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Authors

Lee, Christopher
Tully, Andrew
Fang, James
et al.

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Comprehensive Review

Building and Optimizing the Interdisciplinary Heart Team

Christopher Lee, MD [a], Andrew Tully, MD [b], James C. Fang, MD [c], Lissa Sugeng, MD, MPH [d], Sammy Elmariah, MD, MPH [e], Kendra J. Grubb, MD, MHA [b], Michael N. Young, MD [a,*]

[a] *Heart and Vascular Center, Dartmouth-Hitchcock Medical Center, Lebanon, New Hampshire;* [b] *Department of Cardiothoracic Surgery, Emory University, Atlanta, Georgia;* [c] *Division of Cardiology, University of Utah Health, Salt Lake City, Utah;* [d] *Department of Cardiology, Northwell Health, Manhasset, New York;* [e] *Division of Cardiology, University of California San Francisco, San Francisco, California*

ABSTRACT

A multidisciplinary care team model, or Heart Team approach, has become a central tenet of cardiovascular care. Though initially applied to the management of heart transplantation and subsequently complex coronary artery disease, the Heart Team is now utilized broadly across cardiovascular medicine, including in the treatment of valvular disease, pulmonary embolism, cardiogenic shock, high-risk pregnancies in patients with pre-existing cardiovascular disease, and adult congenital heart disease. The Heart Team model improves interdisciplinary collaboration among specialties, adherence to societal guidelines, and shared decision-making with patients and families. In this review, we highlight the development and rationale supporting the Heart Team model, address the challenges of implementing a multidisciplinary care team, and discuss the optimal methods to continue to build, optimize, and implement this approach.

Introduction

The multidisciplinary Heart Team has formed the cornerstone of contemporary, complex cardiovascular decision-making for over a decade.[1] Driven by technological advances and innovations in cardiovascular care, such as newer generation drug-eluting stents and percutaneous valvular interventions, Heart Teams help navigate treatment strategies that extend beyond the boundaries of individual specialties.[2,3] Heart Teams also help facilitate patient-centered decision-making in liminal spaces, where the guidelines are less clear and where definitive data on treatment strategies has yet to be accrued. By filtering each patient's unique case through multidisciplinary discourse in the context of the contemporary evidence base and societal guidelines, the optimal Heart Team presents the patient and their family with sound recommendations that the patient and team can then adopt or modify via shared decision-making (SDM) (Figure 1).

The multidisciplinary care team model is not unique to cardiovascular care, having been utilized in transplant medicine, oncology, critical care medicine, and biopsychosocial rehabilitation,[4-11] where it has improved patient outcomes and decreased wait list times for transplant recipients, cold ischemia times for solid-organ renal transplants, and mortality in patients undergoing hematopoietic cell transplantation.[6,9] Historically in cardiovascular medicine, the multidisciplinary care team model has been present since the advent of heart transplantation and associated heart transplant teams.[12]

A true interdisciplinary Heart Team draws on the perspectives of multiple specialties and subspecialties—general cardiology, interventional cardiology, cardiothoracic surgery, cardiac imaging, advanced heart failure, cardiac anesthesiology, primary care, nursing, social work, and most importantly, the patients and their family members. Despite the Heart Team's centrality to contemporary cardiovascular care, there are comparatively few papers that explicitly address how to optimize its structure and function.[13] In this review, we will discuss existing Heart Team models in contemporary practice; summarize the ideal development, operationalization, and best practices of the Heart Team; and propose avenues for future innovation.

Contemporary multidisciplinary Heart Team models

The multidisciplinary Heart Team model has been adopted in multiple facets of cardiovascular care, notably for the management of complex coronary artery disease (CAD) and valvular heart disease. Additional multidisciplinary Heart Team models include the Pulmonary

Abbreviations: AUC, appropriate use criteria; CABG, coronary artery bypass grafting; CAD, coronary artery disease; MACE, major adverse cardiovascular event; PCI, percutaneous coronary intervention; PERT, pulmonary embolism response team; SAVR, surgical aortic valve replacement; SDM, shared decision-making; TAVR, transcatheter aortic valve replacement; TEER, transcatheter edge-to-edge repair.

Keywords: Heart Team; multidisciplinary; shared decision-making.

* Corresponding author: Michael.N.Young@Dartmouth.edu (M.N. Young).

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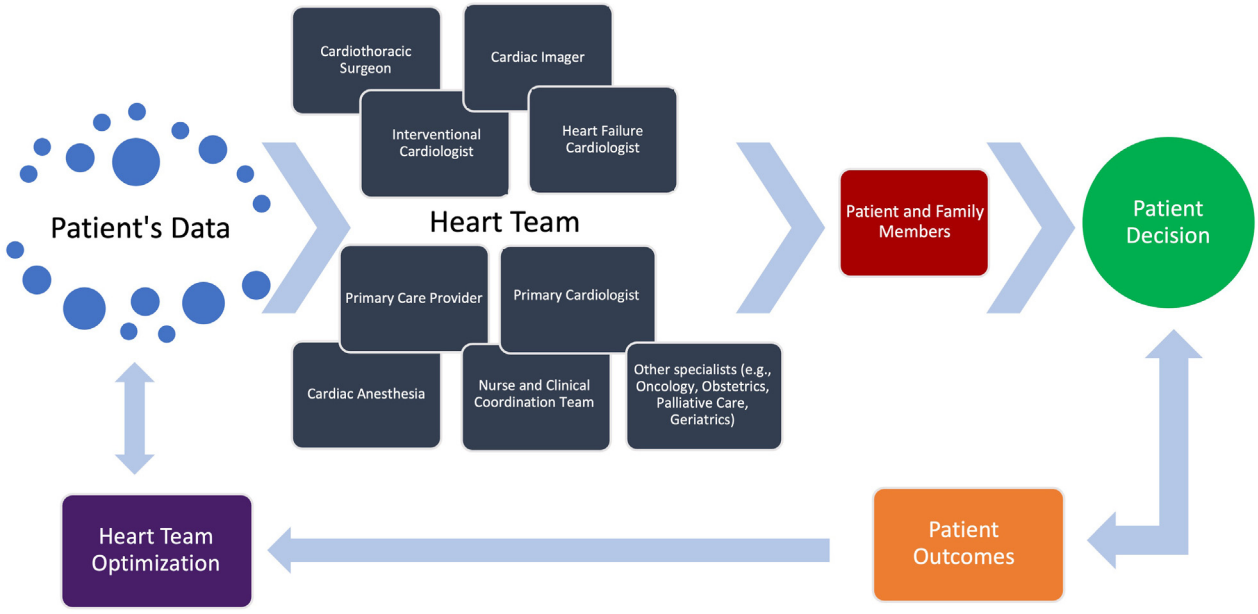

Figure 1.
Heart Team approach and patient-centered shared decision-making.

Embolism Response Team (PERT), Cardiogenic Shock Team, Cardio-Obstetrics Team, Adult Congenital Heart Disease Team, and Heart Failure/Transplant Team. Heart Team models, such as the Adult Congenital Heart Disease and Heart Transplant Teams, are well-established within cardiovascular care,[12,14] and other more nascent multidisciplinary teams, such as the Critical Limb Ischemia Team, have also shown promising results (Figure 2).[15,16] Central tenets of a successful Heart Team include the following: (1) disease-focused; (2) patient-centric; (3) interdisciplinary; and (4) evidence-based.

Complex CAD

The Heart Team's role in CAD was introduced in 2005 with the SYNTAX (Synergy Between PCI with Taxus and Cardiac Surgery) trial and demonstrated that a shared, multidisciplinary team-based approach to decision-making between interventional cardiology and cardiothoracic surgery led to improved patient-centric outcomes.[3] Guideline recommendations calling for widespread adoption of a Heart Team approach soon followed. In 2010, the European Society of Cardiology/European Association for Cardio-Thoracic Surgery guidelines recommended the utilization of a Heart Team approach in discussing revascularization strategies in patients with multivessel CAD as a Class I indication.[17] Numerous studies have examined and highlighted the intricacies in decision-making for complex and multivessel CAD.[18-28] The role and importance of the Heart Team in coronary artery revascularization are summarized in Table 1.[29-43]

Structural heart disease

Over the past 2 decades, Structural Heart Teams have become critical for assessing an increasingly complex, multifaceted population of patients who suffer from valvular heart disease.[44,45] This has been exemplified by the growth of transcatheter aortic valve replacement (TAVR) for the treatment of severe aortic stenosis. Since the Placement of Aortic Transcatheter Valves (PARTNER) A trial and Core Valve High Risk trial,[46,47] the Structural Heart Team has evolved in its central role to establish consensus for a patient's operative risk and to weigh surgical vs percutaneous options. The Centers for Medicare & Medicaid Services National Coverage Determination formalized reimbursement for the TAVR Heart Team in 2012.[48] With over a decade of rigorous randomized clinical trials, the indication for TAVR has been extended to patients of all levels of risk, making the Heart Team even more important as the lifetime management of patients, along with the possibility of a second valve, now must be discussed. Current US and European guidelines have established a Class I indication for TAVR or surgical aortic valve replacement for patients with severe aortic stenosis, relying on the Heart Team to guide the patient to the best therapy.[49,50] Decision-making has become more nuanced as technology has expanded further to multiple valve interventions,[51] leaflet remodeling,[52] and valve-in-valve techniques.[53] The role and importance of the Heart Team in structural heart disease, along with appropriate patient selection and associated clinical dilemmas, is summarized in Tables 2[54-116] and 3.

Pulmonary embolism

The PERT is made up of a multidisciplinary group of physicians from cardiology, vascular medicine, emergency medicine, cardiothoracic surgery, interventional radiology, hospital medicine, and pulmonary and critical care, with the end goal of improving and optimizing care for patients with submassive and massive pulmonary embolism.[117,118] Implementation of institutional PERT programs has demonstrated an impact on patient outcomes by decreasing time spent in the intensive care unit, decreasing total time of hospitalization, standardizing treatment of pulmonary embolism patients, improving time to treatment, and improving 30-day mortality.[119,120]

Cardiogenic shock

The Cardiogenic Shock Team is a multidisciplinary team composed of an advanced heart failure cardiologist, interventional cardiologist, cardiothoracic surgeon, and critical care specialist that fulfills the purpose of facilitating a team-based discussion regarding advanced therapies and allowing faster response times for the management of patients in cardiogenic shock. Single center studies following the implementation of a Cardiogenic Shock Team have demonstrated improved rates of 30-day survival.[121-123] A multicenter study of 24

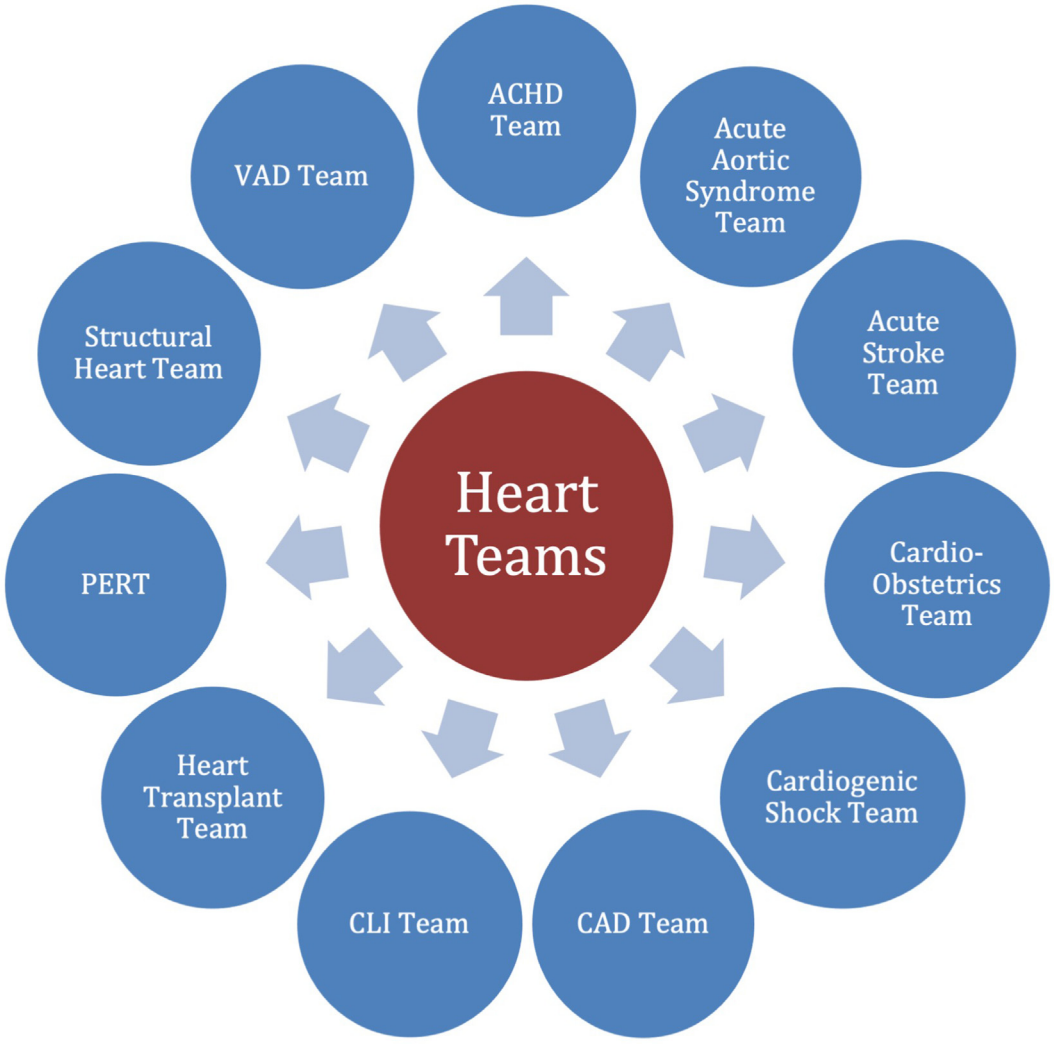

Figure 2.
Multidisciplinary Heart Teams. ACHD, adult congenital heart disease; CAD, coronary artery disease; CLI, critical limb ischemia; PERT, Pulmonary Embolism Response Team; VAD, ventricular assist device.

centers, 10 of which had shock teams, enrolled 1242 consecutive cardiogenic shock patients, finding that a shock team was associated with a statistically significant decreased mortality in the cardiac intensive care unit (28% decreased).[121-124] Recent data from the National Cardiogenic Shock Initiative also reported that utilizing a systematic shock protocol in patients with acute myocardial infarction and cardiogenic shock (Society for Cardiovascular Angiography & Interventions cardiogenic shock stage C/D/E) led to improved mortality as compared to historical averages, underscoring the importance of a multidisciplinary and standardized cardiogenic shock management protocol.[125,126]

Cardiovascular care in pregnancy

The Cardio-Obstetrics Team model, which is composed of a cardiologist, maternal-fetal medicine, anesthesiology, primary care physician, and labor and delivery nursing, has also shown positive outcomes. A single center study of 306 pregnant patients with underlying cardiovascular disease found low rates of maternal mortality and postpartum readmissions.[127] Comprehensive care with a multidisciplinary team approach in the "fourth trimester" postpartum period is also critical to optimize maternal cardiovascular health.[128]

Building and operationalizing the optimal Heart Team—the "Five Star" model

To build and optimize new or existing multidisciplinary team models, the Heart Team should abide by core guidelines and practice principles (ie, "Five Star" model). Though practices have been suggested both in the literature and in routine clinical practice, they have yet to be validated or measured as a bundled intervention. The applicability is intended to be broad for use across diverse clinical settings without losing the specificity required for an intervention within each specific Heart Team model (Central Illustration).

1. *Institutional protocol for accountability*

To successfully operationalize an institutional multidisciplinary Heart Team model, protocols that ensure organization and accountability are essential. For example, regularly scheduled meetings help streamline workflow: patients to be considered, meeting participants, scheduling, frequency, and format. The European guidelines recommend each institution create a written protocol regarding the level of cases and data to be considered (Level of Evidence C).[129] Revascularization guidelines recommend determining an appropriate threshold of complexity on an institutional basis in keeping with local expertise.[36]

Table 1. The role of the Heart Team in coronary artery revascularization.

Role of the Heart Team
- To take a balanced, objective approach to coronary artery revascularization

Evidence for the Heart Team
- Dichotomy in decision-making and operator-based preferences in patients with complex, multivessel CAD with improved agreement on the optimal modality of revascularization following open discussion[29]
- Only moderate agreement between Heart Team recommendations and the initial treatment decision of the interventional cardiologist[30]
- Large discrepancies between optimal guideline-recommended revascularization approaches and treatment received[31,32]
- Heart Team decisions are largely reproducible and concordant with AUC[33,34]

When to convene the Heart Team
- Complex, left main, or multivessel CAD
- Streamline meetings with Heart Team meeting template tools (ie, "CAD Heart Team Decision Aid"[35])

Other considerations and revascularization approaches
- Coronary anatomy
- Concurrent medical comorbidities (eg, diabetes mellitus, bleeding risk factors, renal disease, cerebrovascular accidents)
- Porcelain aorta and other aortic pathology
- Age
- Frailty and rehabilitation potential
- Chest deformities or prior chest radiation
- Patient preference[36,37]
- Technical approaches to revascularization, such as the feasibility of hybrid CABG-PCI options or the necessity of hemodynamic support (eg, intra-aortic balloon pump or percutaneous left ventricular assist devices) with revascularization
- Technical challenges of percutaneous intervention (ie, atherectomy, ventricular mechanical support, bifurcation stenting, stenting in diffuse CAD)

Long-term outcomes
- Limited data on long-term outcomes
- Decreased 3-y MACCE pre- and post-Heart Team implementation (28.1% vs 21.1%, log-rank $P = .001$)[38]
- An observational trial found that Heart Teams were generally convened for older patients with high SYNTAX score CAD. No significant difference in 3-y mortality between patients who underwent PCI or CABG[39]
- Similar 1-y MACE post-Heart Team implementation as compared to previously published national standards[40]

Challenges
- Widespread adoption in everyday practice remains underutilized[41-43]
- Heart Team underutilized (only 11% of stable CAD patients with complex anatomy) with guideline divergence in patients undergoing PCI[42]
- Treatment discordance from Heart Team guidelines in 17% of patients with intermediate/high SYNTAX score left main or multivessel CAD[43]

AUC, appropriate use criteria; CABG, coronary artery bypass grafting; CAD, coronary artery disease; MACCE, major adverse cardiovascular and cerebrovascular event; MACE, major adverse cardiac event; PCI, percutaneous coronary intervention; SYNTAX, Synergy Between PCI with Taxus and Cardiac Surgery.

Current reimbursement for TAVR requires all cases be discussed in a multidisciplinary fashion. Heart Teams can restrict review to only the highest yield data to answer the question at hand and focus on clinically and technically challenging cases, such as the low-risk patient or need for alternative access for TAVR. Several selection models have been proposed.[130,131] In addition, institutional protocols should specify a predictable, uniformly formatted basic dataset required for each case brought before the Heart Team (ie, brief history, echocardiograms, cardiac catheterizations, computed tomography), with more detailed review reserved for equivocal cases. Sample datasets have been proposed.[130]

Meeting participants and the structure of the Heart Team varies depending on the planned clinical focus, whether complex coronary, structural heart disease, pulmonary embolism, or other cardiac fields. Successful teams include key participating members from the patient's care, typically including general cardiology, interventional cardiology, advanced heart failure, cardiac imaging, cardiothoracic surgery, and cardiac anesthesiology. Integrated participation of advanced practice providers, program coordinators, and institutional research staff enriches the patient-centric clinical detail necessary for effective meetings and helps to ensure wider dissemination and adoption of the agreed-upon plan. For complex cases, the inclusion of specialties such as general internal medicine, geriatrics, palliative care, ethics, nephrology, neurology, and critical care helps craft a targeted plan complementing the cardiac focus of the meeting.[132] However diverse the makeup, participant stakeholders should be well-defined to induce buy-in and accountability for Heart Team performance from a core group of regular, predictable multidisciplinary collaborators, as codified in an institutional protocol. A table of practical tips is shown in Table 4.

Scheduling, frequency, and meeting format, noted to be the principal barrier to Heart Team function,[40] should all be specifically codified as well. Best practice guidelines from 2013 recommend a weekly to biweekly meeting to maintain a predictable stream of communication, diminish backlogs of cases, and limit each case discussion to 5 to 10 minutes.[133] During the coronavirus pandemic, many groups employed a variety of virtual and in-person approaches to secure regular attendance and diversity of expert clinical opinion.[134-136] Given their utility, hybridized and completely virtual meetings are likely to continue to be successful. Regarding urgent situations, Heart Teams can shape protocols to circumvent delaying important care decisions until the regularly scheduled meeting. In such situations, instituting an on-call, ad hoc "mini" Heart Team meeting restricted to a few core members may be crucial; virtual platforms will likely be central to this approach.[129,130]

2. *Templates and appropriate use criteria*

Second, the "Five Star" Heart Team appropriately utilizes templates and appropriate use criteria (AUC) tools. Risk-stratification tools such as SYNTAX, Society of Thoracic Surgeons Predicted Risk of Mortality, and EuroSCORE II are useful for officially documented Heart Team assessments.[71,137,138] They provide an objective, reproducible risk-stratification benchmarked to the wider population, and they can even be used as a standard metric to evaluate Heart Team performance. However, risk scores carry acknowledged limitations, performing optimally for designated populations, and do not always translate to others.[72,73,139,140] For this reason, AUC and risk tools should not outweigh patient-specific factors in the final Heart Team assessment and recommendation. Nevertheless, these tools and meeting organization templates[35] keep Heart Team discussions grounded, organized, and ultimately, more measurable.

3. *Fostering diverse opinions and consensus recommendations*

Third, the "Five Star" Heart Team fosters both diverse opinions and consensus recommendations. Diversity of opinion reflects not only differences in specialties but can also include differences in practice settings. British guidelines suggest Heart Team participation to be more inclusive of the wider referral base instead of only tertiary care personnel[131]; this could be one mechanism to reduce rural disparity. Ensuring that Heart Team participants reflect the sociocultural diversity of the patient population may also be considered. In addition, measures should be employed to prevent human bias, "groupthink," over-reliance on old data and assumptions, and geopolitical hierarchy. The Heart Team meeting proceedings should be structured in such a way that actively fosters a psychologically safe forum for debate.[141]

To craft patient-relevant official recommendations, Heart Teams should work toward achieving consensus. How consensus is achieved will depend on each institution's written protocol and ideally should be based in mutual professional respect.[13] British recommendations suggest a multidisciplinary meeting chair, often a senior clinician, who is responsible for facilitating equal dialog among all parties and ensuring accurate documentation of the final recommendations.[130] Another model is akin to the US Supreme Court, where coequal justices attempt to write a single opinion but retain the right to write additional assenting and dissenting opionions where needed. For instances in which a

Table 2. The role of the Heart Team in structural heart disease.

Role of the Heart Team

- Provide an objective, multidisciplinary approach to complex valvular heart disease, weighing anatomic suitability, surgical risk, surgical and percutaneous procedural feasibility, and downstream implications, especially in areas where the guidelines have not yet matured

Aortic valve disease

- Lifetime valve management in low-risk, young patients with AS. Discrepancy under what age a patient is considered young (65 or 75) and where SAVR is favored over TAVR[54,55]
- Intervention strategies: sequential ViV intervention (TAVR in SAVR, redo TAVR, valve explant)[56,57]
- For young patients, the small differences in TAVR vs SAVR outcomes carry larger consequences (paravalvular leak,[58] new conduction abnormalities, pacemaker implantation[59])
- Implantation techniques for redo TAVR involves potentially complex decison-making[60]
- Safe implantation plans: address potential coronary obstruction, whether through stenting or electrosurgical techniques, such as BASILICA,[61] implantation depth, TAVR valve commissural alignment
- Interventional techniques in bicuspid aortic valve disease are associated with specific technical difficulties: where an implanted valve will come to rest—annular or supra-annular—aiming for maximum expansion and minimal paravalvular leak
- Full valve expansion may be impeded by large eccentric calcifications or lead to catastrophic rupture[62]
- Aortopathy may necessitate surgical repair. CT-based risk-stratification has demonstrated good outcomes in bicuspid morphology[63]
- Intervention in groups of patients not included in the landmark trials, but still present for consideration of TAVR—asymptomatic severe AS, moderate AS, pure AR
- Asymptomatic severe AS: ~ 50% of patients with severe AS are asymptomatic.[64] Early intervention may be beneficial (risk of irreversible myocardial fibrosis and sudden death).[65]
  Current ongoing trial:
  - Evaluation of TAVR Compared to Surveillance for Patients With Asymptomatic Severe Aortic Stenosis (EARLY TAVR)[66]
- Moderate AS: patients may benefit from transcatheter therapy, especially with concomitant heart failure.[65]
  Current ongoing trials:
  - Management of Moderate Aortic Stenosis by Clinical Surveillance or TAVR (PROGRESS)[68]
  - Transcatheter Aortic Valve Replacement to Unload the Left Ventricle in Patients With Advanced Heart Failure (TAVR UNLOAD) (NCT02661451)[67]
  - Evolut EXPAND TAVR II Pivotal Trial[69]
- Pure AR: lacks the degree of calcification to anchor TAVR valves and may have larger annuli
- Heart Teams provide an additional assessment of procedural risk
  - Surgical risk scoring systems—Society of Thoracic Surgeons Predicted Risk of Mortality,[70] the EuroSCORE II[71]—provide an estimate of surgical risk
  - Efforts to construct TAVR-specific scoring systems since TAVR populations do not represent the same denominator as traditional surgical populations[72,73]
- Frailty assessments—Clinical Frailty Scale,[74,75] Essential Frailty Toolset—help stratify patient outcomes[76]

Mitral valve regurgitation

- Surgical options for MR: open repair or replacement with excellent surgical results for degenerative (primary) mitral regurgitation (DMR).[77] Limited outcomes data for operative intervention for functional (secondary) MR (FMR)
- Percutaneous transcatheter edge-to-edge repair (TEER) is a therapeutic option for the following groups:
  - DMR patients at elevated surgical risk and for FMR patients with appropriate anatomy[49,50]
  - FMR patients with a "COAPT-like" profile identifies patients who should do well with TEER.[78] However, up to half of all patients do not meet these criteria, but there is growing evidence that select patients beyond this cohort can also benefit[79-81]
- The Heart Team model helps to identify the optimal timing and approach to treatment in patients with severe MR. Ideally, this should involve heart failure cardiologists, in addition to general cardiologists, imaging cardiologists, interventional cardiologists, and cardiothoracic surgeons, to ensure appropriate patient candidacy for procedural intervention
- Earlier intervention in moderate or moderate-to-severe MR may prevent worsened and irreversible LV remodeling
- Percutaneous mitral annuloplasty devices, such as the Carillon Mitral Contour System (Cardiac Dimensions, Inc), significantly reduce both MR and LV volumes and may benefit patients with nonsevere FMR[82,83]
- Anatomic and clinical profiles must be closely considered. Some patient-specific considerations that may preclude TEER of the mitral valve:
  - Anatomic predispositions for postprocedural stenosis (eg, rheumatic valve, severe MAC, severely calcified leaflets, small mitral valve area <3.5 cm^2, previous surgical annuloplasty or ring)
  - Flail leaflet width >15 mm
  - Elevated tethering angle ($>45°$)
  - Leaflet perforation
  - Active endocarditis
  - Short posterior leaflet length (<5 mm)
- Poor candidates for open valve repair/replacement or TEER, may be better candidates for either transcatheter mitral valve replacement (TMVR) or medical therapy alone[84,85]
- TMVR is a potential option for patients at elevated surgical risk who are not candidates for TEER. Current trials utilizing different mitral valve replacement systems:
  - SAPIEN M3 System Transcatheter Mitral Valve Replacement Via Transseptal Access (ENCIRCLE) trial[86]
  - Transcatheter Mitral Valve Replacement With the Medtronic Intrepid TMVR System in Patients With Severe Symptomatic Mitral Regurgitation (APOLLO) trial[87]
  - Clinical Trial to Evaluate the Safety and Effectiveness of Using the Tendyne Transcatheter Mitral Valve System for the Treatment of Symptomatic Mitral Regurgitation (SUMMIT)[88]
- Severe MAC, failed surgical annuloplasty rings, and degenerated bioprosthetic mitral valve replacements require dedicated procedural consideration
- Severe MAC: degree of calcification presents both surgical[89] and procedural hurdles for transcatheter replacement
  - Retrospective registry data demonstrated that off-label TMVR in MAC (ViMAC) with the SAPIEN XT or SAPIEN 3 valves (Edwards Lifesciences) is associated with an elevated risk of left ventricular outflow tract (LVOT) obstruction and at least moderate MR[90,91]
  - MITRAL (Mitral Implantation of Transcatheter Valves) trial showed promising results with stable valve function and improved patient symptoms at 1- and 2-y follow up.[92,93] Careful preprocedural planning resulted in patients at high risk of LVOT obstruction undergoing pre-emptive alcohol septal ablation. However, mortality rates for ViMAC patients were elevated (~40%), emphasizing the importance of thoughtful and appropriate patient selection via a Heart Team approach to avoid ineffective and futile procedures
  - Further data are accruing in the Mitral Implantation of Transcatheter Valves (MITRAL II) pivotal trial[94]
- Failed mitral valve annuloplasty rings pose procedural hurdles
  - Anatomical differences in the shape of the annuloplasty ring pose a challenge for TMVR in mitral valve ring (MViR)—higher risk of paravalvular leak, residual MR, risk of migration, and valvular under expansion[91,92,95]
  - The off-label use of SAPIEN 3 and SAPIEN 3 Ultra valves has been approved since 2021 for MViR[96]
- Degenerated bioprosthetic mitral valve replacements undergoing valve-in-valve (MViV) procedures—more predictable procedural outcome given that surgical bioprosthetic valves are stented and circular
  - Data regarding procedural success, mortality, quality of life, and longitudinal valvular function have been impressive and recent 2-y data from the MITRAL trial have demonstrated mortality rates of ~7% with sustained improvement in symptoms, largely mirroring prior successful results[92,97,98]
  - Early off-label use of MViV procedures with the SAPIEN 3 and SAPIEN 3 Ultra valves has been approved since 2017[99]

Tricuspid valve regurgitation

- No definitive guideline recommendations on treatment. There is evidence to suggest a correlation between TR severity, heart failure readmissions, and overall mortality[100]
- Surgical options for TR usually involve open valve repair or less frequently, valve replacement, at the time of left-sided valve surgery

(*continued on next page*)

Table 2. (*continued*)

- Surgery for isolated tricuspid valve intervention is not commonly performed due to significant perioperative risk of mortality and has frequently been done much later in the disease process following RV remodeling and/or compromise
  - o One study found that surgical intervention was associated with a 10% mortality rate, increased procedural complications, and prolonged postprocedural hospital stays, though many of the patients were suffering from congestive heart failure and RV dysfunction at the time of operative management[101]
- Though the optimal timing for valvular intervention has not been defined, limited data has shown that severe TR is associated with high rates of morbidity and mortality, and earlier intervention may be associated with reduced mortality[102,103]
- Tricuspid TEER for severe TR in high-risk patients is an emerging therapeutic option
  - o TRILUMINATE (Transcatheter Edge-to-Edge Repair for Reduction of Tricuspid Regurgitation) study utilizing the TriClip edge-to-edge repair device (Abbott) in patients with symptomatic moderate or severe TR—demonstrated safety and efficacy of TR reduction at 1-y follow-up[104,105]
  - o Initial studies with the PASCAL transcatheter valve repair system (Edwards Lifesciences) have also demonstrated safety, efficacy, and symptom improvement at 30 d and 1-y follow-up[106-108]
- Patients enrolled in tricuspid TEER trials—required to be medically optimized prior to intervention with primarily diuretic agents
- Heart Team model helps to identify the optimal timing and approach to treatment in patients with severe TR and should ideally involve heart failure cardiologists to help guide appropriate therapy prior to intervention
- Transcatheter tricuspid valve replacement (TTVR) is relatively novel in development but is a potential option in patients predicted to have poor procedural outcomes with TEER
- Potential TTVR options:
  - o EVOQUE tricuspid valve replacement system (Edwards Lifesciences)
  - o Intrepid TTVR system (Medtronic)[109,110]
- Multiple complicating procedural and periprocedural factors for consideration by the Heart Team
  - o Poor device annular anchoring leading to paravalvular leak and valve embolism
  - o Higher risk of conduction abnormalities due to His bundle stretching
  - o Valve thrombosis
  - o Patients frequently require lifelong anticoagulation and/or antiplatelet therapy due to the risk of thrombosis due to the relatively lower flow state of the right heart
- Anatomic and clinical profiles must be closely considered
  - o Patients with leaflet perforations or severely calcified or restricted leaflets—less likely to derive significant benefit from TEER and may be better candidates for TTVR
  - o Larger leaflet coaptation gaps (>7.2 mm) and noncentral/nonanteroseptal regurgitant jets may be predictors of poor procedural success with TEER, and these patients may be better candidates for either TTVR or medical therapy alone[111]
- Patients with device-related TR due to ventricular device leads or from leadless pacemakers may either benefit from device or lead extraction, though extraction may also lead to worsened TR. In this setting, electrophysiologists also play an important role in the Heart Team[112-116]
- RV function must be thoroughly assessed prior to intervention. Patients with severe RV dysfunction may not be ideal candidates for TR intervention as this may lead to RV pressure overload and, in a severely dysfunctional RV, to acute RV failure

AR, aortic regurgitation; AS, aortic stenosis; BASILICA, bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction; CT, computed tomography, DMR, degenerative mitral regurgitation; FMR, functional mitral regurgitation; LV, left ventricle; LVOT, left ventricular outflow tract; MAC, mitral annular calcification; MR, mitral regurgitation; MViR, transcatheter mitral valve replacement in mitral valve ring; MViV, transcatheter mitral valve replacement in degenerated bioprosthetic mitral valve; RV, right ventricle; SAVR, surgical aortic valve replacement; TAVR, transcatheter aortic valve replacement; TEER, transcatheter edge-to-edge repair; TMVR, transcatheter mitral valve replacement; TTVR, transcatheter tricuspid valve replacement; TR, tricuspid regurgitation; ViMAC, transcatheter mitral valve replacement in mitral annular calcification; ViV, valve-in-valve.

Table 3. Patient selection criteria for Heart Team discussion and Heart Team valvular dilemmas and controversies.

Patient selection criteria for Heart Team discussion[38]

Aortic valve	Mitral valve	Tricuspid valve
Low-risk patients in whom surgical intervention is the best option but with concerns about technical feasibility (ie, multiple medical comorbidities, frailty, restricted mobility, porcelain aorta)	Low-risk patients with DMR in whom surgical intervention is the best option but with other concerns (ie, patient prefers to avoid sternotomy, multiple medical comorbidities, frailty, restricted mobility)	Low-risk patients with severe TR in whom a surgical intervention is the best option but with other concerns (ie, patient prefers to avoid sternotomy, multiple medical comorbidities, frailty, restricted mobility)
Higher-risk patients in whom TAVR is the best option but have other features requiring discussion (ie, unclear severity of valve disease, unable to perform via transfemoral access, multivalve disease, dilated aorta)	Higher-risk patients with DMR in whom transcatheter options are the best options and require discussion regarding optimal modality of intervention (ie, TEER, TMVR)	Higher-risk patients in whom transcatheter options are reasonable options and require discussion regarding the role of intervention (ie, TEER or TTVR) vs medical management alone
Patients who are candidates for both surgical and transcatheter intervention	Patients with symptomatic heart failure and FMR requiring multidisciplinary discussion regarding candidacy and role for transcatheter intervention	
Patients in whom the benefit of intervention is unclear		

Heart Team valvular dilemmas and controversies

Aortic valve	Mitral valve	Tricuspid valve
Sequential valve intervention strategies (ie, redo TAVR, ViV, valve explant)	Mitral TEER for severe FMR with a non- "COAPT-like" profile	Timing of intervention in severe TR (ie, asymptomatic, RV dysfunction)
Implantation techniques for redo TAVR	Earlier intervention in moderate or moderate-to-severe MR	Management strategy for severe TR due to ventricular device leads or leadless pacemakers
Interventional technique in bicuspid aortic valve disease	Management of severe MR (ie, surgical, TEER, TMVR) in high-risk patients with severe MAC, failed surgical annuloplasty ring, or degenerated bioprosthetic valve	Tricuspid TEER for severe TR in high-risk patients; Role of TTVR in patients predicted to have poor procedural outcomes with TEER
Early intervention in asymptomatic, severe AS		
Early intervention in moderate AS		
Interventional technique in high-risk patients with pure AR		

AR, aortic regurgitation; AS, aortic stenosis; DMR, degenerative mitral regurgitation; FMR, functional mitral regurgitation; MAC, mitral annular calcification; MR, mitral regurgitation; RV, right ventricle; TAVR, transcatheter aortic valve replacement; TEER, transcatheter edge-to-edge repair; TMVR, transcatheter mitral valve replacement; TTVR, transcatheter tricuspid valve replacement; TR, tricuspid regurgitation; ViV, valve-in-valve.

Central Illustration.
The optimized "Five Star" Heart Team. AUC, appropriate use criteria; SDM, shared decision-making.

consensus decision cannot be reached, the dispute may be adjudicated by seniority, majority, referral basis, or summarized as unresolved options for patient review.

To foster both diversity of opinion and consensus of recommendation, it may be useful to protocolize a level of team science. Communication science and team-building in health care is drawing increasing attention.[142] Local appetite and implementation of this strategy will vary; however, an intervention as simple as a semiannual survey of Heart Team participants regarding their perceptions of the quality of their debate may provide a useful barometer for recalibrating the program's internal balance of both diversity and consensus.

4. *Creation of an official recommendation*

Fourth, the "Five Star" Heart Team creates an official recommendation to present to the patient for SDM. The official recommendation does not need to be rigidly prescriptive; instead, it ought to contain options for the SDM that follows. Additionally, if after SDM, the patient and/or family wish to have the case reconsidered, it can be done in accordance with institutional protocol. Per best practice, the recommendation should be documented as official and reviewable, resulting from the Heart Team discussion. Documentation of Heart Team official recommendations is of medico-legal importance and must clearly convey Heart Team recommendations to the referring clinician. Documentation must, at a minimum, include treatment recommendations, including clinical reasoning and timing of treatment, requirements for a transfer or higher level of care, and any additional necessary work up or investigations.[130] A standardized Heart Team output document should be considered to ensure that all recommended components of the Heart Team decision are included. Heart Team meeting templates and tools, such as the "CAD Heart Team Decision Aid" form detailed by Young et al,[35] can function as a standardized Heart Team output document. In North America, medico-legal responsibility is determined by the formality of a referral. Courts consider referrals to be formal if any of the following are present: written documentation of a referral, significant amount of information conveyed to the specialist, patient awareness of a referral, documentation of a specialist referral and advice, payment for consultation, or reliance of a consultant on a specialist's advice.[143] For formal referrals, documentation comprises a physician's legal responsibility toward patient care, and this responsibility translates also to the Heart Team attempting to do the same.

Although the Heart Team is structured to be patient-centered—especially with frontline team members as core participants—it is rarely practical for the patient or family to be in attendance. Therefore, an official Heart Team recommendation does not alone constitute SDM. SDM is best accomplished by a skilled clinical communicator on the Heart Team already known to the patient. The official recommendation should be reviewed and explained to the patient and family, stipulating how it fits into the context of their care. Optimal methods for SDM are still early in investigation, such as the use of patient decision aids.[44,144] Overall, such aids generate a variable patient response and merit more study, but if successful, could powerfully dovetail with an effort to generate effective Heart Team official recommendations for patient review.[145]

5. *Quality and feedback mechanisms*

Lastly, the "Five Star" Heart Team employs feedback mechanisms. These feedback mechanisms should function such that the treatment path selected by the patients after SDM and the resulting outcomes are summarized and reported back to the Heart Team. These outcomes should be readily compared to local, national, and international outcomes. Feedback mechanisms are not restricted only to individual patient outcomes; they may fall into 4 domains: guideline adherence and AUC, interprofessional communication, SDM, and programmatic and health system outcomes.[145] Some centers have opted to devote specific meetings to review these outcomes in the context of quality

Table 4. Practical tips for the Heart Team.

Member selection[38]
- Core attendees: Will vary based on the type of Heart Team. For a structural Heart Team, core attendees should include a multidisciplinary meeting coordinator, structural interventional cardiologist, cardiac critical care specialist, general cardiologist/cardiothoracic surgeon/imaging cardiologist specializing in valvular heart disease
- Other participating members of patient's care and inclusion of other specialties for complex cases: Will vary based on the type of Heart Team. Can include advanced practice providers, general internal medicine, geriatrics, palliative care, ethics, nephrology, neurology, critical care

Schedule and frequency
- Scheduling and frequency: Weekly to biweekly meetings, specifically codified by institutional protocol, to occur predictably on the same day(s) every week.
- Format: In-person with a virtual option

Mobilizing the Heart Team
- In the case that additional urgent meetings are required to discuss high-risk cases that require immediate attention (ie, cardiogenic shock, PERT, complex coronary artery disease), an on-call "ad hoc" meeting should be held with the core Heart Team attendees.
- The system for calling an ad hoc meeting should be codified by institutional protocol and will vary per team and institution. For instance, for the complex coronary artery Heart Team, the ability to call an "ad hoc" meeting may be limited to the general cardiologist, interventional cardiologist, or cardiothoracic surgeon, whereas for the PERT team, only the emergency room physician, general or interventional cardiologist, or vascular medicine specialist may be able to initiate an ad hoc meeting.
- On-call "ad hoc" meeting: In-person, hybrid, or virtual meeting. Notified by a team page or text message (ie, Cardiogenic Shock Team page can be equivalent to a STEMI page).

Case review and feedback
- Dedicated Heart Team meetings for follow up and morbidity and mortality should exist to review patient outcomes. This should include patient outcomes and feedback regarding specific cases.
- Frequency: Once or twice monthly.

Encouraging member participation
- To encourage robust Heart Team participation, institutions and department chiefs/chairs should adequately recognize membership; can be either clinically (ie, sans wRVU credit) or academically (ie, registry participation, quality improvement/quality assurance review).

PERT, Pulmonary Embolism Response Team; STEMI, ST-elevation myocardial infarction; wRVU, work relative value unit.

reviews or morbidity and mortality conferences. These meetings examine time frame to intervention, Heart Team referrals in relation to overall system volume, and original Heart Team recommendations that were or were not followed, along with the rationale.[130]

Accumulating evidence for the Heart Team approach

Obtaining traditional high-quality evidence for the Heart Team approach through randomized controlled trials is challenging but feasible. Quantitating clinical outcome benefit has been difficult to demonstrate, with a few studies providing notable exceptions. A 2012 study of cardiac resynchronization therapy compared a prospective cohort of 254 patients receiving multidisciplinary review with 173 patients receiving contemporary conventional care, and at 2 years, the multidisciplinary group enjoyed a significant event-free survival advantage (61% vs 46%, $P = .001$).[146] Meanwhile, a 2017 single center study in heart failure compared 1-year mortality between 196 patients seen in the 6 months prior to the establishment of a Heart Team with the 211 patients hospitalized the year afterwards, with the Heart Team group enjoying significantly lower rates of mortality (27% vs 43%, $P = .001$).[147] Baseline characteristics were not significantly different, but the medical regimen in the Heart Team group was more aggressive. Additionally, from a systems level perspective, recent data from the Vancouver 3M TAVR Study demonstrated that the use of a more protocolized, multidisciplinary team approach to TAVR was associated with overall decreased in-hospital costs without differences in clinical outcomes.[148,149] Considering that the Heart Team approach may be used as a tool to solve problems with patient outcome guideline adherence, interprofessional communication, and SDM, success with these 3 end points may be used as proxy measures for the success or failure of a Heart Team approach.[129,150] Multiple study designs have been proposed.[133]

With an end point of guideline adherence, Heart Team recommendations have been shown across multiple studies to be appropriate and reproducible. A single center prospective trial of 301 consecutive patients with complex CAD found 99.3% concordance between Heart Team recommendations and AUC.[33] The same center noted 30-day periprocedural mortality was low—1% for coronary artery bypass grafting, 8% for percutaneous coronary intervention—and major adverse cardiovascular events over a median of 12.1 months was 14% for coronary artery bypass grafting and 23% for percutaneous coronary intervention, within contemporary national standards.[40] Additionally, multiple single center studies demonstrated reproducibility of previous Heart Team decisions upon revisitation of previous cases.[151,152] With the goal of optimizing care for the individual patient, any given patient's situation may diverge from the guidelines. The Heart Team approach should not suppress all deviation, as room for innovation is needed at times for improved patient outcomes, the growth of the field, and ultimately, the refinement and renewal of the guidelines themselves.[152]

Improved interprofessional communication has been touted as a feature of the Heart Team approach and was qualitatively highlighted in initial trials.[40,133] Improved communication in surveys of cancer tumor boards has been linked to increased provider wellbeing and job satisfaction.[153] However, the quality of the communication itself and using it as an end point for measuring Heart Team success has not been investigated. Interprofessional communication is widely studied in other areas of health care, such as nursing, and analysis largely depends on surveys and focused interview sessions, which could readily be applied to Heart Teams.[154,155]

SDM is a third potential measurable end point of successful Heart Team output. SDM has been associated with improved patient-reported health outcomes, whereas poor SDM has been associated with worse established quality-of-care indicators. However, heterogeneous patient populations have mixed preferences, and SDM outcome measures can vary greatly depending on how questions are formulated.[156,157] There are multiple models of implementing SDM as well as multiple tools for measuring SDM, which may be broadly summarized as ensuring and verifying a patient's decision is both adequately informed by data-driven guidelines and in harmony with the patient's own values.[158,159] Whichever model and measurement of SDM is chosen, US and European guidelines now recommend this approach,[17,160] and payors require it for reimbursement.[161] Effective Heart Teams should take note and incorporate SDM results as a measure of their efficacy. Additionally, given that minorities report worse rates of SDM, a diverse and conscientious Heart Team may serve as a mechanism for reducing health care disparity in the future.[157]

Conclusion

The multidisciplinary Heart Team model has become a central tenet of clinical care across several cardiovascular disease spectrums. As novel surgical and transcatheter treatment options for cardiovascular

care continue to expand, the role of a multidisciplinary approach cannot be understated. A Heart Team approach to complex patient cases establishes an environment in which physicians, patients, and families are fully informed and engaged in SDM. There is accumulating evidence that institutional Heart Teams may be associated with improvement in clinical outcomes, augmented practice guideline adherence, and enhanced patient-provider SDM. The appropriate development, operationalization, and seamless integration of a Heart Team into institutional practice requires a concerted effort to abide by core guidelines and principles that make up the optimal "Five Star" model.

Declaration of competing interest

Michael Young has received consulting fees from Edwards Lifesciences and has served on the advisory board for Medtronic. Sammy Elmariah has received consulting fees and research grants from Edwards Lifesciences and Medtronic. Kendra Grubb serves on the advisory board for Medtronic, Boston Scientific, Abbott, 4C Medical, Gore, HLT, Ancora, and Bioventrix; is a proctor for Medtronic, Boston Scientific, and Edwards Lifesciences; and has received an honorarium from OpSens. Christopher Lee, Andrew Tully, James Fang, and Lissa Sugeng reported no financial interests.

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