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Developing a Toolkit to Reduce Infections Following Durable LVAD Implantation in the United States Using a Multistage Mixed Methods Design

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Abstract

Background: Infections following durable left ventricular assist device (dLVAD) implantation are common and associated with increased morbidity and mortality. Despite documented interhospital variability, few studies have identified strategies to mitigate their occurrence. This national study uses a multistage mixed methods design to develop a customizable and deployable toolkit of expert-guided recommendations to reduce infections post-dLVAD.

Methods: Using purposeful sampling, participants (e.g., clinical and operational ventricular assist device “VAD” team members) from low, medium, and high-performance hospitals (based on their risk-adjusted, 90-day post-implantation infection rates) across the U.S. were interviewed to assess factors contributing to post-dLVAD infections. Draft toolkit recommendations were iteratively developed after integrating thematically analyzed qualitative and quantitative data from a merged national registry with Medicare and hospital survey data. A national advisory team of

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DISCLOSURES

Outside of this work, Donald S. Likosky receives research funding from the Agency for Healthcare Research and Quality (AHRQ) and the National Institutes of Health and is a consultant for the American Society of Extracorporeal Technology. Donald S. Likosky receives partial salary support from Blue Cross Blue Shield of Michigan to advance quality in Michigan in conjunction with the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative. Francis D. Pagani is an *ad hoc*, non-compensated scientific advisor for Medtronic, Abbott, FineHeart, and BrioHealth Solutions and receives partial salary support from Blue Cross Blue Shield of Michigan to advance quality in Michigan in conjunction with the Michigan Society of Thoracic and Cardiovascular Surgeons Quality Collaborative.

VAD subject matter experts provided mixed methods input to refine the toolkit's content and structure.

Results: Seventy-three clinical and operational VAD team members across eight U.S. hospitals were interviewed, spanning low (n=4), medium (n=1) and high (n=3) performance groups. Fourteen subject matter experts provided stakeholder feedback to refine the toolkit. The resulting toolkit contains 39 infection prevention recommendations that address VAD program care processes (e.g., real-time provider communication), clinicians (e.g., multidisciplinary protocol development), patients & caregivers (e.g., engaging patient advisors in patient education), and VAD leadership (e.g., unit and service level data reporting). Accompanying resources (e.g., team-based exercises, data collection worksheets) support implementing and evaluating site-specific strategies.

Conclusions: Using mixed methods approaches, an infection prevention toolkit was developed to enhance care coordination among VAD team members and mitigate post-dLVAD infections. Future work should evaluate the effectiveness of implementing this infection prevention toolkit within the dLVAD setting.

Keywords

ventricle-assist device; infections; quality improvement; qualitative research

INTRODUCTION

Patients undergoing durable left ventricular assist device (dLVAD) implantation are at risk for developing postoperative infections.¹ Analyses of the Multicenter Study of MagLev Technology in Patients Undergoing Mechanical Circulatory Support Therapy with HeartMate 3 (MOMENTUM 3) clinical trial found that nearly 6 out of every 10 patients undergoing implant of a dLVAD develop a device-related infection (i.e., percutaneous lead) and/or non-device-related infection (i.e., pneumonia) within 2 years of implantation.² These infections, which vary between 0.0 to 35.6 per 100 patient-months across hospitals,³ expose patients to an increased risk of major morbidity and resource utilization, diminishment in quality of life, and increased risk of mortality.⁴⁻⁶

Despite documented large-scale interhospital variability in infections, few studies have identified strategies to mitigate their occurrence.⁷ Early infection prevention efforts focused on identifying risk factors across phases of longitudinal care (e.g., pre-, intra- and post-operative settings) for patients with implanted dLVADs.^{1,8,9} Differences in infection rates across hospitals are minimally accounted for by patient risk.⁸ Therefore, efforts to advance infection prevention should evaluate other determinants, including the context (e.g., social determinants of health, caregiver support) and organizational structure (e.g., staffing and leadership model of the VAD program) of care, both within and outside of the index admission.

This multistage, mixed methods study was undertaken to develop a customizable and deployable toolkit of expert-guided infection prevention recommendations across the continuum of dLVAD care. The study team hypothesized that integrating VAD team

members' perspectives across hospitals and actively engaging key dLVAD subject matter experts would advance a customizable infection-prevention toolkit that may potentially reduce infections following dLVAD implantation.

MATERIALS AND METHODS

Overview

The data that support the findings of this study are available from the corresponding author upon request and review to ensure adherence to contractual and regulatory requirements. The study team grounded its approach towards creating the dLVAD Care Conceptual Framework based on: (1) the Joint Commission Patient Tracer Methodology;¹⁰ (2) prior literature findings;^{1,8,9} and (3) evolving analytical insights.^{1,8,9} The study's framework (Figure S1) delineates the phases of dLVAD care (e.g., pre-admission through post-discharge), key stakeholders involved (e.g., patients and caregivers, VAD coordinators, dLVAD surgeons, heart failure cardiologists, intra and postoperative nursing staff), and contextual domains of infection prevention (e.g., culture of collaboration, feedback reporting, data quality).

Methodologically, this study consisted of three stages (see Figure 1 for the procedural diagram and Supplemental Text S2 for the Strengthening the Reporting of Observational Studies in Epidemiology checklist). Stage 1 involved mixed methods formative assessment research, as detailed elsewhere.¹¹ The assessment combined an explanatory sequential design with a case series approach. Specifically, the collection and analysis of quantitative data informed a holistic qualitative approach that focused on understanding care practices and experiences among hospitals that were each evaluated as a complete case (i.e., distinct organizational unit). The study team conducted quantitative analyses of merged national datasets of dLVAD procedures to: (1) identify determinants of post-implantation infections; and (2) select low, medium, and high-performing hospitals for a qualitative case series investigation. These findings informed the focus of qualitative in-depth interviews with clinical and administrative team members across the continuum of hospital performance, aiming to understand the experiences, barriers and facilitators of infection prevention and to advance candidate infection prevention recommendation topics. During Stage 2, the study team integrated qualitative findings on infection prevention experience, barriers and facilitators with quantitative findings on the determinants of hospital performance to synthesize a prototype toolkit. Stage 3 involved developing, iteratively enhancing, and piloting the prototype toolkit based on clinical expert feedback from a national dLVAD Toolkit Advisory Team (dLVAD-AT) of multidisciplinary subject matter experts. Additionally, the toolkit was piloted for usability and intended effectiveness. All study phases received approval from the Institutional Review Board of Michigan Medicine (Study IDs: HUM00155687, HUM00165178, and HUM00218501).

Data Sources

Low, medium, and high-performing case hospitals were identified for qualitative inquiry through the analysis of a merged national dataset comprising: (1) Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs); (2) Center for Medicare &

Medicaid Services (CMS) Fee-For-Service Medicare claims; and (3) American Hospital Association Annual Survey.^{12,13}

Several data sources were used to advance stakeholder input to advance the toolkit development during Stage 1, Table S1.^{14,15} Interviews were conducted with a purposeful sample of 73 participants across 8 U.S. hospitals that were selected for case series investigations based on their risk-adjusted, 90-day post-implantation infection rates. As described elsewhere, risk adjustment factors included multiple patient and healthcare factors determined to be relevant by dLVAD experts and documented to be associated with mortality (see Table S3).¹⁶ Three of the eight hospitals involved in the interviews were classified as high-performers (i.e., lowest tertile of risk-adjusted 90-day infection rate) while four hospitals were low-performers (i.e., highest tertile of infection rate) and one hospital was a middle-performer. Qualitative and quantitative feedback was received from the dLVAD-AT, while qualitative data was received during the pilot testing of the toolkit.

Analysis and Toolkit Synthesis

During Stage 2, the analytical team (SS, PPC, LMC, DSL) iteratively developed the toolkit in collaboration with the broader study team. First, the Qualitative Analyst (SS) conducted thematic analyses of the semi-structured interviews, focusing on infection prevention roles, experiences, and recommendations.¹⁷ Analyses were also undertaken to identify thematic similarities and differences across quantitatively derived low-, medium, and high-performing hospitals and intended stakeholders (e.g., dLVAD surgeon, Heart Failure cardiologist).¹⁶ As noted above, the qualitative findings of all case hospitals were considered equally regardless of their infection performance. Protocols implemented at high-performing (i.e., low infection rate) hospitals were thought to potentially provide useful infection prevention recommendations for broader dissemination to other hospitals; however, some recommendations may also pose a challenge to implement, particularly at low-performing, under-resourced hospitals.¹⁷ To advance the development of a toolkit that could be customized across a diverse set of hospitals and contexts, the qualitative team solicited feedback from dLVAD team members regarding their preferences for prioritization of recommendations, with special attention given to toolkit recommendations that emerged across multiple interviews and a diversity of contexts. The drafted toolkit included the infection-prevention recommendations and topic-specific supporting materials that were inductively derived through qualitative and quantitative analyses. The drafted recommendations were stratified by care delivery domain, phase of dLVAD care, and intended stakeholder.

Expert Feedback, Refinement, and Pilot Testing of the Toolkit

During Stage 3, the analytical team (SS, PPC, LMC, DSL) conducted several rounds of multi-method feedback to iteratively refine the toolkit recommendations, supporting materials, and implementation resources. The clinical and quantitative team members prioritized feedback, including but not limited to ranking the relative importance of each drafted recommendation and editorial suggestions to the toolkit statements. The analytical team developed criteria (see Table S2) to consider editorial suggestions (e.g., syntax

and clarification) for each recommendation, and more broadly discussed recommendation revisions with the study team.

Next, the analytical team conducted two rounds of focus group engagement with the dLVAD-AT. The dLVAD-AT consisted of a purposeful sample of multidisciplinary subject matter experts. The dLVAD-AT members were affiliated with nine hospitals across the spectrum of infection rates (6 low-performing, 1 middle-performing, 2 high-performing). Subject matter experts agreed to provide quantitative (ratings of prototype recommendation content and phrasing) and qualitative (open-ended comments) survey feedback before each focus group. The 10-item surveys incorporated Likert responses: 1=Strongly agree; 2=agree; 3=neutral; 4=disagree; 5=strongly disagree. Using a “think out loud” approach, the focus groups involved soliciting feedback concerning the toolkit’s: (1) content, usability, acceptability, and likelihood of impact (during the first round of engagement); and (2) anticipated resource needs (e.g., personnel) as well as facilitators and barriers for implementing the proposed toolkit (during the second round of engagement). Using the revision approach described above, the quantitative and qualitative feedback was integrated before and after each round to enhance all toolkit components.

The toolkit was piloted at the study institution, a middle-performance hospital, based on strong engagement with members of the VAD team that enhanced pilot data collection. The pilot focused on gaining feedback on the toolkit’s usability and likelihood of success. The institution’s VAD Program Manager received feedback electronically and through discussions during dLVAD team meetings. The qualitative feedback was reviewed and incorporated into an iteratively enhanced toolkit.

RESULTS

This mixed methods study involved 73 VAD team members from eight hospitals (interviews, Stage 1) and 14 dLVAD-AT participants (focus groups, Stage 2). Interviewees included clinical and operational VAD team members from low (n=36), medium (n=11) and high (n=26) performing hospitals. The characteristics of participants are listed in Table 1 and the characteristics of hospitals are summarized in Table S4.

Findings derived from analyses of the qualitative interviews supported the development of 19 infection prevention themes (Table 2). Broadly, the themes intersected multiple levels and factors (e.g., patient, clinician, hospital) underlying infection risk, VAD infection prevention processes (e.g., patient selection, patient education, intra-operative care, post-discharge care, infection surveillance, provider and patient education), and facilitators and barriers to infection prevention adherence. Initially, 23 preliminary recommendations were drafted from these themes and subsequently categorized by context and anticipated stakeholder group. The contextual domains reflected the recommendations’ focus on infection prevention (e.g., culture of collaboration, feedback reporting, data quality) and phase of dLVAD care (e.g., pre-implantation to post-discharge, and longitudinal phase of care). Each recommendation had distinct goals, required resources, and implementation requirements. As such, each recommendation was aligned with any of the four target stakeholder groups: VAD Program, Clinicians, Patients and caregivers, and VAD leadership.

The recommendations were further edited by the substantive feedback from both study team members and the dLVAD-AT focus groups. For instance, 11/39 recommendations received syntax and clarifying revisions. A total of 9/39 recommendations received changes, with a further 3/39 receiving contextual clarification. A minor portion of 5/39 recommendations were either split or combined, and 2/39 were preserved in their initial form. Consequently, the total number of recommendations grew from 23 to 39. Illustrative examples of the iterative nature of the recommendations are documented in Table S2.

The focus groups generated feedback related to the toolkit's organization, supporting materials, and method of dissemination. Some of the input resulted in including: 1) an executive summary; 2) implementation materials to support team meeting discussions; 3) implementation instructions to select and tailor recommendations; 4) alternative formatting of the recommendations; 5) data collection worksheets; and 6) research and methodological evidence supporting the toolkit's content.

Table 3 summarizes the quantitative survey ratings related to the toolkit's recommendation statements, content, organization, and ease of implementation. Overall, all four areas of target stakeholder group recommendations received favorable mean ratings (range: 1.6-1.8). On a 5-point scale (from strongly agree to strongly disagree), the mean ratings across domains ranged from 1.5 to 2.4. The most and least favorable ratings were attributed to the organization of recommendations and ease of implementation, respectively. The qualitative open-ended comments of dLVAD-AT members support the importance of simplifying recommendation wording to maximize toolkit uptake and the need for additional resources to assist in prioritizing and delineating concrete processes for implementing the recommendations.

The final version of the toolkit contains 39 infection prevention recommendations. The recommendations span topics for four audiences: the VAD program (e.g., real-time provider communication), clinicians (e.g., multidisciplinary protocol development), patients & caregivers (e.g., engaging patient advisors in patient education), and VAD leadership (e.g., unit and service level data reporting). The packaging of the recommendations for the four audiences is intended to support programmatic priorities, resources, and implementation strategies to maximize the effectiveness of selected recommendations.

Based on stakeholder feedback, the toolkit includes a customizable, eight-step implementation guide (Figure 2). Steps 1-3 focus on assessing a VAD program's strengths and weaknesses concerning infection prevention, identifying candidate recommendations that address areas of weakness, and providing tailorable criteria to prioritize which recommendations to implement. Steps 4-6 focus on identifying the roles and responsibilities of VAD team members during the implementation of the recommendations, developing a plan of action, and collecting discrete data elements to evaluate the implementation intervention. Steps 7-8 focus on implementing the action plan with periodic monitoring and reporting back to the VAD team. The toolkit has been designed to support the implementation of selected recommendations over iterative intervention cycles.

The toolkit includes accompanying resources to support the implementation of the recommendations. Resources (e.g., fact sheets regarding the rate and impact of infections, interactive worksheets) have been designed to support team discussions and the planning, implementation, and evaluation of hospital-specific action plans. For example, the toolkit resources include a prioritization table to support team-based decision-making regarding choosing recommendations. This guide enables teams to rate the anticipated impact and ease of implementation of each recommendation - a key gap noted during dLVAD-AT focus groups. Other implementation materials include an L-V-A-D-S assignment matrix that supports the delegation of roles and tasks to VAD team members: Leader (e.g., administrative and institutional support), Validator (e.g., data navigation training), Actor (e.g., educational lead), Delegator (task delegation authority), Supporter (e.g., data gathering support). These resources have been developed to support the implementation, evaluation, and anticipated effectiveness of hospital-specific infection prevention initiatives.

Pilot Feedback on the Toolkit

Two VAD team members practicing at a high-volume dLVAD implanting hospital piloted the toolkit. The study team received qualitative feedback, which indicated preliminary evidence of the toolkit's acceptability regarding the feasibility of implementing the toolkit within their VAD programs. Overall, VAD team members noted the importance of the toolkit's collaborative engagement materials and customizable implementation support. One respondent shared, "It's helpful to have a step-by-step guide to help programs work through the infection prevention/management process. It can be hard to know where to start." Respondents favorably commented on the ability to tailor the implementation of the recommendations: "I appreciate how you mention this should be tailored to each individual program based on context. I think it's important to highlight it's not one-size-fits-all." However, respondents shared concerns about the toolkit's length and complex organizational structure that may inhibit its use, especially for busy clinicians. Accordingly, one respondent offered suggestions to condense the toolkit to make it "easy to navigate, concise, and user friendly." The study team received additional suggestions to refine the wording of the recommendation statements. The analytical team reviewed the feedback and responsively advanced the toolkit's anticipated effectiveness by creating an interactive website (<https://lvadinfectionpreventiontoolkit.org/>) to disseminate the toolkit, Figure S2.

DISCUSSION

This large-scale, multistage, mixed methods study advances determinants of and targeted action plans for reducing infections following dLVAD implantation. This study makes the following three important contributions. First, this study is among the first to leverage a multistage mixed methods research design to evaluate determinants of infections in this setting. The integration of qualitative and quantitative findings supports the development of contextualized and evidence-supported infection prevention recommendations grounded in the perspectives and ongoing practices of dLVAD implanting hospitals nationwide. Second, this study is among the first to develop evidence-supported infection prevention recommendations that span the acute and longer-term post-implantation periods. Third, this

study is among the first to leverage focus groups with VAD team stakeholders to design implementation materials to advance local adoption.

More than 40%¹ of patients undergoing dLVAD are at risk for developing a spectrum of infections within 1 year of implantation, reaching nearly 60%¹⁸ within 2 years. Patients developing infections in this setting are, in turn, exposed to an increased risk for further morbidity and mortality, as well as decrements in quality of life.^{7,11,19} Large-scale interhospital variability in post-implantation infections is unaccounted for by differences in patient case mix.^{9,20} Fragmentation within a hospital's care delivery network (defined through network analyses to include the number of shared patients among clinicians) has been identified as a significant predictor of outcomes, including infections and mortality.⁸

To date, many infection prevention initiatives have been limited in how they incorporate stakeholder input.^{8,21} The present study integrated qualitative and quantitative findings to design a customizable infection prevention toolkit. The formative mixed methods assessment stage leveraged quantitative analyses of merged clinical registry datasets to select candidate hospitals (based in part on their risk-adjusted 90-day infection rates) for qualitative inquiry. Next, infection prevention themes emerging from the qualitative analysis of stakeholder interviews were merged with quantitative findings to identify emerging themes that served as the foundation for an infection prevention toolkit. Last, the qualitative and quantitative data generated from surveys and focus groups with our dLVAD-AT members supported the development of iteratively enhanced recommendations and implementation resources.

Prior structured literature reviews and surveys across dLVAD practices have identified risk factors for and interventions to prevent infections. Broadly, these studies have focused on: (1) patient risk factors²⁰ (e.g., obesity, malnutrition, hypoalbuminemia); (2) non-patient factors⁸ (e.g., increasing center experience); (3) intraoperative strategies^{8,21} (e.g., silicone-skin interface at the driveline exit site); (4) diagnosis and early treatment of infections²⁰ (e.g., use of F-fluorodeoxyglucose positron emission tomography, serial surgical debridement); and (5) driveline care²² (e.g., driveline immobilization). While findings from these studies inform which practices “work”, they lack insight into barriers and facilitators for advancing their implementation (e.g., patients may lack a stable caregiver to facilitate sterile driveline dressing changes, patients may have inadequate access to sterile dressing change kits). The present study's qualitative interviews with key stakeholders across low, medium, and high-performing hospitals revealed the role of a VAD team's structure and function to (1) address barriers for advancing evidence-supported infection prevention practices and (2) support quality assurance, standardization of practices, and targeted improvement. Uniquely, the present study advances the development of a toolkit, with content and recommendations specific to the VAD program (e.g., real-time provider communication), clinicians (e.g., multidisciplinary protocol development), patients & caregivers (e.g., engaging patient advisors in patient education), and VAD leadership (e.g., unit and service level data reporting). Notably, the resources contained within the toolkit (e.g., recommendation prioritization table) enable VAD program team members to prioritize recommendations based on each hospital's specific context (e.g., resources and staffing) and required resources for implementing the recommendations.

Solely publishing findings that support evidence-based infection prevention practices is insufficient for advancing their everyday use across diverse healthcare contexts. The field of implementation science has defined the strategies (e.g., promoting adaptability and engaging key stakeholders)²³ necessary to advance the incorporation of evidence-supported infection prevention practices within healthcare delivery systems. The present study leveraged a stakeholder advisory committee composed of VAD-team members (e.g., cardiac surgeons, cardiologists, VAD Coordinators, infectious disease personnel) to identify key facets of the toolkit's content, resources, and dissemination plan to facilitate its adaptability and use across a wide range of institutional settings (e.g., hospital volume, infection performance). This feedback was leveraged to iteratively enhance the toolkit's content and resources (e.g., an 8-step implementation guide) to promote its implementation across VAD programs. The prototype toolkit was further piloted and disseminated online to enhance its usability and anticipated effectiveness. At present, the study team is collaborating with a web design team to utilize key pilot feedback (e.g., length and organizational structure) to further refine and customize the toolkit for web-based dissemination. The interactive website (<https://lvadinfectionpreventiontoolkit.org/>) also enables users to provide feedback on the toolkit to iteratively enhance its usability and anticipated effectiveness. Aligned with the iterative Plan-Do-Study-Act (PDSA) cycle, these iterative processes will crucially inform planned testing of the toolkit across VAD centers nationwide.

This study's findings should be considered in light of several limitations. First, while the toolkit was developed in conjunction with clinical and non-clinical VAD stakeholders, the toolkit's anticipated effectiveness would be enhanced by incorporating perspectives that span geography, lived experiences (i.e., patient and caregivers) and expertise (e.g., social workers, patient navigators). Second, while this large mixed methods study leveraged a national advisory group and pilot testing to advance the toolkit's usability and acceptability, further evidence (e.g., acceptability, appropriateness, feasibility) across VAD programs is warranted.

This multistage mixed methods study integrated national registry and claims-based data on dLVADs with qualitative interviews to develop an adaptable infection prevention toolkit. The toolkit includes accompanying resources as well as implementation and dissemination materials to support its use. Future work should evaluate the effectiveness of implementing this infection prevention toolkit across diverse dLVAD settings. More broadly, the integration of stakeholder feedback into the development and design of a customizable toolkit may be used as a methodological approach for other high-risk operations.

CONCLUSION

This large, multi-stage mixed methods study significantly advances infection prevention initiatives in the context of dLVAD implantation. Uniquely, this study integrates key determinants of infections with prevention practices and dLVAD team member perspectives to develop a practical, customizable infection prevention toolkit. This toolkit is designed to support implementation across dLVAD implantation settings by addressing the needs of VAD programs, clinicians, patients, caregivers, as well as hospital and service-line leaders. While further evaluation is warranted to assess the toolkit's effectiveness and

adaptability across broader contexts, this work lays a strong foundation for future efforts aimed at improving infection outcomes in high-risk surgical populations. More broadly, the methodological approach and collaborative framework presented here may serve as a model for similar initiatives in other complex healthcare contexts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Non-Standard Abbreviations and Acronyms:

dLVAD	Durable Left Ventricular Assist Device
dLVAD-AT	durable left ventricular assist device Toolkit Advisory Team
Intermacs	Interagency Registry for Mechanically Assisted Circulatory Support
MOMENTUM 3	Multicenter Study of MagLev Technology in Patients Undergoing Mechanical Circulatory Support Therapy with HeartMate 3
STS	The Society of Thoracic Surgeons
VAD	Ventricular Assist Device

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What is Known:

- Six out of every 10 patients develop an infection within 2 years of durable left ventricular assist device (dLVAD) implantation.
- Infections contribute to an increased risk of major morbidity and mortality.
- Post-dLVAD infection rates vary across hospitals, even after risk adjustment.

What the Study Adds:

- A customizable toolkit of infection prevention recommendations was developed and pilot tested using mixed methods approaches.
- Recommendations focus on modifiable aspects of organizational structure, patient care, patient education, and quality reporting.

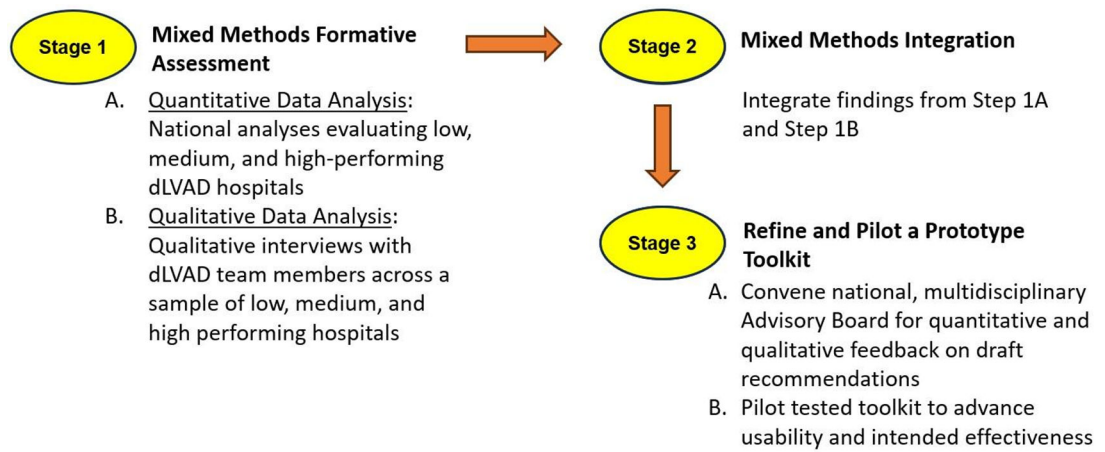


Figure 1. Study procedural diagram
dLVAD: Durable Left Ventricular Assist Device

How to use the Toolkit in Collaboration with your institutional LVAD Team (8-step process):

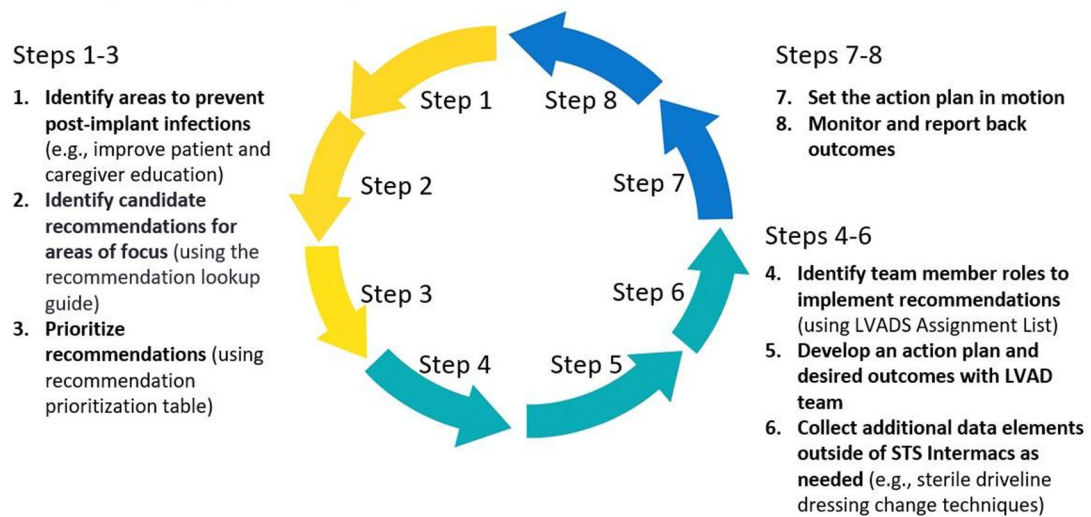


Figure 2. Eight-step process of the toolkit

Left Ventricular Assist Device (LVAD)

Interagency Registry for Mechanically Assisted Circulatory Support (Intermacs)

The Society of Thoracic Surgeons (STS)

Table 1. Characteristics of Participants

Interview and Advisory Team Participants (n=87)			
	Low Performing Hospitals	Middle Performing Hospitals	High Performing Hospitals
Participant Hospital Volume, median (IQR)	192 (169-213)	189 (189-189)	33 (32-96)
90-day Infection Rate per 100 patient-months	26.18	5.93	2.52
Role			
<u>Physicians</u> n=38 (44%)			
Anesthesiologist/Intensivist	3 (3.4%)	1 (1.1%)	3 (3.4%)
Cardiac Surgeon	4 (4.6%)	1 (1.1%)	4 (4.6%)
Heart Failure Cardiologist	6 (6.9%)	1 (1.1%)	4 (4.6%)
Hospital Epidemiologist	3 (3.4%)	2 (2.3%)	0 (0.0%)
Infectious Disease Specialist	3 (3.4%)	1 (1.1%)	1 (1.1%)
Quality Officer	1 (1.1%)	0 (0.0%)	0 (0.0%)
<u>Advanced Practice Provider</u> n=10 (11%)			
Inpatient Advanced Practice Provider	3 (3.4%)	1 (1.1%)	2 (2.3%)
Outpatient Advanced Practice Provider	1 (1.1%)	1 (1.1%)	2 (2.3%)
<u>Nurse</u> n=32 (37%)			
Cardiac Surgery Intensive Care Unit Nurse	3 (3.4%)	1 (1.1%)	1 (1.1%)
Floor Nurse	1 (1.1%)	0 (0.0%)	0 (0.0%)
Infection Prevention Specialist Nurse	2 (2.3%)	0 (0.0%)	1 (1.1%)
Nurse Specialist	1 (1.1%)	0 (0.0%)	2 (2.3%)
Outpatient Nurse	0 (0.0%)	0 (0.0%)	1 (1.1%)
Quality Officer Nurse	1 (1.1%)	0 (0.0%)	1 (1.1%)
Ventricular Assist Device Coordinator	4 (4.6%)	1 (1.1%)	5 (5.7%)
Ward Nurse	3 (3.4%)	2 (2.3%)	2 (2.3%)
<u>LVAD Education Lead</u> n=3 (3%)	2 (2.3%)	0 (0.0%)	1 (1%)
<u>LVAD Specialist</u> (e.g., Infection Prevention Specialist, Perfusionist) n=4 (5%)	2 (2.3%)	1 (1.1%)	1 (1.1%)

LVAD: Left Ventricular Assist Device

Table 2. Illustrative Themes and Quotations from the Qualitative Interviews

Selected Theme	Illustrative Quotation
<u>Infection Data Access</u> : Up-to-date unit and service-line level infection data (e.g., rates, prevention practices) should be provided to members of the LVAD team, including consulting services, to advance evidence-based care and outcomes.	"[Our internal database] has gone out for many years which is the advantage of having programmatic data collections where they may be catching things obviously that we're missing. 'Cause anyone who has a VAD is at risk for infection anytime, for however long they have the device in place, not just for 90 days." – Hospital Epidemiologist, Hospital 4
<u>Well-rounded provider education</u> : Teaching evidence-based infection-prevention practices should balance device-related concerns with patient quality of life, such as their ability to participate safely in pre-implant hobbies and to engage in functional activities pre- and post-implant.	"I think that the VAD-apoluza's a wonderful thing...I think it's a great opportunity for everyone to ask questions, and be re-exposed to the content. Uh, there's a lot of information that's thrown at you in orientation. We have a ton, like a very robust classroom, front heavy orientation, for our cardiac unit... so I think it's a great refresher." – Ward Nurse, Hospital 5
<u>Standardizing Infection Prevention Practices</u> : Efforts should be made to raise awareness of and disseminate evidence-based infection prevention practices across clinicians in varied care settings.	"So,...we do have...a big document that is call[ed], ...LVAD,...Clinical Practice Guidelines. It's a document that is published on...our intranet. Uh, the person in charge of,... coordinate and, and..., takes the lead on, on reviewing those guidelines every 2 years we do it, is our,... clinical, specialist... she's in charge of, keepin' those,... CPG's updated. Whenever we review them, which is every 2 year[s] more or less,..... the different people take the lead on different aspects." - Cardiac Surgeon, Hospital 3
<u>Offering a Reference for Standards of Care</u> : Efforts to implement standards of care may benefit from an accessible, up-to-date repository of infection-prevention resources, policies, and procedures (e.g., hand hygiene program, line replacement protocol, patient and caregiver education tips).	"I do think there's a lot more than we can do, especially within larger institutions that have multiple different hands in the pots, and very, the different silos at work. Just making sure that what works for Service A also works for Service B, and that is actually done in the same light." -- Infection Prevention Specialist, Hospital #1

Abbreviations: Ventricular Assist Device (VAD); Left Ventricular Assist Device (LVAD)

Table 3. Summary Ratings of the Toolkit Recommendations

Domain	Program (n=11)		Clinician (n=12)		Patient & Caregiver (n=5)		Leadership (n=14)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Recommendation Content	1.5	0.8	1.7	1	1.4	0.7	1.5	0.8
Recommendation Phrasing	2	0.8	1.7	0.7	1.9	0.6	1.5	0.8
Organization of Recommendations	1.5	0.5	1.6	0.7	1.6	0.5	1.2	0.4
Ease of Comprehension	1.7	0.8	1.6	0.9	1.4	0.7	1.5	0.8
Ease of Implementation	2.2	0.7	2.4	0.9	2.6	0.7	2.3	0.9
Relevance to My Practice	1.8	1.1	1.7	1	1.7	0.7	1.5	0.5

Note: Surveys were administered using a Likert Scale (1=Strongly agree; 2=agree; 3=neutral; 4=disagree, 5=strongly disagree). Lower values indicate higher level of agreement with the rating of that domain.