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Original Research Article

Enhancing efficiency in length of stay for ventricular assist device patients during routine right heart catheterization

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ABSTRACT

Background: Left ventricular assist device (LVAD) patients undergoing right heart catheterization (RHC) were traditionally admitted pre- and post-procedure for inpatient anticoagulation bridging. From 2021 to 2025, transition to outpatient RHC and eliminate length of stay (LOS) using an IACT-PDCA initiative enhanced with virtual ventricular assist device (VAD) clinic reminders.
Methods: In 2021-2024, patients were instructed to complete international normalized ratio (INR) testing 3 days before RHC. In early 2025, a retrospective review revealed cancellations due to missed INR testing. Consequently, we integrated a virtual VAD clinic in 2025, with reminders initiated 7 days prior to ensure timely INR testing.
Results: LOS was reduced to zero days; INR-related cancellations were nearly eliminated. Estimated cost savings totaled ~875,744 SAR.
Conclusions: A staged quality improvement approach using IACT-PDCA and virtual care effectively transformed RHC workflow into a sustainable outpatient model.

Keywords: Ventricular assist device, Right heart catheterization, Length of stay, Quality improvement, Virtual clinic

INTRODUCTION

Patients with Left ventricular assist device (LVADs) for end-stage heart failure routinely undergo RHC for many purposes, including hemodynamic optimization and pre-transplant evaluation. Prior to 2021, LVAD patients at our center were hospitalized before and after right heart catheterization (RHC) for anticoagulation bridging with heparin until a therapeutic international normalized ratio (INR) was achieved. This method prolonged hospitalizations, increased healthcare expenses, and subjected patients to unnecessary inpatient risks, including infection and functional deterioration.[1,2] Frequent hospitalizations and extended lengths of stay adversely impact the quality of life in patients using mechanical circulatory support devices such as LVADs.[3]

A quality improvement project was implemented utilizing the IACT framework (Identify-analyze-change-transform) and enhanced through PDCA (Plan-do-check-act) cycles. The objective was to safely transition RHC to an outpatient procedure. Starting in 2021, patients were given instructions to check their INR three days prior to their planned RHC. Although this substantially decreased the length of stay (LOS), a 2025 evaluation indicated that overlooked INR testing resulted in numerous cancellations.

Telemedicine was then integrated via the virtual ventricular assist device (VAD) clinic, which provided automatic reminders seven days before to RHC to guarantee the completion of INR testing. This concept utilized increasing global and regional data endorsing telemedicine for chronic illness and anticoagulant

treatment. Research indicates that virtual clinics can effectively oversee warfarin medication, yielding outcomes comparable to those of in-person clinics, particularly in Saudi Arabia.[4,5] Throughout the COVID-19 pandemic, virtual care was essential for ensuring continuity of care and shown comparable safety, patient satisfaction, and cost-effectiveness.[6,7] Cardiology programs in Saudi Arabia have demonstrated favorable results through telecardiology clinics, including excellent patient satisfaction and a decrease in emergency admissions.[8,7] These observations guided our choice to incorporate a virtual clinic to further improve our outpatient RHC approach.

METHODS

Study type

The performance improvement project utilizes the IACT framework and integrates iterative PDCA cycles. The analyses were descriptive and focused on process outcomes instead of hypothesis testing (Figure 1).

Study place and period

King Faisal specialist hospital and research center (KFSH and RC), Riyadh, Saudi Arabia; Jan-2019 to July-2025.

Selection criteria

We included adult (≥18 years) LVAD recipients scheduled for routine RHC at our center during the study period. We excluded urgent/emergent inpatient RHCs, non-routine indications, and patients who had undergone heart transplantation before 31-Dec-2018.

Procedure

Baseline (2019-2020): Routine RHCs were often managed through inpatient admission for anticoagulation adjustment or bridging until achieving a therapeutic INR, leading to prolonged lengths of stay.

Outpatient pathway (2021-2024): Routine RHCs were scheduled as same-day outpatient procedures. Patients were given instructions to obtain an INR three days before the RHC. Supratherapeutic INR (often >3.0) necessitated postponement or rescheduling, or, where clinically acceptable proceeded with additional precautions; several procedures were cancelled on the day of RHC due to risky INR levels or lack of results (Figure 2 and Figure 3).

Virtual clinic enhancement (2025): A virtual VAD clinic workflow has been implemented. Automated reminders began 7 days before to RHC, accompanied by follow-up calls to verify INR testing and adjust anticoagulation as necessary, with the goal to minimize same-day cancellations (Figure 2 and Figure 3).

Ethical approval

This study received ethics clearance from the institutional review board (IRB) of KFSH and RC, Riyadh, Saudi Arabia (Reference # 2255993).

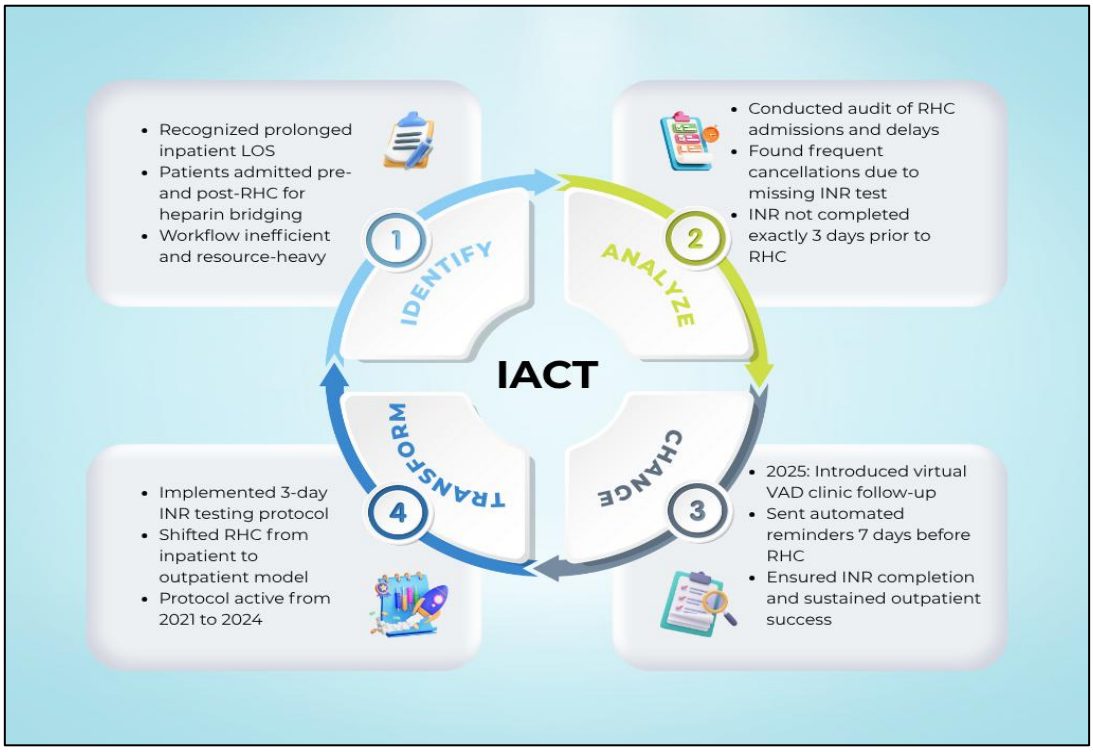

Figure 1: IACT framework for RHC workflow transformation (2021-2025). Schematic representation of the IACT framework used to guide RHC quality improvement initiative, illustrating sequential phases and feedback loops.

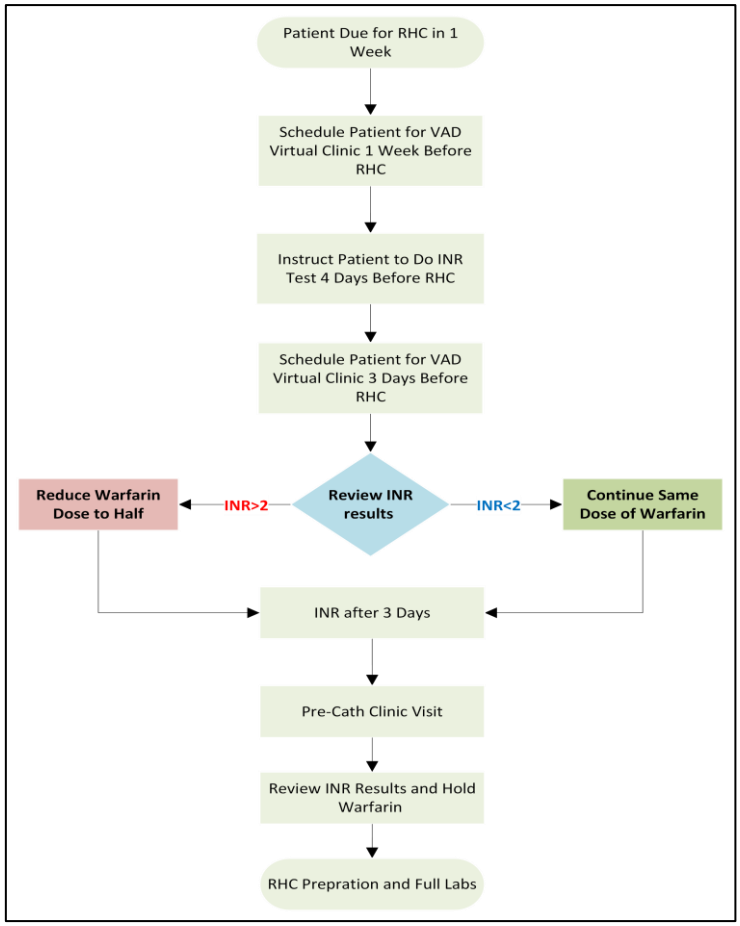

Figure 2: Pre-RHC protocol, flow diagram showing the standardized steps and INR testing process implemented for LVAD patients prior to outpatient RHC.

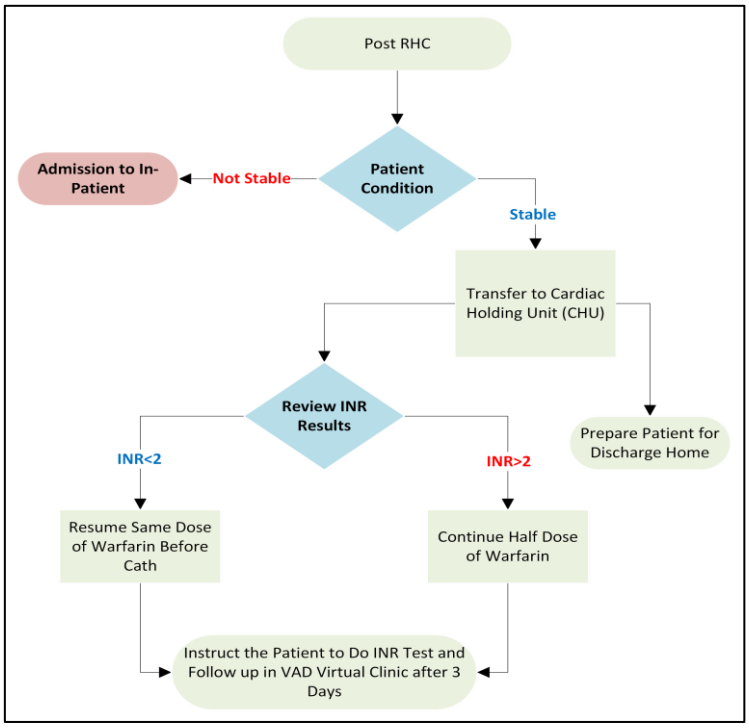

Figure 3: Post-RHC protocol, flow diagram outlining the immediate post-procedure care steps, discharge readiness assessment, and follow-up coordination in the outpatient model.

Statistical analysis

Continuous variables were presented as mean±SD and median (IQR); categorical variables as n (%). Annual RHC volumes are reported as a percentage of the total. Predefined process outcomes including LOS and INR-related complications (cancellations due to high INR; procedures performed with INR >3). The analyses were descriptive, and no formal hypothesis testing and were performed using IBM SPSS statistics, version 26 (IBM Corp., Armonk, NY).

RESULTS

Patient characteristics

Fifty-five LVAD recipients underwent routine RHC during the study period. The median age was 48.0 years (IQR 40.0-56.0); the mean±SD was 46.8±12.4 years. Male patients comprised 46/55 (84%), and female patients 9/55 (16%) (Table 1).

LOS and annual volume

At baseline (2019), routine RHCs were associated with a mean LOS of 7 days. In 2020, no routine RHCs were performed (COVID-19 service interruption). After adoption of the same-day outpatient pathway, all routine RHCs from 2021 to 2025 were completed with LOS 0 days. Annual RHC volumes were 2019=7, 2020=0, 2021=27, 2022=20, 2023=24, 2024=18, and 2025=31 (Table 2 and Figure 4).

INR-related issues

INR-related disruptions declined over time and were eliminated in 2025 following the virtual clinic enhancement. “Any INR issue” occurred in 2021: 3/27 (11%) [cancelled high INR 1 (4%); performed with INR >32 (7%)], 2022: 4/20 (20%) [3 (15%), 1 (5%)], 2023: 3/24 (12%) [2 (8%), 1 (4%)], 2024: 5/18 (28%) [3 (17%), 2 (11%)], and 2025: 0/31 (0%) (Table 2).

Table 1: Demographic and baseline characteristics of LVAD patients (n=55).

Characteristics	Value
Age (in years)	Median (IQR): 48.0 (40.0–56.0); mean±SD: 46.8±12.4
Male, N (%)	46 (84)
Female, N (%)	9 (16)

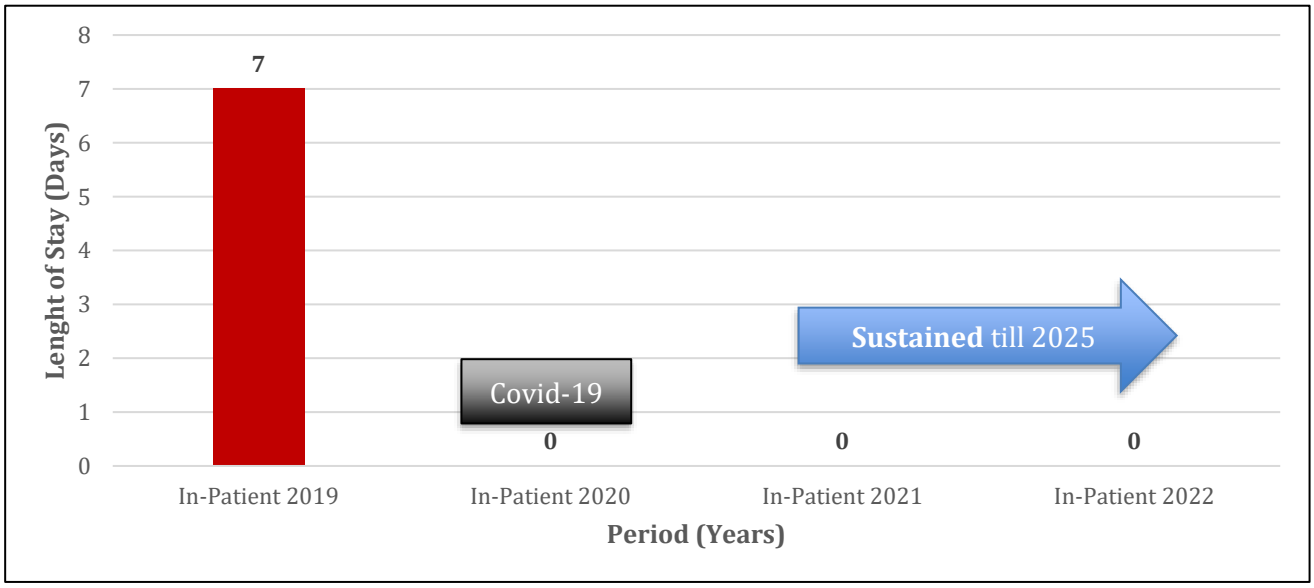

Figure 4: LOS In-patient 2019-2022. Graph comparing the LOS for LVAD patients undergoing RHC before and after outpatient transition.

Table 2: Annual RHC volume, average LOS, and INR-related outcomes (LVAD patients), 2019–2025.

Years	RHC	% of total	Average LOS, days	INR: any issue, N (%)	INR: canceled high INR, N (%)	INR: performed with INR >3, N (%)	INR: No issue, N (%)
2019	7	5.5	7	-	-	-	-
2020	0	0.0	0				
2021	27	21.3	0	3 (11)	1 (4)	2 (7)	24 (89)

Continued.

Years	RHC	% of total	Average LOS, days	INR: any issue, N (%)	INR: canceled high INR, N (%)	INR: performed with INR >3, N (%)	INR: No issue, N (%)
2022	20	15.7	0	4 (20)	3 (15)	1 (5)	16 (80)
2023	24	18.9	0	3 (12)	2 (8)	1 (4)	21 (88)
2024	18	14.2	0	5 (28)	3 (17)	2 (11)	13 (72)
2025	31	24.4	0	0 (0)	0 (0)	0 (0)	31 (100)
Total	127	100	-	-	-	-	-

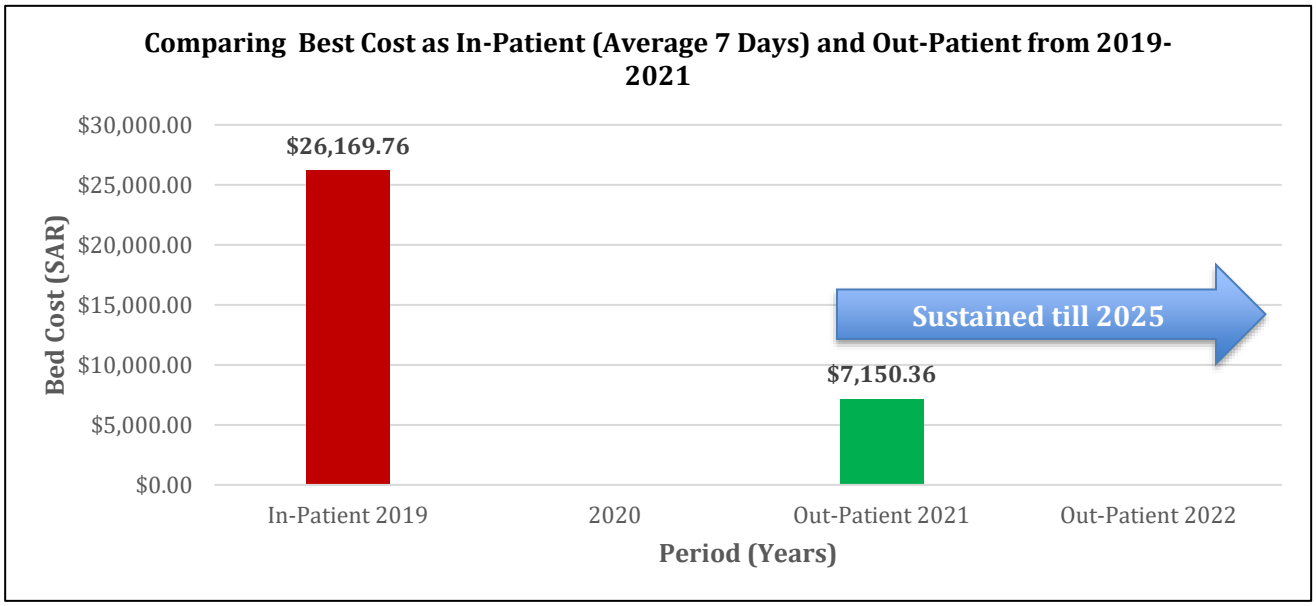

Figure 5: Bed cost 2019–2022, the chart illustrates the estimated cost savings attained through the elimination of inpatient stays for RHC.

Cost and resource utilization

Eliminating inpatient stays for routine RHC produced substantial efficiency gains. The project's cumulative estimated cost savings were ~875,744 SAR (Figure 5), reflecting the transition to zero-day stays and the prevention of avoidable cancellations.

DISCUSSION

This quality improvement initiative demonstrates that transitioning LVAD-related routine RHC from inpatient to a standardized same-day outpatient pathway is both achievable and sustainable using the IACT framework with iterative PDCA support. By removing pre- and post-procedural hospitalization, we eliminated LOS for routine RHC-mean 7 days in 2019 vs. 0 days from 2021 to 2025-with no routine RHC in 2020 during the COVID-19 service interruption. Annual volumes recovered and then exceeded baseline (2019=7; 2021=27; 2022=20; 2023=24; 2024=18; 2025=31), indicating that reliability improved without added inpatient capacity. These findings mirror other QI programs achieving LOS reduction and care transformation in cardiac and surgical populations.[9,10]

The virtual VAD clinic was pivotal for sustaining gains. With automated reminders beginning seven days prior and proactive INR follow-up, INR-related disruptions fell to zero in 2025 (0/31; 0%) after measuring 5/18 (25%) in 2024 (cancelled 3/18 [15%], performed with INR >3 2/18 [10%]) and modest rates in 2021-2023 (3/27 [11%], 4/20 [20%], 3/24 [12%]). This pattern aligns with literature showing that pharmacist-or nurse-led virtual anticoagulation services and tele-HF models improve adherence, reduce preventable cancellations, and optimize resource use.[5,7,8,11,12] Our protocol's readiness checks (scheduled INR, reminder cadence, and escalation) and day of standardization (INR verification, anticoagulation plan, ultrasound-guided access, and defined discharge criteria) likely explain the observed reliability gains.

Moreover, our findings support the growing body of literature on the role of digital health solutions in chronic disease and procedural management. Remote monitoring and pre-procedure coordination reduce the need for hospital visits, lower the risk of exposure to nosocomial infections, and allow healthcare providers to triage and prioritize patients more effectively.[5,8,11] In high-acuity cardiac populations, where procedural delays can impact outcomes, the ability to guarantee readiness before the day of intervention is critical.

From a health-economics standpoint, substituting outpatient care for routine RHC generated substantial

efficiency benefits. Using 2019 as the counterfactual (7 inpatient days per procedure), the 120 routine RHCs performed during 2021-2025 represent ~840 bed-days avoided (120×7), a tangible capacity release with direct cost offset once multiplied by the institution's per diem. Previous studies have highlighted that process redesign combined with telehealth integration can lead to sustained financial benefits, particularly when applied to high-cost specialty services.[9,13,14] Our project adds to this evidence base by demonstrating measurable cost avoidance in a Middle Eastern tertiary care context.

Integrating a virtual VAD clinic allowed timely INR coordination and significantly reduced cancellation rates. Literature supports that pharmacist-led or nurse-led virtual anticoagulation programs can maintain INR control and enhance operational efficiency.[5,11,12] Notably, a Saudi telepharmacy model during COVID-19 achieved similar anticoagulation outcomes to in-person care and saved staff time.[15]

Our intervention aligns with global and regional trends in expanding virtual care infrastructure. Health systems across the Gulf region, including Saudi Arabia's Ministry of Health, have embraced virtual platforms for chronic disease management.[7,8] Studies indicate that virtual heart failure and telecardiology programs can triage patients appropriately and intervene early when risk is identified, enhancing patient safety.[8,14]

Additionally, the COVID-19 pandemic served as a catalyst for rapid adoption of virtual care models. It revealed telehealth's potential to sustain high-quality care across chronic and high-acuity services, and its success in anticoagulation, heart failure, and even procedural planning contexts is now well established.[6,7,16,17]

Importantly, our findings also reflect core principles of sustainability, scalability, and patient safety. Similar to intensive care unit (ICU) telemonitoring and outpatient fast-track programs, our model ensured patient safety while optimizing workflow and cost.[9,13,18] Virtual care expands capacity by centralizing specialized follow-up and reducing inpatient demand, making it highly scalable. Satisfaction scores and outcome measures from comparable projects indicate virtual clinics are well-received and safe, especially when embedded into structured QI frameworks.[5,8,14,15]

Importantly, patient safety remained uncompromised throughout the transition to an outpatient model. No adverse events related to anticoagulation management or same-day discharge were reported, underscoring that with adequate pre-procedure assessment and timely INR testing, outpatient RHC in LVAD patients can be performed safely. Future research could focus on patient-reported outcomes, satisfaction levels, and long-term follow-up to further validate the model's impact.

This single-center quality improvement report presents a limited sample of routine right heart catheterizations in LVAD recipients and may lack generalizability to all settings. This IACT/PDCA-driven improvement effort lacks contemporaneous control and relies on descriptive analysis, which may render the results susceptible to unmeasured confounding and secular trends. Certain operational components (e. g., the timing of INR testing conducted outside) were inadequately documented, and outcomes beyond LOS and cancellations were not sufficiently powered for inference. Cost estimates depend on internal bed-day assumptions instead of comprehensive cost accounting. A prospective, multi-center assessment, encompassing patient-reported outcomes and a rigorous economic analysis, is necessary.

In conclusion, this initiative reflects a broader shift in cardiovascular care towards decentralization, virtual integration, and efficiency optimization. By demonstrating that outpatient RHC for LVAD patients is safe, cost-effective, and sustainable, our study provides a framework for similar transformations across cardiac and non-cardiac procedural services.

CONCLUSION

Between 2021 and 2025, implementation of an IACT-PDCA-guided QI protocol with virtual VAD clinic support transformed RHC from an inpatient to a zero-day outpatient redesign, eliminating LOS, reducing cancellations, and generating significant cost savings. The model provides a reproducible framework for streamlined care in other specialty procedures.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee IRB of King Faisal Specialist Hospital and Research Center, Riyadh, Saudi Arabia (Reference # 2255993).

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