Mitral Regurgitation

Primary MR

Severe MR
- Vena contracta ≥ 0.7 cm
- RVol ≥ 60 mL
- RF ≥ 50%
- ERO ≥ 0.4 cm²
- LV dilation

Symptomatic (stage D)
- LVEF > 30%

NO → YES

Asymptomatic (stage C)
- LVEF 30% to ≤ 60%
- LVESD ≥ 40 mm (stage C2)

Likelihood of successful repair ~ 95% and Expected mortality < 1%

YES → NO

MV Surgery* (IIa)

MV Surgery* (I)

MV Repair (IIa)

Periodic Monitoring

Secondary MR

Progressive MR
- Vena contracta < 0.7 cm
- RVol < 60 mL
- RF < 50%
- ERO < 0.4 cm²

Symptomatic severe MR (stage D)
- New onset AF or PASP > 50 mm Hg (stage C1)

Asymptomatic severe MR (stage C)
- Persistent NYHA class III-IV symptoms

Secondary MR (stage B)

CAD Rx
- HF Rx
- Consider CRT

* Mitral valve repair is preferred over MVR when possible.

AF indicates atrial fibrillation; CAD, coronary artery disease; CRT, cardiac resynchronization therapy; ERO, effective regurgitant orifice; HF, heart failure; LV, left ventricular; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic dimension; MR, mitral regurgitation; MV, mitral valve; MVR, mitral valve replacement; NYHA, New York Heart Association; PASP, pulmonary artery systolic pressure; RF, regurgitant fraction; RVol, regurgitant volume; and Rx, therapy.

8. Tricuspid Valve Disease: Recommendations

8.1. Stages of TR
Trace-to-mild degrees of TR of no physiological consequence are commonly detected on TTE in subjects with anatomically normal valves. Primary disorders of the tricuspid apparatus that can lead to more significant degrees of TR include rheumatic disease, prolapse, congenital disease (Ebstein’s), IE, radiation, carcinoid, blunt chest wall trauma, RV endomyocardial biopsy–related trauma, and intra-annular RV pacemaker or implantable cardioverter-defibrillator leads. Approximately 80% of cases of significant TR are functional in nature and related to tricuspid annular dilation and leaflet tethering in the setting of RV remodeling due to pressure and/or volume overload. The tricuspid annulus is a saddle-shaped ellipsoid that becomes planar and circular as it dilates in an anterior-posterior direction and will often not return to its normal size and configuration after relief of RV
overload. Table 17 shows the stages (A through D) of primary and functional TR as defined for other valve lesions. Severe TR (stages C and D) is associated with poor prognosis independent of age, LV and RV function, and RV size. Patients with signs or symptoms of right HF would fit into the stage D category even if they do not meet other hemodynamic or morphological criteria.

Supporting Reference: (236)
Table 17. Stages of TR

<table>
<thead>
<tr>
<th>Stage</th>
<th>Definition</th>
<th>Valve Anatomy</th>
<th>Valve Hemodynamics*</th>
<th>Hemodynamic Consequences</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>At risk of TR</td>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
<td>• None or in relation to other left heart or pulmonary/pulmonary vascular disease</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mild rheumatic change</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Mild prolapse</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Other (e.g., IE with vegetation, early carcinoid deposition, radiation)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Intra-annular RV pacemaker or ICD lead</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Postcardiac transplant (biopsy related)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><strong>Functional</strong></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>• Normal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Early annular dilation</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>B</td>
<td>Progressive TR</td>
<td><strong>Primary</strong></td>
<td></td>
<td>Mild TR</td>
<td>• None or in relation to other left heart or pulmonary/pulmonary vascular disease</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Progressive leaflet deterioration/destruction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Moderate-to-severe prolapse, limited chordal rupture</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><strong>Functional</strong></td>
<td></td>
<td>Mild TR</td>
<td>• RV/RA/IVC size normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Early annular dilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Moderate leaflet tethering</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><strong>Moderate TR</strong></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>• Central jet area &lt;5.0 cm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vena contracta width not defined</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• CW jet density and contour: soft and parabolic</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Hepatic vein flow: systolic dominance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Asymptomatic, severe TR</td>
<td><strong>Primary</strong></td>
<td></td>
<td>Moderate TR</td>
<td>• No RV enlargement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Flail or grossly distorted leaflets</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td><strong>Functional</strong></td>
<td></td>
<td>Moderate TR</td>
<td>• No or mild RA enlargement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Severe annular dilation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>**Severe annular dilation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Central jet area &gt;10.0 cm²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vena contracta width &gt;0.7 cm</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• CW jet density and contour: dense, triangular with early peak</td>
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<tr>
<td></td>
<td></td>
<td>• Hepatic vein flow: systolic blunting</td>
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<tr>
<td></td>
<td></td>
<td><strong>Symptoms</strong></td>
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<tr>
<td></td>
<td></td>
<td>• RV/RA/IVC dilated with decreased IVC respirophasic variation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Elevated RA pressure with “c-V” wave</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diastolic interventricular</td>
<td></td>
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</tr>
</tbody>
</table>
Several valve hemodynamic criteria are provided for assessment of severity of TR, but not all criteria for each category will necessarily be present in every patient. Categorization of severity of TR as mild, moderate, or severe also depends on image quality and integration of these parameters with clinical findings.

CW indicates continuous wave; ICD, implantable cardioverter-defibrillator; IE, infective endocarditis; IVC, inferior vena cava; RA, right atrium; RV, right ventricle; and TR, tricuspid regurgitation.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>reversal</th>
<th>septal flattening may be present</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td></td>
<td>Symptomatic severe TR</td>
<td></td>
</tr>
<tr>
<td>Primary</td>
<td></td>
<td>Flail or grossly distorted leaflets</td>
<td></td>
</tr>
<tr>
<td>Functional</td>
<td></td>
<td>Severe annular dilation (&gt;40 mm or &gt;21 mm/m²)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marked leaflet tethering</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Central jet area &gt;10.0 cm²</td>
<td>• RV/RA/IVC dilated with decreased IVC respirophasic variation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vena contracta width &gt;0.70 cm</td>
<td>• Elevated RA pressure with “c-V” wave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CW jet density and contour: dense, triangular with early peak</td>
<td>• Diastolic interventricular septal flattening</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hepatic vein flow: systolic reversal</td>
<td>• Reduced RV systolic function in late phase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fatigue, palpitations, dyspnea, abdominal bloating, anorexia, edema</td>
<td></td>
</tr>
</tbody>
</table>
8.2. Tricuspid Regurgitation
See Figure 5 (Section 8.2.3) for indications for surgery.

8.2.1. Diagnosis and Follow-Up

Class I
1. TTE is indicated to evaluate severity of TR, determine etiology, measure sizes of right-sided chambers and inferior vena cava, assess RV systolic function, estimate pulmonary artery systolic pressure, and characterize any associated left-sided heart disease. (Level of Evidence: C)

Class IIa
1. Invasive measurement of pulmonary artery pressures and pulmonary vascular resistance can be useful in patients with TR when clinical and noninvasive data regarding their values are discordant. (Level of Evidence: C)

Class IIb
1. CMR or real-time 3-dimensional echocardiography may be considered for assessment of RV systolic function and systolic and diastolic volumes in patients with severe TR (stages C and D) and suboptimal 2-dimensional echocardiograms. (Level of Evidence: C)
2. Exercise testing may be considered for the assessment of exercise capacity in patients with severe TR with no or minimal symptoms (stage C). (Level of Evidence: C)

8.2.2. Medical Therapy

Class IIa
1. Diuretics can be useful for patients with severe TR and signs of right-sided HF (stage D). (Level of Evidence: C)

Class IIb
1. Medical therapies to reduce elevated pulmonary artery pressures and/or pulmonary vascular resistance might be considered in patients with severe functional TR (stages C and D). (Level of Evidence: C)

8.2.3. Intervention

Class I
1. Tricuspid valve surgery is recommended for patients with severe TR (stages C and D) undergoing left-sided valve surgery. (Level of Evidence: C)

Class IIa
1. Tricuspid valve repair can be beneficial for patients with mild, moderate, or greater functional TR (stage B) at the time of left-sided valve surgery with either 1) tricuspid annular dilation or 2) prior evidence of right HF (237-246). (Level of Evidence: B)
2. Tricuspid valve surgery can be beneficial for patients with symptoms due to severe primary TR that are unresponsive to medical therapy (stage D). (Level of Evidence: C)

Class IIb
1. Tricuspid valve repair may be considered for patients with moderate functional TR (stage B) and pulmonary artery hypertension at the time of left-sided valve surgery. (Level of Evidence: C)
2. Tricuspid valve surgery may be considered for asymptomatic or minimally symptomatic patients with severe primary TR (stage C) and progressive degrees of moderate or greater RV dilation and/or systolic dysfunction. *(Level of Evidence: C)*

3. Reoperation for isolated tricuspid valve repair or replacement may be considered for persistent symptoms due to severe TR (stage D) in patients who have undergone previous left-sided valve surgery and who do not have severe pulmonary hypertension or significant RV systolic dysfunction. *(Level of Evidence: C)*

**Figure 5.** Indications for Surgery

*See Table 17 for definition of stages. TA dilation is defined by >40 mm on TTE (>21 mm/m²) or >70 mm on direct intraoperative measurement.*

LV indicates left ventricular; PHTN, pulmonary hypertension; RV, right ventricular; TA, tricuspid annular; TR, tricuspid regurgitation; TTE, transthoracic echocardiogram; TV, tricuspid valve; and TVR, tricuspid valve replacement.

**8.3. Stages of Tricuspid Stenosis**

See Table 18 for the stages of severe tricuspid stenosis (TS).
The transtricuspid diastolic gradient is highly variable and is affected by heart rate, forward flow, and phases of the respiratory cycle. However, severe TS usually has mean pressure gradients >5 to 10 mm Hg at heart rate 70.

IVC indicates inferior vena cava; RA, right atrium; T ½, pressure half-time; and TS, tricuspid stenosis. (9)

8.4. Tricuspid Stenosis

8.4.1. Diagnosis and Follow-Up

Class I
1. TTE is indicated in patients with TS to assess the anatomy of the valve complex, evaluate severity of stenosis, and characterize any associated regurgitation and/or left-sided valve disease. (Level of Evidence: C)

Class IIb
1. Invasive hemodynamic assessment of severity of TS may be considered in symptomatic patients when clinical and noninvasive data are discordant. (Level of Evidence: C)

8.4.2. Intervention

Class I
1. Tricuspid valve surgery is recommended for patients with severe TS at the time of operation for left-sided valve disease. (Level of Evidence: C)
2. Tricuspid valve surgery is recommended for patients with isolated, symptomatic severe TS. (Level of Evidence: C)

Class IIb
1. Percutaneous balloon tricuspid commissurotomy might be considered in patients with isolated, symptomatic severe TS without accompanying TR. (Level of Evidence: C)

9. Stages of Pulmonic Valve Disease

See Table 19 for the stages of severe pulmonic regurgitation and Table 20 for the stages of severe pulmonic stenosis.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Definition</th>
<th>Valve Anatomy</th>
<th>Valve Hemodynamics</th>
<th>Hemodynamic Consequences</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>C, D</td>
<td>Severe PR</td>
<td>Distorted or absent leaflets, annular dilation</td>
<td>Color jet fills RVOT, CW jet density and contour: dense laminar flow with steep deceleration slope; may terminate abruptly</td>
<td>Paradoxical septal motion (volume overload pattern), RV enlargement</td>
<td>None or variable and dependent on cause of PR and RV function</td>
</tr>
</tbody>
</table>

CW indicates continuous wave; PR, pulmonic regurgitation; RV, right ventricular; and RVOT, right ventricular outflow tract. (247)
10. Prosthetic Valves: Recommendations

10.1. Evaluation and Selection of Prosthetic Valves

10.1.1. Diagnosis and Follow-Up

Class I
1. An initial TTE study is recommended in patients after prosthetic valve implantation for evaluation of valve hemodynamics (248-251). *(Level of Evidence: B)*
2. Repeat TTE is recommended in patients with prosthetic heart valves if there is a change in clinical symptoms or signs suggesting valve dysfunction. *(Level of Evidence: C)*
3. TEE is recommended when clinical symptoms or signs suggest prosthetic valve dysfunction. *(Level of Evidence: C)*

Class IIa
1. Annual TTE is reasonable in patients with a bioprosthetic valve after the first 10 years, even in the absence of a change in clinical status. *(Level of Evidence: C)*

10.1.2. Intervention

See Table 21 for a summary of recommendations for prosthetic valve choice.

Class I
1. The choice of valve intervention, that is, repair or replacement, as well as type of prosthetic heart valve, should be a shared decision-making process that accounts for the patient’s values and preferences, with full disclosure of the indications for and risks of anticoagulant therapy and the potential need for and risk of reoperation. *(Level of Evidence: C)*
2. A bioprosthesis is recommended in patients of any age for whom anticoagulant therapy is contraindicated, cannot be managed appropriately, or is not desired. *(Level of Evidence: C)*

Class IIa
1. A mechanical prosthesis is reasonable for AVR or MVR in patients less than 60 years of age who do not have a contraindication to anticoagulation (252-254). *(Level of Evidence: B)*
2. A bioprosthesis is reasonable in patients more than 70 years of age (255-258). *(Level of Evidence: B)*
3. Either a bioprosthetic or mechanical valve is reasonable in patients between 60 and 70 years of age (259, 260). *(Level of Evidence: B)*

Class IIb
1. Replacement of the aortic valve by a pulmonary autograft (the Ross procedure), when performed by an experienced surgeon, may be considered in young patients when VKA anticoagulation is contraindicated or undesirable. \((\text{Level of Evidence: C})\)

### Table 21. Summary of Recommendations for Prosthetic Valve Choice

<table>
<thead>
<tr>
<th>Recommendations</th>
<th>COR</th>
<th>LOE</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of valve intervention and prosthetic valve type should be a shared decision process</td>
<td>I</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>A bioprosthesis is recommended in patients of any age for whom anticoagulant therapy is contraindicated, cannot be managed appropriately, or is not desired</td>
<td>I</td>
<td>C</td>
<td>N/A</td>
</tr>
<tr>
<td>A mechanical prosthesis is reasonable for AVR or MVR in patients &lt;60 y of age who do not have a contraindication to anticoagulation</td>
<td>IIA</td>
<td>B</td>
<td>(252-254)</td>
</tr>
<tr>
<td>A bioprosthesis is reasonable in patients &gt;70 y of age</td>
<td>IIA</td>
<td>B</td>
<td>(255-258)</td>
</tr>
<tr>
<td>Either a bioprosthetic or mechanical valve is reasonable in patients between 60 y and 70 y of age</td>
<td>IIA</td>
<td>B</td>
<td>(259, 260)</td>
</tr>
<tr>
<td>Replacement of the aortic valve by a pulmonary autograft (the Ross procedure), when performed by an experienced surgeon, may be considered in young patients when VKA anticoagulation is contraindicated or undesirable</td>
<td>IIB</td>
<td>C</td>
<td>N/A</td>
</tr>
</tbody>
</table>

AVR indicates aortic valve replacement; COR, Class of Recommendation; LOE, Level of Evidence; MVR, mitral valve replacement; N/A, not applicable; and VKA, vitamin K antagonist.

### 10.2. Antithrombotic Therapy for Prosthetic Valves

**Class I**

1. Anticoagulation with a VKA and international normalized ratio (INR) monitoring is recommended in patients with a mechanical prosthetic valve (261-263). \((\text{Level of Evidence: A})\)

2. Anticoagulation with a VKA to achieve an INR of 2.5 is recommended in patients with a mechanical AVR (bileaflet or current-generation single tilting disc) and no risk factors for thromboembolism (264-266). \((\text{Level of Evidence: B})\)

3. Anticoagulation with a VKA is indicated to achieve an INR of 3.0 in patients with a mechanical AVR and additional risk factors for thromboembolic events (AF, previous thromboembolism, LV dysfunction, or hypercoagulable conditions) or an older-generation mechanical AVR (such as ball-in-cage) (267). \((\text{Level of Evidence: B})\)

4. Anticoagulation with a VKA is indicated to achieve an INR of 3.0 in patients with a mechanical MVR (267, 268). \((\text{Level of Evidence: B})\)

5. Aspirin 75 mg to 100 mg daily is recommended in addition to anticoagulation with a VKA in patients with a mechanical valve prosthesis (269, 270). \((\text{Level of Evidence: A})\)

**Class IIa**

1. Aspirin 75 mg to 100 mg per day is reasonable in all patients with a bioprosthetic aortic or mitral valve (271-274). \((\text{Level of Evidence: B})\)

2. Anticoagulation with a VKA is reasonable for the first 3 months after bioprosthetic MVR or repair to achieve an INR of 2.5 (275). \((\text{Level of Evidence: C})\)

**Class IIb**

1. Anticoagulation, with a VKA, to achieve an INR of 2.5 may be reasonable for the first 3 months after bioprosthetic AVR (276). \((\text{Level of Evidence: B})\)

2. Clopidogrel 75 mg daily may be reasonable for the first 6 months after TAVR in addition to lifelong aspirin 75 mg to 100 mg daily. \((\text{Level of Evidence: C})\)
Class III: Harm
1. Anticoagulant therapy with oral direct thrombin inhibitors or anti-Xa agents should not be used in patients with mechanical valve prostheses (277-279). \( \text{(Level of Evidence: B)} \)

10.3. Bridging Therapy for Prosthetic Valves

Class I
1. Continuation of VKA anticoagulation with a therapeutic INR is recommended in patients with mechanical heart valves undergoing minor procedures (such as dental extractions or cataract removal) where bleeding is easily controlled. \( \text{(Level of Evidence: C)} \)
2. Temporary interruption of VKA anticoagulation, without bridging agents while the INR is subtherapeutic, is recommended in patients with a bileaflet mechanical AVR and no other risk factors for thrombosis who are undergoing invasive or surgical procedures. \( \text{(Level of Evidence: C)} \)
3. Bridging anticoagulation with either intravenous unfractionated heparin (UFH) or subcutaneous low-molecular-weight heparin (LMWH) is recommended during the time interval when the INR is subtherapeutic preoperatively in patients who are undergoing invasive or surgical procedures with a 1) mechanical AVR and any thromboembolic risk factor, 2) older-generation mechanical AVR, or 3) mechanical MVR. \( \text{(Level of Evidence: C)} \)

Class IIa
1. Administration of fresh frozen plasma or prothrombin complex concentrate is reasonable in patients with mechanical valves receiving VKA therapy who require emergency noncardiac surgery or invasive procedures. \( \text{(Level of Evidence: C)} \)

10.4. Excessive Anticoagulation and Serious Bleeding With Prosthetic Valves
See Figure 6 for anticoagulation for prosthetic valves.

Class IIa
1. Administration of fresh frozen plasma or prothrombin complex concentrate is reasonable in patients with mechanical valves and uncontrollable bleeding who require reversal of anticoagulation (280, 281). \( \text{(Level of Evidence: B)} \)

Figure 6. Anticoagulation for Prosthetic Valves
Risk factors include AF, previous thromboembolism, LV dysfunction, hypercoagulable condition, and older-generation mechanical AVR.

AF indicates atrial fibrillation; ASA, aspirin; AVR, aortic valve replacement; INR, international normalized ratio; LMWH, low-molecular-weight heparin; MVR, mitral valve replacement; PO, by mouth; QD, every day; SC, subcutaneous; TAVR, transcatheter aortic valve replacement; UFH, unfractionated heparin; and VKA, vitamin K antagonist.

10.5. Prosthetic Valve Thrombosis
See Figure 7 for evaluation and management of suspected valve thrombosis.

10.5.1. Diagnosis and Follow-Up

Class I
1. TTE is indicated in patients with suspected prosthetic valve thrombosis to assess hemodynamic severity and follow resolution of valve dysfunction (282, 283). *(Level of Evidence: B)*
2. TEE is indicated in patients with suspected prosthetic valve thrombosis to assess thrombus size and valve motion (283-285). *(Level of Evidence: B)*

Class IIa
1. Fluoroscopy or CT is reasonable in patients with suspected valve thrombosis to assess valve motion. *(Level of Evidence: C)*

10.5.2. Medical Therapy
Class IIa

1. Fibrinolytic therapy is reasonable for patients with a thrombosed left-sided prosthetic heart valve, recent onset (<14 days) of NYHA class I to II symptoms, and a small thrombus (<0.8 cm²) (283, 286). (Level of Evidence: B)

2. Fibrinolytic therapy is reasonable for thrombosed right-sided prosthetic heart valves (287, 288). (Level of Evidence: B)

10.5.3. Intervention

Class I

1. Emergency surgery is recommended for patients with a thrombosed left-sided prosthetic heart valve with NYHA class III to IV symptoms (287, 289, 290). (Level of Evidence: B)

Class IIa

1. Emergency surgery is reasonable for patients with a thrombosed left-sided prosthetic heart valve with a mobile or large thrombus (>0.8 cm²) (283, 285, 290). (Level of Evidence: C)

Figure 7. Evaluation and Management of Suspected Prosthetic Valve Thrombosis

*See full-text guideline for dosage recommendations.
10.6. Prosthetic Valve Stenosis

Class I

1. Repeat valve replacement is indicated for severe symptomatic prosthetic valve stenosis. *(Level of Evidence: C)*

10.7. Prosthetic Valve Regurgitation

Class I

1. Surgery is recommended for operable patients with mechanical heart valves with intractable hemolysis or HF due to severe prosthetic or paraprosthetic regurgitation *(291, 292).* *(Level of Evidence: B)*

Class IIa

1. Surgery is reasonable for operable patients with severe symptomatic or asymptomatic bioprosthetic regurgitation. *(Level of Evidence C)*

2. Percutaneous repair of paravalvular regurgitation is reasonable in patients with prosthetic heart valves and intractable hemolysis or NYHA class III/IV HF who are at high risk for surgery and have anatomic features suitable for catheter-based therapy when performed in centers with expertise in the procedure *(293-295).* *(Level of Evidence B)*

11. Infective Endocarditis: Recommendations

11.1. Diagnosis and Follow-Up

See Figure 8 for recommendations for imaging studies in native valve endocarditis and prosthetic valve endocarditis.

Class I

1. At least 2 sets of blood cultures should be obtained in patients at risk for IE (e.g., those with congenital or acquired VHD, previous IE, prosthetic heart valves, certain congenital or heritable heart malformations, immunodeficiency states, or injection drug users) who have unexplained fever for more than 48 hours *(296)* *(Level of Evidence: B)* or patients with newly diagnosed left-sided valve regurgitation. *(Level of Evidence: C)*

2. The Modified Duke Criteria should be used in evaluating a patient with suspected IE *(Tables 24 and 25 in the full-text guideline)* *(297-300).* *(Level of Evidence: B)*

3. Patients with IE should be evaluated and managed with consultation of a multispecialty Heart Valve Team including an infectious disease specialist, cardiologist, and cardiac surgeon. In surgically managed patients, this team should also include a cardiac anesthesiologist *(301).* *(Level of Evidence: B)*

4. TTE is recommended in patients with suspected IE to identify vegetations, characterize the hemodynamic severity of valvular lesions, assess ventricular function and pulmonary pressures, and detect complications *(302-306).* *(Level of Evidence: B)*

5. TEE is recommended in all patients with known or suspected IE when TTE is nondiagnostic, when complications have developed or are clinically suspected, or when intracardiac device leads are present *(307-315).* *(Level of Evidence: B)*

6. TTE and/or TEE are recommended for reevaluation of patients with IE who have a change in clinical signs or symptoms (e.g., new murmur, embolism, persistent fever, HF, abscess, or atroventricular heart block) and in patients at high risk of complications (e.g., extensive infected...
tissue/large vegetation on initial echocardiogram or staphylococcal, enterococcal, or fungal infections) (316, 317). (Level of Evidence: B)

7. **Intraoperative TEE is recommended for patients undergoing valve surgery for IE** (318, 319). (Level of Evidence: B)

**Class IIa**

1. TEE is reasonable to diagnose possible IE in patients with *Staphylococcal aureus* bacteremia without a known source (320-322). (Level of Evidence: B)

2. TEE is reasonable to diagnose IE of a prosthetic valve in the presence of persistent fever without bacteremia or a new murmur (323, 324). (Level of Evidence: B)

3. Cardiac CT is reasonable to evaluate morphology/anatomy in the setting of suspected paravalvular infections when the anatomy cannot be clearly delineated by echocardiography (325-328). (Level of Evidence: B)

**Class IIb**

1. TEE might be considered to detect concomitant staphylococcal IE in nosocomial *Staphylococcal aureus* bacteremia with a known portal of entry from an extracardiac source (329-331). (Level of Evidence: B)

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**Figure 8.** Recommendations for Imaging Studies in NVE and PVE

*Repeat TEE and/or TTE recommended for reevaluation of patients with IE and a change in clinical signs or symptoms and in patients at high risk of complications.

CT indicates computed tomography; IE, infective endocarditis; NVE, native valve endocarditis; PVE, prosthetic valve endocarditis; *S. aureus*, *Staphylococcus aureus*; TEE, transesophageal echocardiography; and TTE, transthoracic echocardiography.

**11.2. Medical Therapy**

**Class I**
1. Appropriate antibiotic therapy should be initiated and continued after blood cultures are obtained with guidance from antibiotic sensitivity data and infectious disease consultants (296). \textit{(Level of Evidence: B)}

Class IIa

1. It is reasonable to temporarily discontinue anticoagulation in patients with IE who develop central nervous system symptoms compatible with embolism or stroke regardless of the other indications for anticoagulation (332-337). \textit{(Level of Evidence: B)}

Class IIb

1. Temporary discontinuation of VKA anticoagulation might be considered in patients receiving VKA anticoagulation at the time of IE diagnosis (333, 338-341). \textit{(Level of Evidence: B)}

Class III: Harm

1. Patients with known VHD should not receive antibiotics before blood cultures are obtained for unexplained fever. \textit{(Level of Evidence: C)}

11.3. Intervention

See Figure 9 for diagnosis and treatment of IE.

Class I

1. Decisions about timing of surgical intervention should be made by a multispecialty Heart Valve Team of cardiology, cardiothoracic surgery, and infectious disease specialists (301). \textit{(Level of Evidence: B)}

2. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) is indicated in patients with IE who present with valve dysfunction resulting in symptoms of HF (342-347). \textit{(Level of Evidence: B)}

3. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) is indicated in patients with left-sided IE caused by \textit{Staphylococcal aureus}, fungal, or other highly resistant organisms (347-354). \textit{(Level of Evidence: B)}

4. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) is indicated in patients with IE complicated by heart block, annular or aortic abscess, or destructive penetrating lesions (347, 355-359). \textit{(Level of Evidence: B)}

5. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) for IE is indicated in patients with evidence of persistent infection as manifested by persistent bacteremia or fevers lasting longer than 5 to 7 days after onset of appropriate antimicrobial therapy (347, 352, 353, 360-362). \textit{(Level of Evidence: B)}

6. Surgery is recommended for patients with prosthetic valve endocarditis and relapsing infection (defined as recurrence of bacteremia after a complete course of appropriate antibiotics and subsequently negative blood cultures) without other identifiable source for portal of infection. \textit{(Level of Evidence: C)}

7. Complete removal of pacemaker or defibrillator systems, including all leads and the generator, is indicated as part of the early management plan in patients with IE with documented infection of the device or leads (363-366). \textit{(Level of Evidence: B)}

Class IIa

1. Complete removal of pacemaker or defibrillator systems, including all leads and the generator, is reasonable in patients with valvular IE caused by \textit{Staphylococcal aureus} or fungi, even without evidence of device or lead infection (363-366). \textit{(Level of Evidence: B)}

2. Complete removal of pacemaker or defibrillator systems, including all leads and the generator, is reasonable in patients undergoing valve surgery for valvular IE. \textit{(Level of Evidence: C)}

3. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) is reasonable in patients with IE who present with recurrent emboli and persistent vegetations despite appropriate antibiotic therapy (302, 367, 368). \textit{(Level of Evidence: B)}
Class IIb
1. Early surgery (during initial hospitalization before completion of a full therapeutic course of antibiotics) may be considered in patients with native valve endocarditis who exhibit mobile vegetations greater than 10 mm in length (with or without clinical evidence of embolic phenomenon) (302, 367, 368). (Level of Evidence: B)

Figure 9. Diagnosis and Treatment of IE

*Early surgery defined as during initial hospitalization before completion of a full therapeutic course of antibiotics.

HF indicates heart failure; ICD, implantable cardioverter-defibrillator; IE, infective endocarditis; NVE, native valve endocarditis; PVE, prosthetic valve endocarditis; Rx, therapy; S. aureus, Staphylococcus aureus; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography; and VKA, vitamin K antagonist.

12. Pregnancy and VHD: Recommendations

12.1. Native Valve Stenosis

Class I
1. All patients with suspected valve stenosis should undergo a clinical evaluation and TTE before pregnancy. (Level of Evidence: C)
2. All patients with severe valve stenosis (stages C and D) should undergo prepregnancy counseling by a cardiologist with expertise in managing patients with VHD during pregnancy. *(Level of Evidence: C)*

3. All patients referred for a valve operation before pregnancy should receive prepregnancy counseling by a cardiologist with expertise in managing patients with VHD during pregnancy about the risks and benefits of all options for operative interventions, including mechanical prosthesis, bioprosthesis, and valve repair. *(Level of Evidence: C)*

4. Pregnant patients with severe valve stenosis (stages C and D) should be monitored in a tertiary care center with a dedicated Heart Valve Team of cardiologists, surgeons, anesthesiologists, and obstetricians with expertise in the management of high-risk cardiac patients during pregnancy. *(Level of Evidence: C)*

### 12.1.1. Diagnosis and Follow-Up

**Class IIa**

1. Exercise testing is reasonable in asymptomatic patients with severe AS (aortic velocity $\geq 4$ m per second or mean pressure gradient $\geq 40$ mm Hg, stage C) before pregnancy. *(Level of Evidence: C)*

### 12.1.2. Medical Therapy

**Class I**

1. Anticoagulation should be given to pregnant patients with MS and AF unless contraindicated. *(Level of Evidence: C)*

**Class IIa**

1. Use of beta blockers as required for rate control is reasonable for pregnant patients with MS in the absence of contraindication if tolerated. *(Level of Evidence: C)*

**Class IIb**

1. Use of diuretics may be reasonable for pregnant patients with MS and HF symptoms (stage D). *(Level of Evidence: C)*

**Class III: Harm**

1. ACE inhibitors and ARBs should not be given to pregnant patients with valve stenosis (369-371). *(Level of Evidence: B)*

### 12.1.3. Intervention

**Class I**

1. Valve intervention is recommended before pregnancy for symptomatic patients with severe AS (aortic velocity $\geq 4.0$ m per second or mean pressure gradient $\geq 40$ mm Hg, stage D). *(Level of Evidence: C)*

2. Valve intervention is recommended before pregnancy for symptomatic patients with severe MS (mitral valve area $\leq 1.5$ cm$^2$, stage D). *(Level of Evidence: C)*

3. Percutaneous mitral balloon commissurotomy is recommended before pregnancy for asymptomatic patients with severe MS (mitral valve area $\leq 1.5$ cm$^2$, stage C) who have valve morphology favorable for percutaneous mitral balloon commissurotomy. *(Level of Evidence: C)*

**Class IIa**

1. Valve intervention is reasonable before pregnancy for asymptomatic patients with severe AS (aortic velocity $\geq 4.0$ m per second or mean pressure gradient $\geq 40$ mm Hg, stage C). *(Level of Evidence: C)*
2. Percutaneous mitral balloon commissurotomy is reasonable for pregnant patients with severe MS (mitral valve area ≤1.5 cm², stage D) with valve morphology favorable for percutaneous mitral balloon commissurotomy who remain symptomatic with NYHA class III to IV HF symptoms despite medical therapy (372-376). (Level of Evidence: B)

3. Valve intervention is reasonable for pregnant patients with severe MS (mitral valve area ≤1.5 cm², stage D) and valve morphology not favorable for percutaneous mitral balloon commissurotomy only if there are refractory NYHA class IV HF symptoms. (Level of Evidence: C)

4. Valve intervention is reasonable for pregnant patients with severe AS (mean pressure gradient ≥40 mm Hg, stage D) only if there is hemodynamic deterioration or NYHA class III to IV HF symptoms (377-383). (Level of Evidence: B)

Class III: Harm
1. Valve operation should not be performed in pregnant patients with valve stenosis in the absence of severe HF symptoms. (Level of Evidence: C)

12.2. Native Valve Regurgitation

12.2.1. Diagnosis and Follow-Up

Class I
1. All patients with suspected valve regurgitation should undergo a clinical evaluation and TTE before pregnancy. (Level of Evidence: C)

2. All patients with severe valve regurgitation (stages C and D) should undergo prepregnancy counseling by a cardiologist with expertise in managing patients with VHD during pregnancy. (Level of Evidence: C)

3. All patients referred for a valve operation before pregnancy should receive prepregnancy counseling by a cardiologist with expertise in managing patients with VHD during pregnancy regarding the risks and benefits of all options for operative interventions, including mechanical prosthesis, bioprosthesis, and valve repair. (Level of Evidence: C)

4. Pregnant patients with severe regurgitation (stages C and D) should be monitored in a tertiary care center with a dedicated Heart Valve Team of cardiologists, surgeons, anesthesiologists, and obstetricians with expertise in managing high-risk cardiac patients. (Level of Evidence: C)

Class IIa
1. Exercise testing is reasonable in asymptomatic patients with severe valve regurgitation (stage C) before pregnancy. (Level of Evidence: C)

12.2.2. Medical Therapy

Class III: Harm
1. ACE inhibitors and ARBs should not be given to pregnant patients with valve regurgitation (369-371). (Level of Evidence: B)

12.2.3. Intervention

Class I
1. Valve repair or replacement is recommended before pregnancy for symptomatic women with severe valve regurgitation (stage D). (Level of Evidence: C)

Class IIa
1. Valve operation for pregnant patients with severe valve regurgitation is reasonable only if there are refractory NYHA class IV HF symptoms (stage D). (Level of Evidence: C)
Valve repair before pregnancy may be considered in the asymptomatic patient with severe MR (stage C) and a valve suitable for valve repair, but only after detailed discussion with the patient about the risks and benefits of the operation and its outcome on future pregnancies. (Level of Evidence: C)

Valve operations should not be performed in pregnant patients with valve regurgitation in the absence of severe intractable HF symptoms. (Level of Evidence: C)

12.3. Prosthetic Valves in Pregnancy

12.3.1. Diagnosis and Follow-Up

All patients with a prosthetic valve should undergo a clinical evaluation and baseline TTE before pregnancy. (Level of Evidence: C)

All patients with a prosthetic valve should undergo prepregnancy counseling by a cardiologist with expertise in managing patients with VHD during pregnancy. (Level of Evidence: C)

TTE should be performed in all pregnant patients with a prosthetic valve if not done before pregnancy. (Level of Evidence: C)

Repeat TTE should be performed in all pregnant patients with a prosthetic valve who develop symptoms. (Level of Evidence: C)

TEE should be performed in all pregnant patients with a mechanical prosthetic valve who have prosthetic valve obstruction or experience an embolic event. (Level of Evidence: C)

Pregnant patients with a mechanical prosthesis should be monitored in a tertiary care center with a dedicated Heart Valve Team of cardiologists, surgeons, anesthesiologists, and obstetricians with expertise in the management of high-risk cardiac patients. (Level of Evidence: C)

12.3.2. Medical Therapy

See Figure 10 for anticoagulation of pregnant patients with mechanical valves.

Therapeutic anticoagulation with frequent monitoring is recommended for all pregnant patients with a mechanical prosthesis (384, 385). (Level of Evidence: B)

Warfarin is recommended in pregnant patients with a mechanical prosthesis to achieve a therapeutic INR in the second and third trimesters (386-391). (Level of Evidence: B)

Discontinuation of warfarin with initiation of intravenous UFH (with an activated partial thromboplastin time [aPTT] >2 times control) is recommended before planned vaginal delivery in pregnant patients with a mechanical prosthesis. (Level of Evidence: C)

Low-dose aspirin (75 mg to 100 mg) once per day is recommended for pregnant patients in the second and third trimesters with either a mechanical prosthesis or bioprosthesis. (Level of Evidence: C)

Continuation of warfarin during the first trimester is reasonable for pregnant patients with a mechanical prosthesis if the dose of warfarin to achieve a therapeutic INR is 5 mg per day or less after full discussion with the patient about risks and benefits (384, 385, 390-393). (Level of Evidence: B)

Dose-adjusted LMWH at least 2 times per day (with a target anti-Xa level of 0.8 U/mL to 1.2 U/mL, 4 to 6 hours postdose) during the first trimester is reasonable for pregnant patients with a
mechanical prosthesis if the dose of warfarin is greater than 5 mg per day to achieve a therapeutic INR (386-389, 394, 395). *(Level of Evidence: B)*

3. Dose-adjusted continuous intravenous UFH (with an aPTT at least 2 times control) during the first trimester is reasonable for pregnant patients with a mechanical prosthesis if the dose of warfarin is greater than 5 mg per day to achieve a therapeutic INR (384, 385, 392). *(Level of Evidence: B)*

**Class IIb**

1. Dose-adjusted LMWH at least 2 times per day (with a target anti-Xa level of 0.8 U/mL to 1.2 U/mL, 4 to 6 hours postdose) during the first trimester may be reasonable for pregnant patients with a mechanical prosthesis if the dose of warfarin is 5 mg per day or less to achieve a therapeutic INR (386-389, 394-396). *(Level of Evidence: B)*

2. Dose-adjusted continuous infusion of UFH (with aPTT at least 2 times control) during the first trimester may be reasonable for pregnant patients with a mechanical prosthesis if the dose of warfarin is 5 mg per day or less to achieve a therapeutic INR (384, 385, 392). *(Level of Evidence: B)*

**Class III: Harm**

1. LMWH should not be administered to pregnant patients with mechanical prostheses unless anti-Xa levels are monitored 4 to 6 hours after administration (387, 388, 394, 395, 397). *(Level of Evidence: B)*

**Figure 10.** Anticoagulation of Pregnant Patients With Mechanical Valves
aPTT indicates activated partial thromboplastin time; ASA, aspirin; INR, international normalized ratio; LMWH, low-molecular-weight heparin; QD, once daily; and UFH, unfractionated heparin.
13. Surgical Considerations: Recommendations

13.1. Evaluation of Coronary Anatomy
See Figure 11 for evaluation and management of CAD in patients undergoing valve surgery.

Class I
1. Coronary angiography is indicated before valve intervention in patients with symptoms of angina, objective evidence of ischemia, decreased LV systolic function, history of CAD, or coronary risk factors (including men age >40 years and postmenopausal women). \(\text{(Level of Evidence: C)}\)
2. Coronary angiography should be performed as part of the evaluation of patients with chronic severe secondary MR. \(\text{(Level of Evidence: C)}\)

Class IIa
1. Surgery without coronary angiography is reasonable for patients having emergency valve surgery for acute valve regurgitation, disease of the aortic sinuses or ascending aorta, or IE. \(\text{(Level of Evidence: C)}\)
2. CT coronary angiography is reasonable to exclude the presence of significant obstructive CAD in selected patients with a low/intermediate pretest probability of CAD. A positive coronary CT angiogram (the presence of any epicardial CAD) can be confirmed with invasive coronary angiography (398-404). \(\text{(Level of Evidence: B)}\)

13.2. Concomitant Procedures

13.2.1. Intervention for CAD

Class IIa
1. CABG or percutaneous coronary intervention is reasonable in patients undergoing valve repair or replacement with significant CAD (≥70% reduction in luminal diameter in major coronary arteries or ≥50% reduction in luminal diameter in the left main coronary artery). \(\text{(Level of Evidence: C)}\)
13.2.2. Intervention for AF

Class IIa
1. A concomitant maze procedure is reasonable at the time of mitral valve repair or replacement for treatment of chronic, persistent AF. (*Level of Evidence: C*)
2. A full biatrial maze procedure, when technically feasible, is reasonable at the time of mitral valve surgery, compared with a lesser ablation procedure, in patients with chronic, persistent AF (405, 406). (*Level of Evidence: B*)

Class IIb
1. A concomitant maze procedure or pulmonary vein isolation may be considered at the time of mitral valve repair or replacement in patients with paroxysmal AF that is symptomatic or associated with a history of embolism on anticoagulation. (*Level of Evidence: C*)
2. Concomitant maze procedure or pulmonary vein isolation may be considered at the time of cardiac surgical procedures other than mitral valve surgery in patients with paroxysmal or persistent AF that is symptomatic or associated with a history of emboli on anticoagulation. (*Level of Evidence: C*)

Class III: No Benefit
1. Catheter ablation for AF should not be performed in patients with severe MR when mitral repair or replacement is anticipated, with preference for the combined maze procedure plus mitral valve repair (407). *(Level of Evidence: B)*

### 14. Noncardiac Surgery in Patients With VHD: Recommendations

**Class IIa**

1. Moderate-risk elective noncardiac surgery with appropriate intraoperative and postoperative hemodynamic monitoring is reasonable to perform in patients with asymptomatic severe AS (408-411). *(Level of Evidence: B)*

2. Moderate-risk elective noncardiac surgery with appropriate intraoperative and postoperative hemodynamic monitoring is reasonable to perform in patients with asymptomatic severe MR. *(Level of Evidence: C)*

3. Moderate-risk elective noncardiac surgery with appropriate intraoperative and postoperative hemodynamic monitoring is reasonable to perform in patients with asymptomatic severe AR and a normal LVEF. *(Level of Evidence: C)*

**Class IIb**

1. Moderate-risk elective noncardiac surgery in patients with appropriate intraoperative and postoperative hemodynamic monitoring may be reasonable to perform in asymptomatic patients with severe MS if valve morphology is not favorable for percutaneous balloon mitral commissurotomy. *(Level of Evidence: C)*

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**Key Words:** ACC/AHA Practice Guidelines ■ anticoagulation therapy ■ aortic stenosis ■ aortic regurgitation ■ bicuspid aortic valve ■ cardiac surgery ■ heart valves ■ infective endocarditis ■ mitral stenosis ■ mitral regurgitation ■ prosthetic valves ■ pulmonic regurgitation ■ pulmonic stenosis ■ transcatheter aortic valve replacement ■ tricuspid stenosis ■ tricuspid regurgitation ■ valvular heart disease.
## Appendix 1. Author Relationships With Industry and Other Entities (Relevant)—AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease

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<th>Committee Member</th>
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<th>Institutional, Organizational, or Other Financial Benefit</th>
<th>Expert Witness</th>
<th>Voting Recusals by Section*</th>
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This table represents the relationships of committee members with industry and other entities that were determined to be relevant to this document. These relationships were reviewed and updated in conjunction with all meetings and/or conference calls of the writing committee during the document development process. The table does not necessarily reflect relationships with industry at the time of publication. A person is deemed to have a significant interest in a business if the interest represents ownership of ≥5% of the voting stock or share of the business entity, or ownership of ≥$10,000 of the fair market value of the business entity; or if funds received by the person from the business entity exceed 5% of the person’s gross income for the previous year. Relationships that exist with no financial benefit are also included for the purpose of transparency. Relationships in this table are modest unless otherwise noted.

According to the ACC/AHA, a person has a relevant relationship IF: a) The relationship or interest relates to the same or similar subject matter, intellectual property or asset, topic, or issue addressed in the document; or b) The company/entity (with whom the relationship exists) makes a drug, drug class, or device addressed in the document, or makes a competing drug or device addressed in the document; or c) The person or a member of the person’s household, has a reasonable potential for financial, professional or other personal gain or loss as a result of the issues/content addressed in the document.

*Writing committee members are required to recuse themselves from voting on sections to which their specific relationships with industry and other entities may apply. Section numbers pertain to those in the full-text guideline.
†No financial benefit.

AATS indicates American Association of Thoracic Surgery; DSMB, data safety monitoring board; and VA, Veterans Affairs.
### Appendix 2. Reviewer Relationships With Industry and Other Entities (Relevant)—AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease

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References


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