

Creation of a Multidisciplinary Drug Use Endocarditis Treatment (DUET) Team: Initial Patient Characteristics, Outcomes, and Future Directions

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Background. Consensus guidelines recommend multidisciplinary models to manage infective endocarditis, yet often do not address the unique challenges of treating people with drug use–associated infective endocarditis (DUA-IE). Our center is among the first to convene a Drug Use Endocarditis Treatment (DUET) team composed of specialists from Infectious Disease, Cardiothoracic Surgery, Cardiology, and Addiction Medicine.

Methods. The objective of this study was to describe the demographics, infectious characteristics, and clinical outcomes of the first cohort of patients cared for by the DUET team. This was a retrospective chart review of patients referred to the DUET team between August 2018 and May 2020 with DUA-IE.

Results. Fifty-seven patients were presented to the DUET team between August 2018 and May 2020. The cohort was young, with a median age of 35, and injected primarily opioids (82.5% heroin/fentanyl), cocaine (52.6%), and methamphetamine (15.8%). Overall, 14 individuals (24.6%) received cardiac surgery, and the remainder (75.4%) were managed with antimicrobial therapy alone. Nearly 65% of individuals were discharged on medication for opioid use disorder, though less than half (36.8%) were discharged with naloxone and only 1 patient was initiated on HIV pre-exposure prophylaxis. Overall, the cohort had a high rate of readmission (42.1%) within 90 days of discharge.

Conclusions. Multidisciplinary care models such as the DUET team can help integrate nuanced decision-making from numerous subspecialties. They can also increase the uptake of addiction medicine and harm reduction tools, but further efforts are needed to integrate harm reduction strategies and improve follow-up in future iterations of the DUET team model.

Keywords. drug use; endocarditis; multidisciplinary team; substance use.

In the context of the ongoing substance use and overdose epidemics, infectious complications of injection drug use represent a significant source of morbidity and mortality. The incidence of drug use–associated infective endocarditis (DUA-IE) has at least doubled nationally, with some states reporting as high as a 12-fold increase in recent years [1–3]. Endocarditis and other bacterial infections are serious complications associated with unsterile injection supplies and techniques, which have poor clinical outcomes and high rates

of recurrence—especially without treatment of underlying addiction [4–8].

The inpatient management of DUA-IE is challenging and requires timely input from multiple clinical perspectives to make key decisions about therapeutic strategy, such as whether a surgical intervention is indicated and appropriate or if the patient should be treated with antimicrobial therapy alone [9]. Despite the need for multidisciplinary input, processes to facilitate these discussions are typically not standardized. The resulting communication difficulties and inefficiencies can lead to conflicts between professional colleagues, as well as between providers and patients [10].

The perceived risk of re-infection due to ongoing or recurrent injection drug use often factors into the decision-making process of whether to offer an operation to patients who otherwise have a guideline-supported surgical indication [11]. There are no clinical guidelines or randomized clinical trial results that address these complex clinical scenarios [12]. In the absence of such guidance, some institutions create policies that

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decline re-operation after a given number of attempts on the rationale of futility or have patients sign a contract pledging to abstain from substance use as a prerequisite for surgery, both of which lack a clear evidence base and raise ethical concerns [13]. The decision of whether to offer an invasive procedure, and if so, which one, is therefore guided largely by individual clinical judgment [14, 15]. Management decisions for DUA-IE thus have the potential to vary significantly within and between institutions and may ultimately depend on the attitudes and perspectives of the clinicians on service [16].

Given the complex decision-making involved in the treatment of DUA-IE, multidisciplinary team models have been proposed for its management [17–19]. But while multidisciplinary models have been heralded as a promising solution for improving DUA-IE care, little has been published regarding the experiences of implementing such a model [20].

To address these challenges, in 2018 we created a team to formally bring together the several specialties involved in the management of people with DUA-IE [21]. As has been previously published, the Drug Use Endocarditis Treatment (DUET) team is made of a core group of members from Addiction Medicine, Cardiac Surgery, Cardiology, and Infectious Diseases. DUET team meetings are multidisciplinary patient care conferences involving the core specialties as well as the primary inpatient medical team, primary care physician, pharmacists, nurses, social workers, recovery coaches, and other relevant medical specialties as needed (eg, nephrology, neurosurgery). The DUET team meets monthly and on an ad hoc basis to provide a regular forum for multiple specialties to discuss their shared patients with DUA-IE, come to a consensus on management decisions within an appropriate time frame, and reflect on outcomes. In a historical comparison of surgical patients before and after the formation of our DUET team, patients who were reviewed by the DUET team had decreased time to Addiction Medicine consultation, which is an essential component to caring for this patient population [21].

As DUA-IE case numbers rise, we expect calls for collaborative care for DUA-IE to also increase. It is important for providers to understand the strengths, challenges, and limitations of implementing such models so that they may be improved upon and replicated [17, 18]. To our knowledge, this is among the first of such reports focusing on patients cared for by a multidisciplinary team created exclusively for the treatment of DUA-IE. Our study therefore adds to a nascent body of literature presenting data on the impact of multidisciplinary models on the care of this complex medical problem.

OBJECTIVES

Given the growing incidence of DUA-IE and the lack of published data on the experiences of dedicated multidisciplinary groups focused on managing it, the primary objective of this

study was to describe the demographic, infectious, and clinical characteristics as well as management decisions and short-term outcomes of patients reviewed by the DUET team. Our second aim was to determine the patient factors and outcomes comparing patients who underwent surgical intervention vs medical management alone. Finally, we sought to report the stated clinical rationale for surgical versus medical management for each DUET patient.

METHODS

A retrospective electronic medical record review was performed on all patients with infective endocarditis presented at a DUET team meeting from its creation in August 2018 until May 2020. Patients were referred for presentation at DUET team meetings through a variety of mechanisms. Any member of the clinical team could submit cases directly to organizers or refer them via a web-based REDCap form [22]. At our institution, clinicians are encouraged to report appropriate patients to the DUET team through posted reminders present in various departments as well as email announcements; DUET team referral has also been integrated into the routine clinical workflow on the cardiothoracic surgical service.

The patients included in this study were discussed at DUET team meetings, met criteria for definite or probable infective endocarditis as defined by the Duke criteria, and had self-reported injection drug use [23]. For each patient, the institutional medical record was manually reviewed from the day of the index admission (defined as the admission during which the DUET meeting took place) through 90 days postdischarge. Baseline characteristics, clinical features, management decisions, survival status, and outcomes of interest were manually extracted by chart review, and at least 2 authors independently verified the accuracy of data input (D.V., L.M., M.P.). The study was approved by the Mass General Brigham Institutional Review Board (protocol #2019P003774).

The following variables were obtained by chart review of notes within the electronic medical record: self-reported drug use, medication history before admission, route of hospital admission, medication list on discharge, presence of subspecialty consultation, antimicrobial course, indications for surgical or medical management, surgical procedures performed, discharge location, and 90-day postdischarge outcomes. Opioid use disorder treatment was defined as being discharged from the index admission on a medication for opioid use disorder (MOUD). Patients noted to be on MOUD before admission had at least 1 MOUD on their prior to admission medication list (PAML), which is part of the standardized admission history and physical. Antibiotic course completion was defined as chart documentation of confirmed completion, whether as inpatient or postdischarge.

These variables were obtained using structured fields within the electronic medical record: patient age, gender identity, insurance type, microbiology data, radiographic studies, and HIV and hepatitis screening. Valve vegetations and severity of valvular insufficiency were obtained from the echocardiography reports. If multiple studies existed in the admission, the highest severity was recorded.

Operative management during the index admission was defined as any cardiac surgery for infective endocarditis, including but not limited to valve repair, valve replacement, or percutaneous intervention. Indications offered for surgical and medical management were obtained by detailed chart review of surgical service and other team notes. The cited reasons were independently reviewed by 2 authors (D.V., M.P.) and categorized into common themes. If multiple reasons were cited for a given patient, each of them was counted.

Descriptive statistics were used to report demographic, infectious, and clinical characteristics, management decisions, and 90-day outcomes. Categorical variables were reported as counts and percentages. Continuous variables were reported as medians with interquartile ranges (IQRs). Variables were compared for surgically vs non-surgically managed patients using the Fisher exact test and Wilcoxon 2-sample test as appropriate. Statistical significance was assessed at a nominal α level of .05; all reported *P* values were 2-sided. Statistical analysis was performed in R 4.0.0 (R Core Team).

RESULTS

Fifty-seven patients reviewed by the DUET team between August 2018 to May 2020 were included in this study. Three individuals brought up for discussion at a DUET meeting who did not have definite or probable endocarditis by the Duke criteria were excluded from this analysis. Analysis of the demographic variables (Table 1) revealed the DUET cohort to have a median age (IQR) of 35 (31.00–40.00) years, and gender identity was split nearly equally between male (56.1%) and female (43.9%). The majority of the cohort had Medicaid insurance coverage (71.9%), with only 1 uninsured individual. Over one-third of the cohort (35.1%) was unstably housed at the time of admission.

The most common substance patients reported injecting was heroin and/or fentanyl (82.5%), followed by cocaine (52.6%) and methamphetamine (15.8%). The most common noninjection substance use reported was nicotine (49.1%), benzodiazepines and alcohol (both 26.3%), cocaine (24.6%), and cannabis (15.8%). Thirty-five percent of patients were on MOUD before admission, including methadone (15.8%), buprenorphine (17.5%), or extended-release naltrexone (1.8%).

Overall, 14 of 57 patients (24.6%) underwent cardiac surgery or an interventional procedure during the index admission. Of

Table 1. DUET Team Patient Characteristics

No.	57
Age, median [IQR], y	35.00 [31.00–40.00]
Male gender identity, No. (%)	32 (56.1)
Insurance, No. (%)	
Medicaid	41 (71.9)
Commercial	8 (14.0)
Medicare	7 (12.3)
Uninsured	1 (1.8)
Admission route, No. (%)	
Emergency department	34 (59.6)
Outside hospital transfer	22 (38.6)
Direct admission	1 (1.8)
Housing instability, No. (%)	20 (35.1)
On MOUD before admission, No. (%)	20 (35.1)
Buprenorphine	10 (17.5)
Methadone	9 (15.8)
Extended-release naltrexone	1 (1.8)
Self-reported injection drug use, No. (%)	
Heroin	45 (78.9)
Cocaine	30 (52.6)
Fentanyl	21 (36.8)
Methamphetamines	9 (15.8)
Self-reported noninjection drug use, No. (%)	
Tobacco smoking	28 (49.1)
Alcohol	15 (26.3)
Benzodiazepines	15 (26.3)
Cocaine	14 (24.6)
Opioids	7 (12.3)
Cannabinoids	9 (15.8)
Methamphetamines	4 (7.0)

Abbreviations: DUET, Drug Use Endocarditis Treatment; IQR, interquartile range; MOUD, medications for opioid use disorder.

Table 2. Types of Procedure Performed and Indications

No.	14
Operation, No. (%)	
Bioprosthetic valve	12 (85.7)
Mechanical valve	1 (7.1)
Endovascular aspiration thrombectomy	1 (7.1)
Type of surgery, No. (%) ^a	
Aortic valve replacement	7 (50.0)
Tricuspid valve replacement	4 (28.6)
Mitral valve replacement	4 (28.6)
Aortic valve repair	2 (14.3)
Mitral valve repair	1 (7.1)
Indications, No. (%) ^a	
Embolic phenomena	6 (42.9)
Nonresponse to medical treatment	6 (42.9)
NYHA class III–IV heart failure	5 (35.7)
Vegetation size	5 (35.7)
Cardiac abscess	5 (35.7)
Prosthetic valve dysfunction	2 (14.3)
Hemodynamic compromise	1 (7.1)

Abbreviation: NYHA, New York Heart Association.

^aSome patients had multiple indications and underwent multiple types of surgery.

Table 3. Clinical Details of Surgically Managed Patients

Valve Involved	Microorganism(s)	Duration of Bacteremia/ Candidemia, d	Specific Surgical Indication(s)
Aortic, native	MSSA	2	NYHA III–IV
Aortic, prosthetic	Culture negative	n/a	NYHA III–IV, paravalvular abscess
Aortic, prosthetic	<i>Candida glabrata</i>	7	Paravalvular abscess, prosthetic valve dysfunction, microorganism
Right atrial mass ^a	MRSA	4	Microorganism
Aortic, native	MRSA	13	NYHA III–IV, systemic emboli
Tricuspid and mitral, native	MRSA	1	Paravalvular abscess, systemic emboli, microorganism, vegetation size
Mitral, native	<i>Candida dubliensis</i> and <i>Streptococcus mitis</i>	1	Microorganism
Mitral, native	<i>Streptococcus viridans</i>	1	Systemic emboli
Mitral and aortic, prosthetic	<i>Candida parapsilosis</i>	7	Prosthetic valve dysfunction, microorganism, systemic emboli, vegetation size
Aortic, native	MSSA	4	Paravalvular abscess, vegetation size
Tricuspid and aortic, native	MSSA	4	Systemic emboli, vegetation size
Aortic, native	<i>Enterococcus faecalis</i>	Unknown ^b	NYHA III–IV, hemodynamic compromise, paravalvular abscess, systemic emboli, vegetation size
Tricuspid, native	<i>Candida albicans</i>	2	Microorganism, vegetation size
Tricuspid, native	MSSA	Unknown ^b	NYHA III–IV

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*; NYHA, New York Heart Association.

^aEndovascular right atrial thrombus percutaneous removal.

^bDuration of bacteremia not available from available outside hospital records; patient had negative blood cultures on admission to this facility.

these 14 operative patients, 12 received bioprosthetic valves (85.7%), 1 (7.1%) received a mechanical valve, and 1 (7.1%) received an endovascular aspiration procedure (Table 2). The most common operations were aortic valve replacement (50%), followed by tricuspid valve replacement (28.6%) and mitral valve replacement (28.6%). The clinical characteristics of patients who underwent surgery are further detailed in Table 3. The most common indications for surgery were embolic phenomenon and lack of response to antimicrobials, followed by vegetation size, heart failure, and presence of perivalvular abscess. Two patients had re-do prosthetic valve operations, and 1 was operated on because of hemodynamic instability.

The remaining 43 of 57 patients (75.4%) were managed with antibiotics alone. The rationale for nonsurgical management is provided in Table 4. Of cases where surgery was not

pursued, the most cited reason within the chart was lack of a surgical indication (40.4%). The second most cited reason to manage medically was ongoing injection drug use (25.6%). Perceived need for individuals to demonstrate sustained abstinence was cited in 6 of the 43 cases (14.0%). Clinical details regarding the 11 patients with either *active substance use* and/or *perceived need to demonstrate abstinence* as a documented rationale for nonsurgical management are included in Table 5.

Table 6 describes the cohort's infectious characteristics. Current or prior hepatitis C virus infection was common (84.2%), while HIV infection was uncommon (3.5%). Nine of the 57 patients (15.8%) had prosthetic valve involvement. The most commonly involved valve position was the tricuspid (57.9%), followed by the aortic (26.3%) and mitral (26.3%); 17.5% of individuals had multiple valves infected, and 14.0% had concurrent right- and left-sided valve involvement. About half of individuals had at least 1 valve with severe insufficiency by echocardiogram.

The most common pathogens isolated were *Staphylococcus aureus* in 63.2%, with methicillin-resistant *Staphylococcus aureus* accounting for 38.9% of all *Staphylococcus aureus* pathogens, followed by *Streptococcus* species then *Candida* and *Enterococcus* species, with gram-negative infections being least common. About one-fifth of infections were polymicrobial. The most common sites of metastatic seeding were lung (61.4%), joint (36.8%), and central nervous system (28.1%).

Table 6 describes the short-term management and outcomes of DUET team patients. Infectious Disease and

Table 4. Rationale for Nonsurgical Management^a

No.	43
No indication for surgery, No. (%)	23 (53.5)
Active substance use, No. (%)	11 (25.6)
Improvement with medical management, No. (%)	7 (16.3)
Perceived need to demonstrate abstinence, No. (%)	6 (14.0)
Increased surgical risk from significant CNS involvement, No. (%)	6 (14.0)
Patient-directed discharge before surgery decision, No. (%)	4 (9.3)
High-risk surgical candidate, No. (%)	2 (4.7)
Poorly controlled HIV, No. (%)	1 (2.3)
Clinically unstable for surgery, No. (%)	1 (2.3)
Perceived risk of patient-directed discharge, No. (%)	1 (2.3)
Patient preference, No. (%)	1 (2.3)

Abbreviation: CNS, central nervous system.

^aSome patients had more than 1 reason for nonoperative management.

Table 5. Clinical Details of Patients Whose Active Substance Use Was a Documented Rationale for Nonsurgical Management

Organism	Valve	Surgical Indication ^a	Discharged on MOUD	90-Day Follow-up
MSSA	Tricuspid, mitral and aortic (native)	Valve dysfunction resulting in symptoms of heart failure Left-sided IE caused by <i>S. aureus</i>	Yes	Lost to follow-up
MSSA	Tricuspid and aortic (native)	Valve dysfunction resulting in symptoms of heart failure Left-sided IE caused by <i>S. aureus</i>	Yes	Completed course of antibiotics Readmitted for decompensated heart failure requiring cardiac surgery
MRSA	Tricuspid (prosthetic)		No	Completed course of antibiotics Developed symptoms of heart failure
MSSA	Mitral (native)	Left-sided IE caused by <i>S. aureus</i>	Yes	Did not complete course of antibiotics
MRSA	Tricuspid (native)		Yes	Did not complete course of antibiotics Readmitted with relapsed infective endocarditis
<i>E. faecium</i> and <i>S. pyogenes</i>	Mitral (native)	Valve dysfunction resulting in symptoms of heart failure	Yes	Did not complete course of antibiotics Readmitted with relapsed infective endocarditis and hemorrhagic stroke
<i>K. pneumonia</i> and <i>S. parasanguinis</i>	Tricuspid (native)		Yes	Did not complete antibiotic course
MRSA	Tricuspid (native)		Yes	Did not complete course of antibiotics Readmitted with relapsed infective endocarditis
<i>Serratia marcescens</i>	Tricuspid (native)		Yes	Completed course of antibiotics Readmitted with ongoing septic pulmonary emboli
MRSA	Tricuspid and mitral (native)		Yes	Completed course of antibiotics Developed complete heart block and underwent pacemaker placement (no abscess visualized on cardiac imaging)
Polymicrobial including MSSA, <i>Candida</i> spp., and gram-negative bacteria	Tricuspid and mitral (prosthetic)	Left-sided IE caused by <i>S. aureus</i>	Yes	Patient left via a patient-directed discharge on oral antibiotics and was lost to follow-up

Abbreviation: AATS, American Association for Thoracic Surgery; IE, infective endocarditis; MOUD, medication for opioid use disorder; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-sensitive *Staphylococcus aureus*.

^aPer AATS guidelines [9].

Addiction Medicine were involved in the care of nearly all patients (94.7% and 86.0%, respectively); however, only 40.4% of patients were seen by Cardiology. Over 40% of patients required a noncardiac surgery. Nearly 65% of patients were discharged on MOUD, with the majority receiving methadone (43.9%) and the remainder buprenorphine (17.5%) or injectable naltrexone (1.8%). In terms of harm reduction associated with injection drug use, HIV and HCV screening were more common than HBV and other STI screening. While 36.8% were given a prescription for naloxone at discharge, only 1 patient (1.8%) was started on pre-exposure prophylaxis for HIV.

In total, 4 patients (7.0%) died during the index admission, 10 patients (17.5%) left in a patient-directed discharge, 31 patients (54.4%) were discharged to a skilled nursing facility or other post-acute care setting, and 6 patients (10.5%) were discharged to home or self-care. The median length of stay (IQR) was 14.0 (9.0–23.0) days. The most common follow-up appointment scheduled at discharge was Infectious Diseases (52.6%);

14 patients (24.6%) were confirmed to have attended at least 1 follow-up appointment. Patients may not have been scheduled for follow-up visits due to patient-directed discharges, transfer back to a referring hospital, or discharge to a post-acute care facility with its own Infectious Diseases and/or Addiction Medicine teams. More than half (58.1%) were confirmed to have completed their antibiotic course. Three patients were prescribed a 2-week course of therapy, and 2 (67%) completed their course of treatment. Three patients were prescribed a 4-week course of therapy, and 2 (67%) completed their course of treatment. Thirty-seven patients were prescribed a 6-week course of therapy, and 19 (51%) completed the course of treatment. Five patients were prescribed an 8–9-week course of therapy, and 4 (80%) completed the course. The remaining patients did not have defined courses of therapy documented at the time of their discharge, due to premature discharge or plan for determination in the outpatient setting. Of the 8 patients who were prescribed oral antibiotic therapy in lieu of parenteral therapy, all due to

Table 6. Infection Characteristics of Nonsurgically vs Surgically Managed DUET Team Patients

	Total	Nonsurgically Managed	Surgically Managed	P
No.	57	43	14	-
HCV antibody positive, No. (%)	48 (84.2)	37 (86.0)	11 (78.6)	.674
HIV antibody positive, No. (%)	2 (3.5)	2 (4.7)	0 (0.0)	1.000
Pathogenic agent(s) cultured, No. (%)				-
Monomicrobial infection	43 (75.4)	31 (72.1)	12 (85.7)	.478
Polymicrobial infection	10 (17.5)	9 (20.9)	1 (7.1)	.423
<i>Staphylococcus aureus</i>	36 (63.2)	30 (69.8)	6 (42.9)	.135
Methicillin-susceptible <i>Staphylococcus aureus</i>	22 (38.6)	18 (41.9)	4 (28.6)	.568
Methicillin-resistant <i>Staphylococcus aureus</i>	14 (24.6)	12 (27.9)	2 (14.3)	.502
<i>Streptococcus</i> species	11 (19.3)	9 (20.9)	2 (14.3)	.714
<i>Candida</i> species	6 (10.5)	2 (4.7)	4 (28.6)	.027 ^a
<i>Enterococcus</i> species	6 (10.5)	5 (11.6)	1 (7.1)	1.000
Gram-negative species	5 (8.8)	4 (9.3)	1 (7.1)	1.000
Culture negative	4 (7.0)	3 (7.0)	1 (7.1)	1.000
Metastatic involvement, No. (%)				-
Lung	35 (61.4)	29 (67.4)	6 (42.9)	.123
Joint	21 (36.8)	18 (41.9)	3 (21.4)	.214
Central nervous system	16 (28.1)	10 (23.3)	6 (42.9)	.183
Spleen	14 (24.6)	8 (18.6)	6 (42.9)	.084
Renal	8 (14.0)	5 (11.6)	3 (21.4)	.391
Spine	7 (12.3)	7 (16.3)	0 (0.0)	.176
Coronary	5 (8.8)	2 (4.7)	3 (21.4)	.089
Eye	3 (5.3)	2 (4.7)	1 (7.1)	1.000
Skin	3 (5.3)	1 (2.3)	2 (14.3)	.146
Valve involvement, No. (%)				-
Tricuspid	33 (57.9)	29 (67.4)	4 (28.6)	.014 ^a
Mitral	15 (26.3)	11 (25.6)	4 (28.6)	1.000
Aortic	15 (26.3)	7 (16.3)	8 (57.1)	.005 ^a
Multiple	10 (17.5)	7 (16.3)	3 (21.4)	.694
Prosthetic valve	9 (15.8)	6 (14.0)	3 (21.4)	.674
None ^b	5 (8.8)	4 (9.3)	1 (7.1)	1.000
Severe insufficiency	29 (50.9)	18 (41.9)	11 (78.6)	.029 ^a

Abbreviations: DUET, Drug Use Endocarditis Treatment; HCV, hepatitis C virus.

^a $P < .05$.

^bSome patients had no vegetations identified on echocardiography but met other criteria for probable or definitive endocarditis or had nonvalvular intracardiac infection.

patient-directed discharges, only 1 had clear documentation of completing the course of treatment. Three patients received outpatient parenteral antibiotic therapy at home. Of these 3, 1 was readmitted with bacteremia felt to be due to an oral source, 1 completed the course of therapy but was readmitted within 90 days with an opioid overdose and a skin and soft tissue infection, and the final patient had home antibiotics arranged out of state, so follow-up was not available.

In the 90 days after discharge, 24 patients (42.1%) were readmitted, 7 (12.3%) had relapsed or recurrent endocarditis, 4 (7.0%) developed new or worsening heart failure, 3 (5.3%) had bacteremia not meeting endocarditis criteria, 1 (1.8%) had a hemorrhagic stroke, 1 (1.8%) had a known overdose, and 1 (1.8%) died.

Infectious characteristics that were associated with the decision to pursue surgical vs nonsurgical management include *Candida* infection (28.6% vs 4.7%; $P = .027$), aortic valve involvement (57.1% vs 16.3%; $P = .005$), and severe regurgitation

(78.6% vs 41.9%; $P = .029$). Patients in the DUET cohort who were managed without surgical intervention were more likely to have tricuspid valve involvement (67.4% vs 28.6%; $P = .014$).

When compared with non-surgically managed patients, surgically managed patients were more frequently seen by cardiology (71.4% vs 30.2%; $P = .011$) and pain (57.1% vs 4.7%; $P < .001$) consultants. Only half of surgically managed patients were discharged on MOUD. Surgically managed patients had a longer length of stay (19.00 days vs 12.00 days; $P = .027$) but the same duration of antibiotic course remaining at discharge. No patients managed with surgery left in a patient-directed discharge, and more surgically managed patients were discharged home (21.4% vs 7%; $P = .151$), but this difference did not reach statistical significance. More surgically managed patients had an Infectious Diseases follow-up scheduled (78.6% vs 44.2%; $P < .033$); rates of scheduled Addiction Medicine follow-up appointments at discharge were low for both groups (7.1% for surgically managed, 11.6% for non-surgically managed). More

Table 7. Short-term Outcomes of Nonsurgical vs Surgically Managed DUET Team Patients

	Total	Nonsurgical Management	Surgical Management	P
No.	57	43	14	-
Consultations, No. (%)				
Infectious Disease	54 (94.7)	41 (95.3)	13 (92.9)	1.000
Addiction Medicine	49 (86.0)	37 (86.0)	12 (85.7)	1.000
Cardiac Surgery	33 (57.9)	19 (44.2)	14 (100.0)	<.001 ^a
Cardiology	23 (40.4)	13 (30.2)	10 (71.4)	.011 ^a
Neurology	12 (21.1)	8 (18.6)	4 (28.6)	.463
Pain	10 (17.5)	2 (4.7)	8 (57.1)	<.001 ^a
Discharged on MOUD, No. (%)				
Methadone	25 (43.9)	22 (51.2)	3 (21.4)	.067
Buprenorphine	10 (17.5)	6 (14.0)	4 (28.6)	.240
Injectable naltrexone	1 (1.8)	1 (2.3)	0 (0.0)	1.000
Harm reduction, No. (%)				
Naloxone prescription on discharge	21 (36.8)	17 (39.5)	4 (28.6)	.538
HCV screening	50 (87.7)	38 (88.4)	12 (85.7)	1.000
HIV screening	40 (70.2)	31 (72.1)	9 (64.3)	.738
HBV screening	30 (52.6)	24 (55.8)	6 (42.9)	.540
STI screening	13 (22.8)	8 (18.6)	5 (35.7)	.271
HIV PREP initiation	1 (1.8)	1 (2.3)	0 (0.0)	1.000
Length of stay, median [IQR], d	14.00 [9.00–23.00]	12.00 [9.00–20.50]	19.00 [15.00–35.00]	.027 ^a
Total antibiotic course, median [IQR], wk	6.00 [6.00–6.00]	6.00 [6.00–6.00]	6.00 [6.00–6.00]	.121
Antibiotic course remaining at discharge, median [IQR], d	29.00 [16.50–33.50]	29.50 [14.00–33.25]	29.00 [21.50–33.00]	.821
Antibiotic course completed, No. (%)	25 (58.1)	16 (51.6)	9 (75.0)	.191
Noncardiac surgery, No. (%)	24 (42.1)	17 (39.5)	7 (50.0)	.544
Disposition, No. (%)				
Subacute nursing facility	31 (54.4)	22 (51.2)	9 (64.3)	.539
Patient-directed discharge	10 (17.5)	10 (23.3)	0 (0.0)	.054
Home	6 (10.5)	3 (7.0)	3 (21.4)	.151
Other	6 (10.5)	5 (11.6)	1 (7.1)	1.000
Died before discharge	4 (7.0)	3 (7.0)	1 (7.1)	1.000
Follow-up appointment scheduled, No. (%)				
Infectious Disease	30 (52.6)	19 (44.2)	11 (78.6)	.033 ^a
Cardiac Surgery	16 (28.1)	5 (11.6)	11 (78.6)	<.001 ^a
Cardiology	13 (22.8)	8 (18.6)	5 (35.7)	.271
Primary Care	12 (21.1)	9 (20.9)	3 (21.4)	1.000
Addiction	6 (10.5)	5 (11.6)	1 (7.1)	1.000
Psychiatry	3 (5.3)	2 (4.7)	1 (7.1)	1.000
90-d postdischarge outcomes, No. (%)				
At least 1 follow-up appointment attended	14 (24.6)	4 (9.3)	10 (71.4)	<.001 ^a
Readmission	24 (42.1)	19 (44.2)	5 (35.7)	.757
Recurrent or relapsed infective endocarditis	7 (12.3)	7 (16.3)	0 (0.0)	.176
Congestive heart failure	4 (7.0)	4 (9.3)	0 (0.0)	.563
Bacteremia	3 (5.3)	0 (0.0)	3 (21.4)	.012 ^a
Skin or soft tissue infection	3 (5.3)	2 (4.7)	1 (7.1)	1.000
Hemorrhagic stroke	1 (1.8)	1 (2.3)	0 (0.0)	1.000
Overdose	1 (1.8)	0 (0.0)	1 (7.1)	.246
Renal failure	1 (1.8)	1 (2.3)	0 (0.0)	1.000
Death	1 (1.8)	0 (0.0)	1 (7.1)	.246
Confirmed completion of antimicrobial therapy without relapse of endocarditis at 90 d	23 (40.4)			
Confirmed completion of antimicrobial therapy without relapse of endocarditis or readmission to hospital at 90 d	13 (22.8)			
Confirmed completion of antimicrobial therapy without relapse of endocarditis, readmission to hospital, or development of congestive heart failure at 90 d	12 (21.1)			

Table 7. Continued

	Total	Nonsurgical Management	Surgical Management	<i>P</i>
Confirmed completion of antimicrobial therapy without relapse of endocarditis, readmission to hospital, development of congestive heart failure, or other complication at 90 d	11 (19.3)			

n = 57 was used in the calculation of all clinical and postdischarge outcomes related to this cohort.

Abbreviations: DUET, Drug Use Endocarditis Treatment; HBV, hepatitis B virus; HCV, hepatitis C virus; IQR, interquartile range; MOUD, medications for opiate use disorder; PREP, pre-exposure prophylaxis; STI, sexually transmitted infection.

^a*P* < .05.

surgically managed patients attended at least 1 follow-up appointment (71.4% vs 9.3%; *P* < .001). While 7 non-operatively managed patients had relapsed or recurrent endocarditis, no surgically managed patients did within the 90-day window; however, that difference was not statistically significant. Of the patients who developed relapsed or recurrent endocarditis, 6 had native valve tricuspid valve endocarditis and 1 had native mitral valve endocarditis; 4 of the 7 had completed full antimicrobial courses for their original infection. Two of the 7 patients had the same organism isolated on re-presentation, 3 were culture negative but with evidence of new emboli or new vegetations on imaging, and 2 had new organisms isolated in blood cultures. The 3 cases of bacteremia and 1 postdischarge death occurred within the surgically managed cohort.

DISCUSSION

In this single-center experience of a multidisciplinary DUA-IE team, we found that despite the young age of patients presented at DUET team meetings, nearly half were re-admitted within 90 days of discharge, and there was an 8.7% overall mortality rate from admission to 90 days postdischarge, confirming the severe morbidity and mortality associated with DUA-IE. This is consistent with prior literature on treating DUA-IE and speaks to the difficult-to-treat scenarios described in the cohort, including *S. aureus*, *Candida*, and polymicrobial infections, concomitant right- and left-sided disease, and high rates of metastatic seeding [4, 5, 24, 25]. Developing improved models of care for people with DUA-IE will thus require an iterative process of design, evaluation, and redesign. Our experience of the DUET team model captures areas of initial success while identifying implementation gaps and hypothesis-generating areas for subsequent research.

One of the main interventions that the DUET team model provides is coalescing the diverse specialties involved in critical decision points for the management of DUA-IE, including the question of whether a patient will be managed operatively or medically. In this cohort, the rate of surgical intervention was slightly under one-quarter of individuals (23.3%). Univariate analysis suggests that variables that might signify serious infection (eg, *Candida* infections, severe valvular insufficiency)

tended to correlate with surgical management. The stated rationale for pursuing surgical management ranged relatively evenly across typical guideline indications. For patients managed nonoperatively, the most common rationale cited was a lack of clear surgical indication. However, the second most cited reason for nonoperative management, in greater than a quarter of our cohort, referenced the individual's ongoing injection drug use. Explicit mention of the need to demonstrate abstinence was made in the case of 6 individuals (14.0%). Of these 11 individuals who had underlying substance use disorder as a documented rationale for nonsurgical intervention, 5 (45%) had clear indications for surgical intervention following American Association for Thoracic Surgery guidelines, including valvular dysfunction resulting in heart failure symptoms and left-sided infective endocarditis caused by *S. aureus* [9]. Of these 5 patients with a surgical indication, 2 were lost to follow-up after discharge, 1 was readmitted with heart failure ultimately requiring cardiac surgery, and 1 was readmitted with a hemorrhagic stroke.

In the face of a life-threatening infection, ongoing drug use as a contraindication to surgery merits further consideration. The risk of re-infection due to injection drug use raises questions of futility of surgical care [11]. While requirements for specified periods of abstinence are appealing in their simplicity, they are both arbitrary and at odds with our current understanding of severe substance use disorder as a chronic health condition akin to diabetes or coronary artery disease (CAD). By analogy to managing CAD in someone who smokes cigarettes and requires bypass grafting, smoking is also a comorbid modifiable risk factor for recurrent disease that might lead to re-intervention. While we would certainly encourage smoking cessation before a coronary artery bypass graft (CABG) surgery, we would not decline someone for CABG surgery solely due to concern for ongoing smoking postoperatively. Moreover, approaches to treatment of people with DUA-IE have often ignored that recurrent infection is most proximally mediated by lack of access to harm reduction resources and sterile injection equipment, rather than simply whether a person continues to use drugs or not [26].

The concept of treating substance use disorder as the ultimate "source control" driving infectious complications is a

cornerstone of the DUET team model, which ensures that the Addiction Medicine perspective is central to the overall care plan. Addiction Medicine consultation has been shown to reduce re-admission rates for patients with infectious complications of opioid use disorder, and patients initiated on MOUD in the inpatient setting can be successfully connected to long-term outpatient treatment [27–29]. But many patients with DUA-IE are still not offered key interventions such as Addiction Medicine consultation or treatment with MOUD [30, 31]. With involvement of the DUET team, Addiction Medicine consultation rates as documented in the chart were nearly 90% (Table 7). Patients referred to the DUET team were also likely to receive interventions meant to address the root cause of endocarditis, as evidenced by nearly 65% of patients in the cohort being discharged on MOUD. Given the low prevalence of Addiction Medicine follow-up appointments captured through the electronic medical record, the rate of MOUD continuation after discharge could not be assessed.

But our findings also identified several areas for improvement in the implementation of harm reduction strategies. Our study revealed a very low rate of initiation of HIV pre-exposure prophylaxis (PrEP), despite its potential to reduce HIV infection when used in patients who inject drugs [31]. Research has demonstrated that people who inject drugs are interested in taking HIV PrEP but often lack information and access, highlighting the critical role providers must play in initiating discussions about HIV PrEP in the hospital setting [32, 33]. Similarly, not performing treatment staging and initiation of therapy for hepatitis C infection represents another missed opportunity in a population of patients with high rates of infection. In addition, as overdose rates continue to climb nationally, ensuring that every patient with DUA-IE is discharged with naloxone and feels empowered to use it is a crucial life-saving measure that must be prioritized.

Whether patients were managed medically or surgically, all patients in the cohort required several weeks of antimicrobial therapy, and several required multiple surgeries for metastatic sites of infection (Table 7). As indicated by the low rates of confirmed antibiotic course completion and follow-up appointment attendance, there are limitations as to what a dedicated inpatient DUET team can do to ensure plan completion or adherence after discharge. Managing postdischarge planning and follow-up for patients transferred from outside hospitals also posed unique challenges and vulnerabilities.

Disposition locations are often limited for patients with DUA-IE. Discrimination against people who use drugs at post-acute care facilities also creates unjust barriers for individuals to access critical medications like antimicrobials and MOUD after discharge [34, 35]. Most DUET patients were discharged to post-acute care settings and required, on average, more than 3 additional weeks of antimicrobial therapy. Literature has suggested feasibility in safely discharging patients home

with history of injection drug use with a peripherally inserted central catheter (PICC), but only 6 patients in this cohort were discharged home or to self-care [36]. Further consideration of home discharge planning may be appropriate for DUA-IE patients requiring continued antibiotic treatment. Additional research into facilitating safe discharges for people with DUA-IE before completing antimicrobial courses is needed.

To improve the DUET team model moving forward, a standardized checklist with best practices could be integrated into the medical record to help address missed opportunities for harm reduction strategies in the inpatient setting. A formal DUET consultation note would help capture and record key management decisions and analyze these decisions over time. Finally, formalizing a process by which the DUET team might maintain postdischarge contact may help ensure appropriate access to medications and postdischarge follow-up.

There are multiple limitations to this single-center retrospective cohort study. Due to small study population size, multivariable analysis was unable to be performed. Patients were included only if they were referred to the DUET team, so referral bias is plausible. The high rate of insurance coverage in the cohort may also reflect the universal health care model unique to Massachusetts. Statistically significant relationships are hypothesis-generating and are not intended to imply causality. Certain variables may not have been recorded reliably in the electronic records. Despite independent data review from 2 authors, errors in data extraction and recording also remain possible. Outcome measurements were also limited by loss to follow-up after discharge; patients may have re-presented to hospitals outside of this hospital network system, and these encounters would not be captured in the electronic medical record.

CONCLUSIONS

Multidisciplinary care teams are often identified as a potential solution to the complex management decisions of patients with DUA-IE. While multidisciplinary care is likely to be a core tenet of improving inpatient management of these life-threatening infections, our study demonstrates that significant barriers remained in the care of this patient population. Future iterations and new versions of the DUET team model should consider implementing mechanisms to improve documentation of key management decisions, standardized checklists to ensure uptake of key harm reduction strategies, and efforts to better support and follow patients postdischarge.

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