies in aortic
9 valve-in-valve therapy including bioprosthetic valve fracture and BASILICA.
10 *EuroIntervention* 2018;14:AB74–AB82.
- 11 146. Babaliaros VC, Greenbaum AB, Khan JM, Rogers T, Wang DD, Eng MH, O’Neill
12 WW, Paone G, Thourani VH, Lerakis S, Kim DW, Chen MY, Lederman RJ. Intentional
13 Percutaneous Laceration of the Anterior Mitral Leaflet to Prevent Outflow Obstruction
14 During Transcatheter Mitral Valve Replacement: First-in-Human Experience. *JACC*
15 *Cardiovasc Interv* 2017;10:798–809.
- 16 147. Arrigo M, Price S, Baran DA, Pöss J, Aissaoui N, Bayes-Genis A, Bonello L,
17 François B, Gayat E, Gilard M, Kapur NK, Karakas M, Kostrubiec M, Leprince P, Levy B,
18 Rosenberg Y, Thiele H, Zeymer U, Harhay MO, Mebazaa A. Optimising clinical trials in
19 acute myocardial infarction complicated by cardiogenic shock: a statement from the 2020
20 Critical Care Clinical Trialists Workshop. *The Lancet Respiratory Medicine* 2021;9:1192–
21 1202.
- 22 148. Diepen S van, Morrow DA. Potential growth in cardiogenic shock research though
23 an international registry collaboration: the merits and challenges of a *Hub-of-Spokes*

- 1 model. *European Heart Journal Acute Cardiovascular Care* 2021;10:3–5.
- 2 149. Johri AM, Durbin J, Newbigging J, Tanzola R, Chow R, De S, Tam J. Cardiac
3 Point-of-Care Ultrasound: State-of-the-Art in Medical School Education. *J Am Soc*
4 *Echocardiogr* 2018;31:749–760.
- 5 150. Prastaro M, Pirozzi E, Gaibazzi N, Paolillo S, Santoro C, Savarese G, Losi MA,
6 Esposito G, Perrone Filardi P, Trimarco B, Galderisi M. Expert Review on the Prognostic
7 Role of Echocardiography after Acute Myocardial Infarction. *J Am Soc Echocardiogr*
8 2017;30:431-443.e2.
- 9 151. Galderisi M, Nistri S, Mondillo S, Losi M-A, Innelli P, Mele D, Muraru D,
10 D’Andrea A, Ballo P, Sgalambro A, Esposito R, Marti G, Santoro A, Agricola E, Badano
11 LP, Marchioli R, Filardi PP, Mercuro G, Marino PN, Working Group of
12 Echocardiography, Italian Society of Cardiology. Methodological approach for the
13 assessment of ultrasound reproducibility of cardiac structure and function: a proposal of
14 the study group of Echocardiography of the Italian Society of Cardiology (Ultra Cardia
15 SIC) part I. *Cardiovasc Ultrasound* 2011;9:26.
- 16 152. Miyazaki R, Watanabe K, Kaneko M, Nagamine S, Hara N, Nakamura T, Nagata
17 Y, Nozato T, Ashikaga T. Acute Ischemic Mitral Regurgitation Treated by Percutaneous
18 Coronary Intervention after an Accurate Diagnosis on Transesophageal Echocardiography.
19 *Intern Med* 2021;60:1417–1421.
- 20
- 21

1 **Figure legends**

2 **Central Illustration. Diagnostic and therapeutic algorithm in cardiogenic shock and**
3 **valvular heart disease.**

4 Diagnostic and therapeutic algorithm leading to valve intervention when a valve heart
5 disease is either the primary cause or an aggravating factor in cardiogenic shock. *The
6 mentioned valve disorders are the most common examples.

7 *PVL=paravalvular leak; TAVI=transcatheter aortic valve implantation;*

8 *TEER=transcatheter edge-to-edge repair; VHD=valvular heart disease*

9

10 **Figure 1. Identification of BVF mechanisms associated with cardiogenic shock.**

11 *BV: bioprosthetic valve, HALT: hypoattenuated leaflet thickening, HVD: haemodynamic*
12 *valve deterioration, MSCT: multislice computed tomography, RLM: reduced leaflet*

13 *motion, TEE: transoesophageal echocardiography, TTE: transthoracic echocardiography.*

14 ** for HVD severity definition.*

15 ** Stage 1 HVD definition: Evidence of SVD, non-structural valve dysfunction (other than*
16 *paravalvular regurgitation or prosthesis-patient mismatch), thrombosis, or endocarditis*
17 *without significant haemodynamic changes.*

18 ** Stage 2 HVD definition: Increase in mean transvalvular gradient ≥ 10 mmHg resulting in*
19 *mean gradient ≥ 20 mmHg with concomitant decrease in EOA ≥ 0.3 cm² or $\geq 25\%$ and/or*
20 *decrease in Doppler velocity index ≥ 0.1 or $\geq 20\%$ compared with echocardiographic*
21 *assessment performed 1–3 months post-procedure, OR new occurrence or increase of ≥ 1*
22 *grade of intraprosthetic AR resulting in \geq moderate AR.*

1 * Stage 3 HVD definition: Increase in mean transvalvular gradient ≥ 20 mmHg resulting in
2 mean gradient ≥ 30 mmHg with concomitant decrease in EOA ≥ 0.6 cm² or $\geq 50\%$ and/or
3 decrease in Doppler velocity index ≥ 0.2 or $\geq 40\%$ compared with echocardiographic
4 assessment performed 1–3 months post-procedure, OR new occurrence, or increase of ≥ 2
5 grades of intraprosthetic AR resulting in severe AR.²¹

6

7 **Figure 2. Proposed diagnostic workflow for the assessment of patients presenting with**
8 **CS.**

9 *Step 1. Point-of-care cardiac ultrasound. Point-of care cardiac ultrasound is generally*
10 *useful as it provides the first clues for a severe VHD.¹⁴⁹ However, it is rarely sufficient. In*
11 *this phase, ruling out acute myocardial ischemia, advanced cardiomyopathies, intolerated*
12 *arrhythmias, acute pulmonary embolism, tamponade or type A acute aortic dissection*
13 *potentially responsible for the CS, is crucial.¹⁵⁰ When point-of-care cardiac ultrasound*
14 *reveals hyperdynamic LV function in a patient with severe acute decompensated heart*
15 *failure or CS, urgent assessment with comprehensive transthoracic echocardiography*
16 *(TTE) is warranted to exclude VHD emergencies.*

17 *Step 2. Comprehensive TTE. Comprehensive TTE is generally adequate to accurately*
18 *investigate valve structure and function. Importantly, increased flow due to sepsis or*
19 *anaemia can elevate Doppler gradients, potentially leading to overestimation of the*
20 *severity of stenotic valve lesions. Likewise, volume overload and systemic hypertension*
21 *often lead to reversible worsening of regurgitant lesion severity. Conversely, low flow*
22 *status might underestimate the severity of valvular diseases. Invasive coronary*

1 *angiography +/- invasive haemodynamic assessment can give in this step additional*
2 *information. At this step, an invasive coronary angiography is indicated to rule out*
3 *concomitant CAD according to guidelines criteria⁹. Alternatively, owing to its high*
4 *negative predictive value, MSCT may be used in patients who are at low risk of*
5 *atherosclerosis.*

6 *Step 3. Complementary valve-specific diagnostic tools include TEE and/or Multislice*
7 *Computed Tomography. Accurate quantification of VHD severity is essential, as only*
8 *severe valvular dysfunction can cause CS.¹⁵¹ Hence, TEE, including 3D modalities, is*
9 *useful in the detailed assessment of valve anatomy and function (native or*
10 *prosthetic)¹⁵² and should be systematically performed when TTE is inconclusive. In*
11 *stabilized patients, MSCT should be performed if required for the planification of the*
12 *transcatheter heart valve intervention.*

13

14 **Figure 3. Factors influencing utility versus futility of emergent TAVI in case of**
15 **patients with AS and CS.**

16

17

18

19

20

1 **Table 1. Checklist for VHD imaging assessment and eligibility to transcatheter**
 2 **procedures.**

		FOR DIAGNOSIS	FOR ELIGIBILITY TO TRANSCATHETER PROCEDURES
AV disease	TTE	Confirm AV disease severity Evaluate valve morphology Check for associated VHD, LV/RV function, PASP	
	TEE	Confirm diagnosis (optional)	Confirm annular sizing (3D evaluation, only if MSCT not available)
	MSCT	Confirm VHD severity (calcium score) in LFLG AS Rule out CAD in selected cases	Confirm annular sizing Evaluate valve morphology and calcium distribution General aortic root assessment (Sinus of Valsalva and STJ dimension, coronary ostia height) Evaluate aorta and vascular access
	ICA	Rule out CAD	
	L-RHC	Confirm disease severity in selected cases	
MV disease	TTE	Confirm MV disease severity Evaluate valve morphology and mechanism of VHD Check for associated VHD, LV/RV function, PASP	
	TEE	Confirm diagnosis in selected cases	Evaluate valve morphology and mechanism of MR for TEER and TMVI Rule out LAA and LA clots
	MSCT	Rule out CAD in selected cases	Evaluate annulus size for TMVI eligibility Predict LVOT obstruction for TMVI eligibility
	ICA	Rule out CAD	
	L-RHC	Confirm disease severity in selected cases	
BVF	TTE	Confirm BVF severity Evaluate valve morphology and mechanism of failure Check for associated VHD, LV/RV function, PASP	
	TEE	Confirm mechanism of bioprosthetic valve dysfunction (SVD, non-SVD, thrombosis, endocarditis) Discriminate between PVL and intra-valvular AR	Rule out LAA and LA clots in case of planned valve-in-valve in mitral position Identify PVL location to select the most appropriate vascular access for transcatheter occlusion
	MSCT	Confirm mechanism of bioprosthetic valve dysfunction (SVD, non-SVD, thrombosis, endocarditis) Rule out CAD in selected cases	Confirm valve size Identify PVL location to select the most appropriate vascular access for transcatheter occlusion Evaluate vascular access + <i>IN AORTIC POSITION:</i> General aortic root assessment (Sinus of Valsalva and STJ dimension, coronary ostia height) Check for interference with coronary ostia Evaluate aorta and vascular access + <i>IN MITRAL POSITION:</i> Predict LVOT obstruction
	ICA	Rule out CAD	
	L-RHC	Confirm disease severity in selected cases	

3

1
2 AR=aortic regurgitation; AS=aortic stenosis; AV=aortic valve; CAD=coronary artery disease;
3 ICA=invasive coronary angiography; L-RHC=left-right heart catheterization; LA=left atrial; LAA=left
4 atrial appendage; LFLG=low flow low gradient; LV=left ventricular; LVOT=left ventricular outflow
5 tract; MSCT=multislice computed tomography; MV=mitral valve; PASP=pulmonary artery systolic
6 pressure; PVL=paravalvular leak; RV=right ventricular; STJ=sino-tubular junction; SVD=structural
7 valve deterioration; TEE=transesophageal echocardiography; TTE=transthoracic echocardiography;
8 TEER=transcatheter edge-to-edge repair; TMVI=transcatheter mitral valve implantation;
9 VHD=valvular heart disease.

10

11

12

13

14

15

16

17

18

19

20

21

22

23

1 **Table 2. Summary of registries on BAV and TAVI in CS.**

2

Author	Setting	Population	Age, years	LVEF, %	30-day mortality
BAV in patients with CS					
NHLBI, 1991 ⁸³	Multicentre	39 BAV	-	-	51%
Cribier, 1992 ⁸⁴	Monocentric	10 BAV	64 ± 9 (54-79)	25±6	20%
Moreno, 1994 ⁸⁵	Monocentric	21 BAV	74 ± 3 (35-90)	29 ± 3	43% (In-hospital)
Buchwald, 2001 ⁸⁶	Monocentric	14 BAV	74 ± 11 (50-91)	-	71%
Saia, 2013 ⁸⁷	Monocentric	23 BAV	70 ± 13	40 ± 15	56.5%
Theiss, 2014 ⁸⁸	Monocentric	13 BAV	79 ± 2	33 ± 3	38.5%
Bongiovanni, 2017 ⁸⁹	Multicentre	118 BAV	81 ± 8	-	33.0%
Debry, 2018 ⁹⁰	Multicentre	44 BAV	77 ± 8	30 ± 14	47%
Eugène, 2018 ⁹¹	Monocentric	17 BAV	79 ± 9	27 ± 11	48%
Varela, 2019 ⁹²	Monocentric	14 BAV	76 ± 7	-	21.4%
TAVI in patients with CS					
D’Ancona, 2012 ⁹³	Monocentric	21 TAVI TA	75 ± 11	26 ± 13	19%
Frerker, 2016 ⁷⁰	Monocentric	27 TAVI	78 ± 9	40 ± 15	33.3%
Bongiovanni, 2017 ⁸⁹	Multicentre	23 TAVI	76 ± 11	-	23.8%
Fraccaro, 2019 ⁵⁰	Multicentre	51 TAVI	76 ± 13 (31-93)	43 ± 15	11.8%
Huang, 2019 ⁹⁴	Monocentric	31 emergent TAVI (26/31 in CS)	73 ± 14	32 ± 15	19.4%
Masha, 2020 ⁴¹	Multicentre	2,220 TAVI	83 (median)	53 (median)	19.1%
Steffen, 2022 ⁹⁵	Monocentric	47 TAVI	-	-	42.6% (@90-day)

3

4 BAV=balloon aortic valvuloplasty; CS=cardiogenic shock; LVEF=left ventricular ejection fraction;
 5 TA=transapical; TAVI=transcatheter aortic valve implantation.

6

7

8

9

10

11

1 **Table 3. Pro and cons of BAV and TAVI in CS.**

	BAV	TAVI
Residual transvalvular gradient	↑↑	↓↓
Risk of significant post-procedural AR	↑↑	↓
Insertion profile	↓	↑
Availability	↑↑	↑↓*
Feasibility	↑↑	↑↓**
Costs	↓↓	↑↑

2 **(potential need for transfer); ** (need for emergent CT scan)*

3 BAV=balloon aortic valvuloplasty; CS=cardiogenic shock; TAVI=transcatheter aortic valve
 4 implantation.

5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29

1 **Table 4. Summary of studies (single case reports) on emergent TAVI for the**
2 **treatment of acute AR during CS.**

Author	Setting	Treatment
Spina, 2019 ¹⁰⁷	Acute AR after iatrogenic surgical injury during complicated mitral valve surgery	Transfemoral TAVI (Medtronic Evolut R)
Herrmann, 2017 ¹⁰⁸	Acute AR after iatrogenic injury from Impella [®] implantation	Transfemoral TAVI (Edwards Sapien 3)
Van der Werf, 2017 ¹⁰⁹	Acute AR in a left ventricular assist device patient	Transfemoral TAVI (Medtronic CoreValve)
Abdelaziz, 2018 ¹¹⁰	Acute AR and aortic root dissection after previous supracoronary aortic replacement	Transapical TAVI (Edwards Sapien S3)

3

4 AR=aortic regurgitation; CS=cardiogenic shock; TAVI=transcatheter aortic valve implantation.

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

1 **Table 5. Observational studies of transcatheter mitral valve repair in patients with**
 2 **MR and CS*.**

Author	Setting	n	Clinical scenario	Device	Mechanical circulatory support	Procedural successes	Outcomes
Adamo, 2017 ¹²⁷	Single - centre	4	Secondary MR: 100% (acute MR post-AMI 100%)	MitraClip	IABP: 100%	100%	30-day mortality: 0%
Seizer, 2017 ¹²⁸	Single - centre	10	N/A	MitraClip	IABP: 30.0% ECMO: 70.0% Impella: 30.0%	90.0%	30-day mortality: 60.0%
Flint, 2019 ¹²⁹	Single - centre	12	Primary MR: 33.3% Secondary MR: 16.7% Mixed MR: 50.0%	MitraClip	IABP: 33.3% ECMO: 8.3%	75.0%	30-day mortality: 16.7% Follow-up mortality (median 198 days): 41.7%
Chan, 2019 ¹³⁰	Single - centre	27	Primary MR: 7.4% Secondary MR: 92.6% (ischaemic 92.0%)	MitraClip	IABP: 18.5%	92.6%	30-day mortality: 25.9% Follow-up mortality (mean 202 days): 63.0%
Cheng, 2019 ⁵⁹	Single - centre	29	Secondary MR: 100% (non-ischaemic 65.5%, ischaemic 34.5%)	MitraClip	Impella: 17.2% IABP: 10.3%	96.6%	In-hospital mortality: 17.2% Survival to 6 months: 75.6 ± 8.0%
Garcia, 2020 ¹³¹	Single - centre	11	Primary MR: 63.6% Secondary MR: 36.4%	MitraClip	IABP: 45.5%	72.7%	30-day mortality: 27.3% One-year mortality: 66.7%
Jung, 2021 ¹²⁶	Multicentre	141	Primary MR: 23.4% Secondary MR: 75.2% Mixed MR: 1.4%	MitraClip	50.4%	88.7%	In-hospital mortality: 15.6% One-year mortality: 42.6%
Estévez-Loureiro, 2021 ⁷¹	Multicentre	50	Secondary MR: 100% (acute MR post-AMI 100%)	MitraClip	IABP/Impella: 66.0% VA ECMO: 12.0%	90.0%	30-day mortality: 10.0% Follow-up mortality (median 7 months): 28%
Vandenbriele, 2021 ⁶²	2 centres	6	Primary MR: 50% Secondary MR: 50%	MitraClip	Impella: 100%	100%	In-hospital mortality: 16.7% 6-month mortality: 16.7%

Falasco ni, 2021 ¹³²	Multic entre	31	Secondary MR: 100% (papillary muscle rupture 12.9%)	MitraCli p	IABP: 58.1% Impella: 22.6% ECMO: 6.5%	87.1%	30-day mortality: 22.6% 6-month mortality: 38.7%
---------------------------------------	-----------------	----	--	---------------	---	-------	--

1

2

ECMO: extracorporeal membrane oxygenation; IABP: intra-aortic balloon pump; AMI: myocardial infarction; MR: mitral regurgitation; N/A: not available; VA: veno-arterial

3

4

** Studies including exclusively patients with cardiogenic shock or studies including also patients without cardiogenic shock, but in which data on patients with cardiogenic shock could be extracted from the manuscript*

5

6

7

8

9

10

11

12

13

14

15

16

17

18

19

20

21

22

23

24

25

1 **Table 6. Transcatheter treatment options in case of BVF.**

	No/mild calcifications	Severe calcification
Stenosis	Valve-in-valve	Valve-in-valve (consider cerebral protection) ¹⁴⁴
Regurgitation	Valve-in-valve Plug in case of severe PVL ¹³⁸⁻¹⁴⁰	Valve-in-valve (consider cerebral protection) ¹⁴⁴

2

3 BVF=bioprosthetic valve failure; PVL=paravalvular leak.

4

5

6

7

8

9

10

11

12

13

14

15

16

17

1 **Table 7. Advanced techniques to overcome complex situations for valve-in-valve.**

Complex situations for valve-in-valve	Advanced techniques
Small aortic bioprosthesis (label size \leq 21 mm)	Bioprosthesis valve ring fracture
Risk of coronary obstruction	Coronary chimney stenting, endovascular electro-surgery leaflet splitting ¹⁴⁵
Risk of LV outflow tract obstruction in mitral valve-in-valve	Endovascular electro-surgery leaflet splitting ¹⁴⁶ , alcohol septal ablation

2

3 LV=left ventricle

4

5







