Implementation of a Multidisciplinary Team–Based Clinical Care Pathway Is Associated With Increased Surgery Rates for Infective Endocarditis

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ABSTRACT

Objective: Multidisciplinary teams (MDTs) improve outcomes for patients with infective endocarditis (IE), but methods of implementation vary. In our academic medical center, we developed an MDT approach guided by a clinical care pathway and assessed outcomes of patients with IE.

Methods: We compared outcomes of patients with IE and indications for surgery between December 2018 and June 2020 with our prior published data for the period January to December 2016. MDT interventions involved recurring conferences with infectious diseases physicians in team meetings and promoting a clinical care pathway to guide providers on steps in management. Primary outcomes were surgery and in-hospital death.

Results: Prior to the intervention, 6 of 21 (28.6%) patients with indications for surgery underwent surgery or were transferred to higher centers for surgery, and 6 (28.6%) patients died. Post intervention, 17 of 31 (54.8%) patients underwent or were transferred for surgery, and 5 (16.1%) died. After adjusting for age and gender, the odds of surgery or transfer for surgery for patients in the postintervention period were 4.88 (95% CI, 1.20-19.79; $P = .027$) compared with the pre-intervention period. The odds ratio for death among patients in the postintervention period was 0.40 (95% CI, 0.09-1.69; $P = .21$).

Conclusion: An MDT team approach using a clinical pathway was associated with an increased number of surgeries performed for IE and may lower rates of in-hospital mortality.

Keywords: infective endocarditis, clinical pathway, quality improvement, multidisciplinary team, valve surgery.

Infective endocarditis (IE) is associated with significant morbidity and mortality.[1] Rates of IE due to *Staphylococcus aureus* are increasing in the United States.[2] Reported in-hospital mortality from IE ranges from 15% to 20%.[3] Optimal management of IE requires input from a number of specialties, including infectious diseases (ID), cardiology, cardiothoracic surgery (CTS), oromaxillofacial surgery, radiology (eg, nuclear medicine), and neurology, among others, depending on the site of complications. Guidelines from the United States and Europe recommend incorporating multidisciplinary teams (MDTs) in the management of IE.[1,3-5] These recommendations are based on quasi-experimental before-and-after studies that have consistently demonstrated that MDTs reduce in-hospital and 1-year mortality.[6-11] However, implementation of MDTs can be challenging. Successful MDTs require good team dynamics, unified participation, and seamless communication among team members.

Clinical pathways are defined as "structured, multidisciplinary plans of care used by health services to detail essential steps in the care of patients with a specific clinical problem."[12] In the modern era, these pathways are often developed and implemented via the electronic health record (EHR) system. Studies of clinical pathways generally demonstrate improvements in patient outcomes, quality of care, or resource utilization.[13,14] Clinical

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pathways represent 1 possible approach to the implementation of a MDT in the care of patients with IE.[15]

In our earlier work, we used quality improvement principles in the design of an MDT approach to IE care at our institution.[16] Despite having indications for surgery, 12 of 21 (57.1%) patients with IE did not undergo surgery, and we identified these missed opportunities for surgery as a leverage point for improvement of outcomes. With input from the various specialties and stakeholders, we developed a clinical pathway (algorithm) for the institutional management of IE that guides next steps in clinical care and their timelines, aiming to reduce by 50% (from 57.1% to 28.6%) the number of patients with IE who do not undergo surgery despite guideline indications for early surgical intervention. In this report, we describe the implementation of this clinical pathway as our MDT approach to the care of patients with IE at our institution.

Methods

The University of Missouri, Columbia, is a tertiary care academic health system with 5 hospitals and more than 60 clinic locations across central Missouri. In the spring of 2018, an MDT was developed, with support from administrative leaders, to improve the care of patients with IE at our institution. The work group prioritized one leverage point to improve IE outcomes, which was improving the number of surgeries performed on those IE patients who had guideline indications for surgery. A clinical pathway was developed around this leverage point (**Figure 1**). The pathway leveraged the *6 T's* (**Table 1**) to guide providers through the evaluation and management of IE.[17] The pathway focused on improving adherence to standards of care and reduction in practice variation by defining indications for referrals and diagnostic interventions, helping to reduce delays in consultation and diagnosis. The pathway also clearly outlined the surgical indications and timing for patients with IE and provided the basis for decisions to proceed with surgery.

Starting in late 2018, in collaboration with cardiology and CTS teams, ID specialists socialized the clinical pathway to inpatient services that cared for patients with IE. Infectious diseases physicians also provided recurring conferences on the effectiveness of MDTs in IE management and participated in heart-valve team case discussions. Finally, in May 2019, an electronic version of the pathway was embedded in the EHR system using a Cerner PowerChart feature known as Care Pathways. The feature presents the user with algorithm questions in the EHR and provides recommendations, relevant orders, timelines, and other decision support in the clinical pathway. The feature is available to all providers in the health system.

To evaluate the effectiveness of our intervention, we recorded outcomes for patients with IE with surgical indications between December 2018 and June 2020 and compared them with our prior published data from January to December 2016. Cases of IE for the current study period were identified via retrospective chart review. Records from December 2018 to June 2020 were searched using *International Statistical Classification of Diseases, Tenth Revision* (ICD-10) discharge codes for IE (I33, I33.0, I33.9, I38, I39, M32.11). To select those patients with definitive IE and indications for surgery, the following criteria were applied: age ≥18 years; fulfilled modified Duke criteria for definite IE[18]; and met ≥1 American Heart Association (AHA)/Infection Diseases Society of America criteria for recommendation for surgery. Indications for surgery were ≥1 of the following: left-sided endocarditis caused by *S aureus*, fungal, or highly resistant organism; new heart block; annular or aortic abscess; persistent bacteremia or fever despite 5 days of appropriate antimicrobials; vegetation size ≥10 mm and evidence of embolic phenomena; recurrence of prosthetic valve infection; recurrent emboli and persistent vegetation despite antimicrobials; and increase in vegetation size despite antimicrobials.[16]

Age was treated as a categorical variable, using the age groups 18 to 44 years, 45 to 64 years, and 65 years and older. Gender was self-reported. Primary outcomes were surgery or transfer to a higher center for surgery and in-hospital death. Secondary outcomes included consults to teams involved in multidisciplinary care of patients with IE, including ID, cardiology, and CTS. Bivariate analyses were performed using Pearson χ^2 tests. Odds ratios for surgery and death were calculated using a multivariate logistic regression model including age and gender covariates. Statistical significance was defined at $\alpha = 0.05$, and statistical analysis was performed using Stata/IC v16.1 (StataCorp LLC). Our university institutional review board

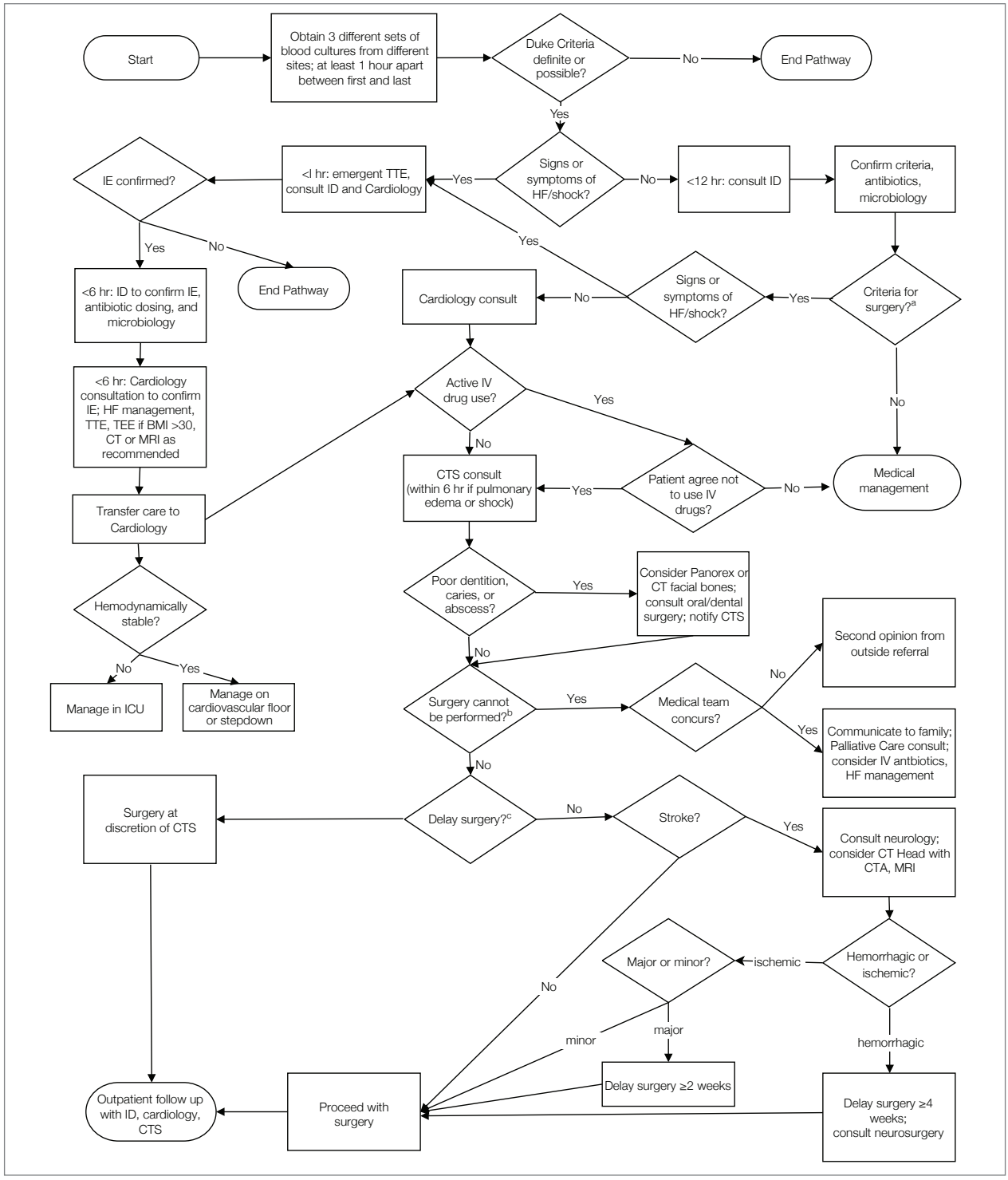

Figure 1. Clinical care pathway for the care of patients with infective endocarditis (IE). BMI, body mass index; CT, computed tomography scan; CTA, computed tomography angiography; CTS, cardiothoracic surgery; HF, heart failure; ICU, intensive care unit; ID, infectious diseases; IV, intravenous; MRI, magnetic resonance imaging; TEE, transesophageal echocardiogram; TTE, transthoracic echocardiogram.
[a]Criteria for surgery: vegetation >10 mm, severe regurgitation, uncontrolled infection with >5 days of positive blood cultures, embolic manifestations.
[b]Surgery cannot be performed due to: poor compliance, high operative risk, surgical contraindications, surgeon not available.
[c]Potential reasons to delay surgery: coma, multiple organ dysfunction syndrome, ongoing sepsis.

Table 1. **Stepwise Sequential Summary of Infectious Endocarditis Care Pathway: The 6 T's**

The 6 T's Stepwise Sequential Summary of Clinical Pathway
1. Trigger: Clinical suspicion for IE includes the following high-risk markers
Unexplained fever, known structural/valvular/congenital heart disease with shunt lesions, end-stage renal disease on hemodialysis, history of substance or intravenous drug use, *S aureus* bacteremia, recent invasive dental/endoscopic procedures
2. Task: Apply modified Duke criteria to classify as definite or possible endocarditis
Pathological criteria: Microorganisms demonstrated by culture or histological exam of vegetation/abscess/lesion showing active endocarditis
Clinical criteria: two major criteria, one major criterion and three minor criterion, five minor criteria[18]
3. Triage: Evaluate for presence of, risk for life-threatening conditions or complications
Cardiac: Acute heart failure, acute pulmonary edema, perforation, destruction
Systemic: Sever sepsis or septic shock
4. Track: Determine timeline for interventions
Fast-track: If at risk for or have the above critical conditions, urgent consultations (preferably within 6 h) were placed to infectious diseases and cardiology followed by transfer of care to the cardiac intensive care unit, where cardiothoracic teams are readily available
Nonurgent track: If minimal or no risk, then routine consultations (within 24 h) were requested to infectious diseases and cardiology, followed by cardiac surgery consultations per guideline recommendations
5. Testing
Transesophageal echocardiogram, brain imaging studies, repeat blood cultures until negative, dental/other imaging studies, etc
6. Transition: Execute care plan and transition to post-care plan
If surgical risk acceptable between cardiac surgeon and medical teams (using scoring tool or subjective), proceed with surgery and transition to postoperative care as appropriate for the surgical operation performed
If surgical risk is considered high or conflicting opinions between medical and surgical teams, primary team to decide on further options (eg, informed decision-making with patient/family, transfer to another center or palliative care consultation)

IE, infective endocarditis.

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(IRB) reviewed the project (#2010858-QI) and determined that the project was quality-improvement activity, not human subject research, and therefore did not require additional IRB review.

Results

We identified 21 patients in the pre-intervention period and 31 patients in the postintervention period with definitive IE who had guideline indications for surgery. The postintervention cohort was older and had more male patients; this difference was not statistically significant. No differences were noted between the groups for race, gender, or intravenous (IV) drug use (**Table 2**). Chi-square tests of independence were performed to assess the relationship between age and our primary outcomes. There was a significant relationship between age and the likelihood of receiving or being transferred for surgery (59.3% vs 50% vs 7.7% for 18-44 y, 45-64 y, and ≥65 y, respectively; χ^2 [2, N=52] = 9.67; P=.008), but not between age and mortality (14.8% vs 25.0% vs 30.8% for 18-44 y, 45-64 y, and ≥ 65 y, respectively; χ^2 =1.48 [2, N=52; P=.478]. The electronic version of the clinical pathway was activated and used in only 3 of the 31 patients in the postintervention period. Consultations to ID, cardiology, and CTS teams were compared between the study periods (Table 2). Although more consultations were seen in the postintervention period, differences were not statistically significant.

The unadjusted primary outcomes are shown in Table 2. More surgeries were performed per guideline indications, and fewer deaths were noted in the postintervention period than in the pre-intervention

Table 2. **Demographics, Consults, and Primary Outcomes of Patients With Infective Endocarditis Before and After Implementation of MDT Clinical Care Plan**

Demographics	Before intervention, No. (%) N = 21	After intervention, No. (%) N = 31	χ^2	*P* value
Male	10 (47.6)	16 (51.6)	0.080	.777
Age, y			0.453	.797
18-44	12 (57.1)	15 (48.4)		
45-64	4 (19.0)	8 (25.8)		
>64	5 (23.8)	8 (25.8)		
Race/ethnicity[a]			0.841	.657
White, non-Hispanic	18 (85.7)	28 (90.3)		
Black	2 (9.5)	2 (6.5)		
East Asian	0	1 (3.2)		
IV drug use	11 (52.4)	17 (54.8)	0.030	.862
Consults				
ID	18 (85.7)	30 (96.8)	2.157	.142
Cardiology	13 (61.9)	22 (71.0)	0.467	.494
CTS	18 (85.7)	28 (90.3)	0.261	.610
All	12 (57.1)	19 (61.3)	0.089	.765
Primary outcomes				
Surgery/transfer	6 (28.6)	17 (54.8)	3.502	.061
Death	6 (28.6)	5 (16.1)	1.162	.281

CTS, cardiothoracic surgery; ID, infectious disease; IV, intravenous; MDT, multidisciplinary team.
[a]One pre-intervention patient with no race reported.

period, but the differences were not statistically significant (Table 2).

Because the postintervention period had more male patients and older patients, we evaluated the outcomes using a logistic regression model controlling for both age and gender. The odds of surgery or transfer for surgery for patients in the postintervention period were 4.88 (95% CI, 1.20-19.79; *P* = .027) as compared with the pre-intervention period, and the odds ratio for death among patients in the postintervention period compared with the pre-intervention period was 0.40 (95% CI, 0.09-1.69; *P* = .21) (**Figure 2**).

Discussion

In our study, patients with IE with guideline indications for surgery had significantly higher rates of surgery in the postintervention period than in the pre-intervention period. The implementation of an MDT, recurring educational sessions, and efforts to implement and familiarize team members with the clinical pathway approach are the most likely reasons for this change. The increased rates of surgery in the postintervention period were the likely proximate cause of the 60% reduction in in-hospital mortality. This improvement in mortality, while not statistically significant, is very likely to be clinically significant and helps reinforce the value of the MDT intervention used.

Our findings are consistent with existing and mounting literature on the use of MDTs to improve outcomes for patients with IE, including 2 studies that noted an increased rate of surgery for patients with indications.[8,19] Several other studies in both Europe and North America have found significant decreases in mortality,[6-11,20,21] rates of complications,[9] time to diagnosis and treatment,[11] and length of stay[9,20] for patients with IE managed with an MDT strategy. Although current AHA guidelines for care of patients with IE do suggest an MDT approach, the strategy for this approach is not well

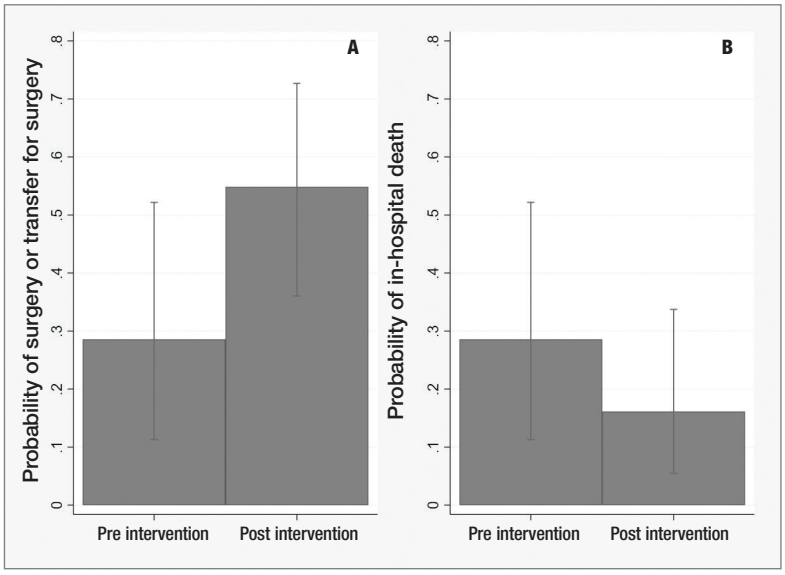

Figure 2. Multivariate logistic regression models showing (**A**) probability of surgery or transfer for surgery and (**B**) probability of in-hospital death.

established.[22] Only 1 study that has implemented a new MDT protocol for care of IE has been conducted in the United States.[8]

While effective MDTs certainly improve outcomes in patients with IE, there are reported differences in implementation of such an approach. With the MDT model as the core, various implementations included regular case conferences,[10,11,19,21,23] formation of a consulting team,[6,8] or establishment of a new protocol or algorithm for care.[8,9,20] Our approach used a clinical pathway as a basis for improved communication among consulting services, education of learning providers via regular case conferences, and implementation of an electronic clinical care pathway to guide them step by step. Our pathway followed the institutionally standardized algorithm (Figure 1), using what we called the *6 T's* approach (Table 1), that guides providers to evaluate critical cases in a fast track.[17]

To the best of our knowledge, ours is the first report of an MDT that used an electronic clinical care pathway embedded within the EHR. The electronic version of our clinical pathway went live for only the second half of the postintervention study period, which is the most likely reason for its limited utilization. It is also possible that educational efforts in the first half of the intervention period were sufficient to familiarize providers with the care pathway such that the electronic version was seldom needed. We are exploring other possible ways of improving electronic pathway utilization, such as improving the feature usability and further systemwide educational efforts.

Our study has other limitations. Quasi-experimental before-and-after comparisons are subject to confounding from concurrent interventions. We had a substantial change in cardiothoracic faculty soon after the commencement of our efforts to form the MDT, and thus cannot rule out differences related to their comfort level in considering or offering surgery. We also cannot rule out a Hawthorne effect, where knowledge of the ongoing quality-improvement project changed provider behavior, making surgery more likely. We did not evaluate rates of right- versus left-sided endocarditis, which have been linked to mortality.[24] Our study also was performed across a single academic institution, which may limit its generalizability. Finally, our study may not have been adequately powered to detect differences in mortality due to implementation of the MDT approach.

Conclusion

Our work suggests that an MDT for IE can be successfully designed and implemented with a clinical pathway using quality-improvement tools in centers where subspecialty services are available. Our approach was associated with a higher rate of surgery among patients with guideline indications for surgery and may reduce in-hospital mortality. An electronic clinical care pathway embedded in the EHR is feasible and may have a role in MDT implementation.

These data were also accepted as a poster at IDWeek 2022, Washington, DC. The poster abstract is published in an online supplement of Open Forum Infectious Diseases as an abstract publication.

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References

1. Baddour LM, Wilson WR, Bayer AS, et al. Infective endocarditis in adults: diagnosis, antimicrobial therapy, and management of complications: a scientific statement for healthcare professionals from the American Heart Association. *Circulation.* 2015;132(15):1435-1486. doi:10.1161/cir.0000000000000296
2. Federspiel JJ, Stearns SC, Peppercorn AF, et al. Increasing US rates of endocarditis with *Staphylococcus aureus*: 1999-2008. *Arch Intern Med.* 2012;172(4):363-365. doi:10.1001/archinternmed.2011.1027
3. Nishimura RA, Otto CM, Bonow RO, et al. 2014 AHA/ACC Guideline for the Management of Patients With Valvular Heart Disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation.* 2014;129(23):e521-e643. doi:10.1161/cir.0000000000000031
4. Chambers J, Sandoe J, Ray S, et al. The infective endocarditis team: recommendations from an international working group. *Heart.* 2014;100(7):524-527. doi:10.1136/heartjnl-2013-304354
5. Habib G, Lancellotti P, Antunes MJ, et al. 2015 ESC Guidelines for the management of infective endocarditis: The Task Force for the Management of Infective Endocarditis of the European Society of Cardiology (ESC). Endorsed by: European Association for Cardio-Thoracic Surgery (EACTS), the European Association of Nuclear Medicine (EANM). *Eur Heart J.* 2015;36(44):3075-3128. doi:10.1093/eurheartj/ehv319
6. Chirillo F, Scotton P, Rocco F, et al. Impact of a multidisciplinary management strategy on the outcome of patients with native valve infective endocarditis. *Am J Cardiol.* 2013;112(8):1171-1176. doi:10.1016/j.amjcard.2013.05.060
7. Botelho-Nevers E, Thuny F, Casalta JP, et al. Dramatic reduction in infective endocarditis-related mortality with a management-based approach. *Arch Intern Med.* 2009;169(14):1290-1298. doi:10.1001/archinternmed.2009.192
8. El-Dalati S, Cronin D, Riddell IV J, et al. The clinical impact of implementation of a multidisciplinary endocarditis team. *Ann Thorac Surg.* 2022;113(1):118-124.
9. Carrasco-Chinchilla F, Sánchez-Espín G, Ruiz-Morales J, et al. Influence of a multidisciplinary alert strategy on mortality due to left-sided infective endocarditis. *Rev Esp Cardiol (Engl Ed).* 2014;67(5):380-386. doi:10.1016/j.rec.2013.09.010
10. Issa N, Dijos M, Greib C, et al. Impact of an endocarditis team in the management of 357 infective endocarditis [abstract]. *Open Forum Infect Dis.* 2016;3(suppl 1):S201. doi:10.1093/ofid/ofw172.825
11. Kaura A, Byrne J, Fife A, et al. Inception of the 'endocarditis team' is associated with improved survival in patients with infective endocarditis who are managed medically: findings from a before-and-after study. *Open Heart.* 2017;4(2):e000699. doi:10.1136/openhrt-2017-000699
12. Rotter T, Kinsman L, James E, et al. Clinical pathways: effects on professional practice, patient outcomes, length of stay and hospital costs. *Cochrane Database Syst* Rev. 2010;(3):Cd006632. doi:10.1002/14651858.CD006632.pub2
13. Neame MT, Chacko J, Surace AE, et al. A systematic review of the effects of implementing clinical pathways supported by health information technologies. J Am Med *Inform Assoc.* 2019;26(4):356-363. doi:10.1093/jamia/ocy176
14. Trimarchi L, Caruso R, Magon G, et al. Clinical pathways and patient-related outcomes in hospital-based settings: a systematic review and meta-analysis of randomized controlled trials. *Acta Biomed.* 2021;92(1):e2021093. doi:10.23750/abm.v92i1.10639
15. Gibbons EF, Huang G, Aldea G, et al. A multidisciplinary pathway for the diagnosis and treatment of infectious endocarditis. *Crit Pathw Cardiol.* 2020;19(4):187-194. doi:10.1097/hpc.0000000000000224
16. Regunath H, Vasudevan A, Vyas K, et al. A quality improvement initiative: developing a multi-disciplinary team for infective endocarditis. *Mo Med.* 2019;116(4):291-296.
17. Regunath H, Whitt SP. Multidisciplinary service delivery for the endocarditis patient. In: *Infective Endocarditis: A Multidisciplinary Approach*. 1st ed. Kilic A, ed. Academic Press; 2022.
18. Durack DT, Lukes AS, Bright DK. New criteria for diagnosis of infective endocarditis: utilization of specific echocardiographic findings. *Duke Endocarditis Service. Am J Med*. 1994;96(3):200-209. doi:10.1016/0002-9343(94)90143-0
19. Tan C, Hansen MS, Cohen G, et al. Case conferences for infective endocarditis: a quality improvement initiative. *PLoS One.* 2018;13(10):e0205528. doi:10.1371/journal.pone.0205528
20. Ruch Y, Mazzucotelli JP, Lefebvre F, et al. Impact of setting up an "endocarditis team" on the management of infective endocarditis. *Open Forum Infect Dis.* 2019;6(9):ofz308. doi:10.1093/ofid/ofz308
21. Camou F, Dijos M, Barandon L, et al. Management of infective endocarditis and multidisciplinary approach. *Med Mal Infect.* 2019;49(1):17-22. doi:10.1016/j.medmal.2018.06.007
22. Pettersson GB, Hussain ST. Current AATS guidelines on surgical treatment of infective endocarditis. *Ann Cardiothorac Surg.* 2019;8(6):630-644. doi:10.21037/acs.2019.10.05
23. Mestres CA, Paré JC, Miró JM. Organization and functioning of a multidisciplinary team for the diagnosis and treatment of infective endocarditis: a 30-year perspective (1985-2014). *Rev Esp Cardiol (Engl Ed).* 2015;68(5):363-368. doi:10.1016/j.rec.2014.10.006
24. Stavi V, Brandstaetter E, Sagy I, et al. Comparison of clinical characteristics and prognosis in patients with right- and left-sided infective endocarditis. *Rambam Maimonides Med J.* 2019;10(1):e00003. doi:10.5041/rmmj.10338