Pediatric Cardiology
https://doi.org/10.1007/s00246-023-03351-2

REVIEW

Enhancing Quality of Congenital Heart Care Within Resource-Limited Settings

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Received: 28 July 2023 / Accepted: 9 November 2023

Abstract

Over 90% of the world's children with congenital heart disease (CHD) are born in the resources poor settings of low- to middle-income countries (LMICs). The shortfall in human and material resources and dysfunctional health systems leads to poor quality of care (QoC) which contributes substantially to suboptimal outcomes of patients with CHD in LMICs. Notwithstanding these challenges, it is possible to develop a quality improvement (QI) framework that can have a significant impact on outcomes and prevent a number of deaths. In this review, we examine the common barriers to implementing effective QI processes in LMICs. Using examples of successful QI initiatives in LMIC, we propose a broad framework that focuses on simple, yet effective measures involving cohesive efforts of all key participants guided and nurtured by a leadership that strongly values QoC.

Keywords Quality improvement (QI) · Low- to middle-income countries (LMIC) · Congenital heart disease (CHD)

Introduction

Congenital heart disease (CHD) remains the most common congenital malformation and accounts for the greatest number of infant deaths related to birth defects [1]. The incidence of CHD is relatively constant according to the birth rate, with approximate prevalence of 8 per 1000 live births, estimating to 1.2 million children born globally with CHD each year [2, 3]. Ninety percent of children with CHD are born in low- to middle-income countries (LMICs) [4]. Data from 2017 showed that CHD resulted in approximately 261,247 deaths and 589,479 years lived in disability across the globe. A systematic analysis on global burden of CHD revealed that the most CHD-related mortality among infants occurred in LMICs. Despite a 4.2% rise in the global prevalence of CHD, there has been a remarkable (60%) reduction in the estimated number of CHD-related deaths in high-income countries (HICs). This decline can be largely attributed to advancements in technology, skill development, and improvements in the quality of care (QoC) [5, 6]. QoC is the degree to which the healthcare services increase the likelihood of better outcomes [7]. Quality improvement (QI) refers to a systematic approach guided by data to improve the QoC [8].

A significant disparity in outcomes exists between HICs and LMICs, primarily stemming from differences in disease burden and inequity in available resources and QoC [5]. This also leads to preventable patient safety problems [9]. Because humans and poorly designed systems are vulnerable to error, it is important to decrease the risk of unnecessary harm and level of error to an acceptable minimum [10]. Thus, it is critical that an effective culture promoting quality and patient safety is established in these systems. There are many published reports describing methods of designing and supporting pediatric cardiac surgery programs in LMICs but there is limited emphasis on the importance of QI and the

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Published online: 20 December 2023

steps involved in QI initiatives [11]. It is imperative that individual or national pediatric and congenital heart disease (PCHD) care strategies adopt QI processes to improve QoC of a CHD patient at each level of facility which caters to patients with CHD, i.e., from community health centers to specialized CHD facilities (Fig. 1) [12]. Learning from successful QI initiatives in HIC and LMICs, we propose a comprehensive framework centered on impactful measures that are relatively easy to implement. This framework emphasizes the collaborative and coordinated efforts of all key stakeholders, guided and fostered by leadership that places a high priority on the QoC.

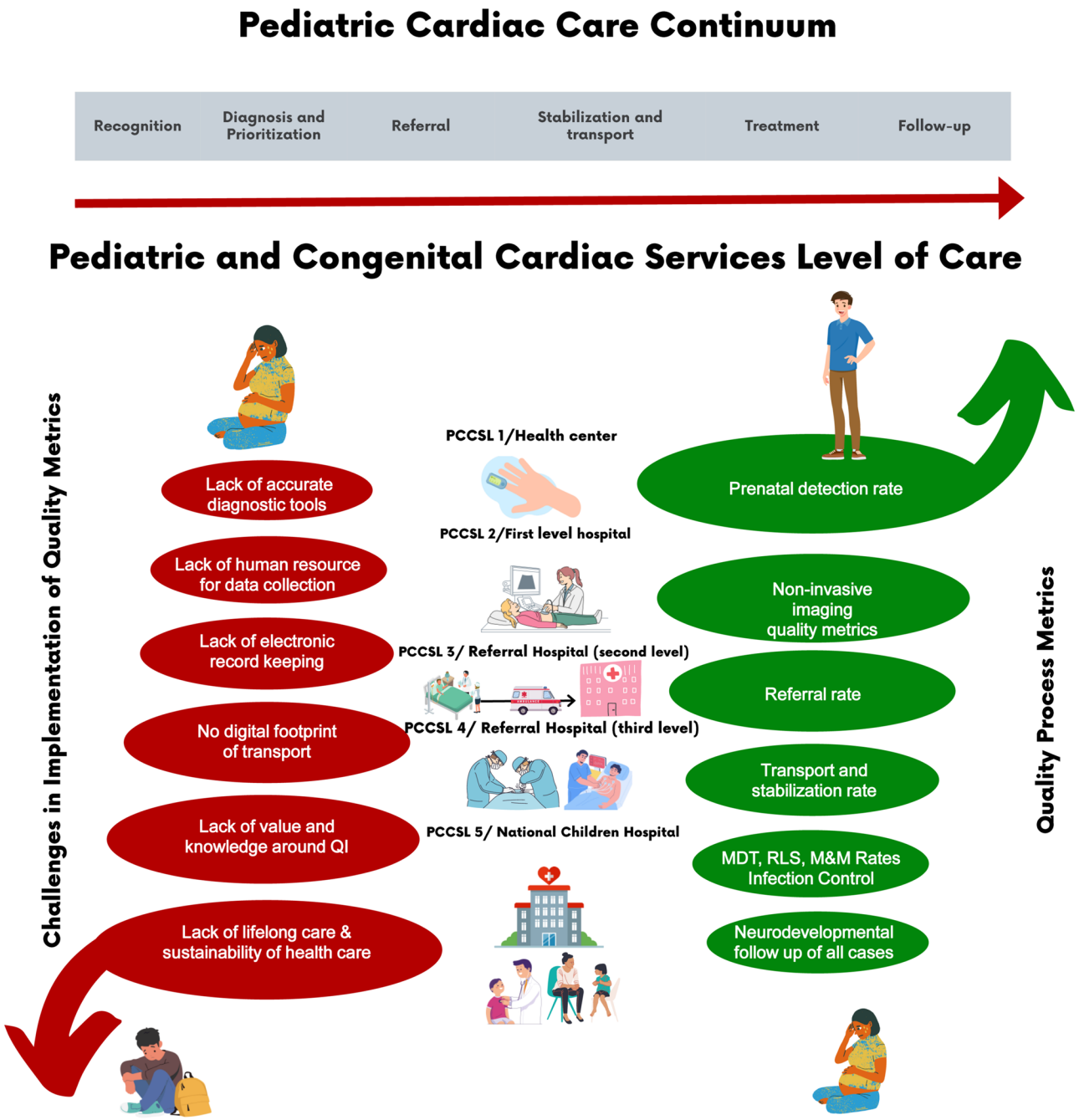

Fig. 1 Metrics for QI framework at each PCHD care level in LMIC

Methodology

We conducted an extensive literature search to identify relevant studies on QI initiatives in CHD from HIC and LMICs. Based on the insights gathered from the literature review, we formulated a framework that encompasses quality metrics (QMs) at various levels of CHD care. Our review paper includes three sections, each covering distinct aspects.

1. Illustrating the significance of QI in CHD with specific examples from LMIC.
2. Guiding principles for delivery of quality CHD care in low resource settings.
3. Proposed QI framework with implementation strategies.

Significance of QI in PCHD, Specific Examples From LMICs

The conventional view that surgical outcomes of a patients with CHD are related only to the surgeon's technical skill has been replaced by an evolving and broader framework wherein it is acknowledged that healthcare outcomes are affected by multiple elements in a highly integrated and complex ecosystem [13]. Each element, including preoperative diagnosis, planning of surgery or catheter intervention, post-operative/intervention management, and lifelong care, plays a pivotal role in the outcomes of CHD patients and encompasses the care continuum as shown in Fig. 2. QI initiatives along the entire CHD care continuum are crucial for optimizing patient care and outcomes. Each element contributes to the power of marginal gain in improving the QoC. The scope of these QI activities can evolve over a period of time from basic patient safety measures and institutional/local internal audits to multi-institutional QI collaborative. Through the collection of audited data from multiple institutions, these QI registries aid in the development of risk-stratified outcome metrics. These metrics can be employed to assess and compare the performance of individual programs with other centers, thereby facilitating collaborative learning and collective improvement efforts. Data visualization, benchmarking, and timely response to improvement opportunities enable QI culture [14] and have driven the paradigm shift in outcomes of CHD seen in HICs [15, 16]. Table S1 summarizes the network of registries from HIC around different elements of CHD care. Sustainable QI practices in HIC are encouraged by better governance, pay for performance (P4P), and requirements for compliance with best practice. Many of these factors are tied to reimbursement, national hospital rankings, and patient satisfaction [17], all of which further incentivize continuous improvements.

The significance of QI in CHD care in LMIC cannot be overstated [18]. Limited published literature exists regarding QI initiatives in CHD care originating from LMICs and include the following.

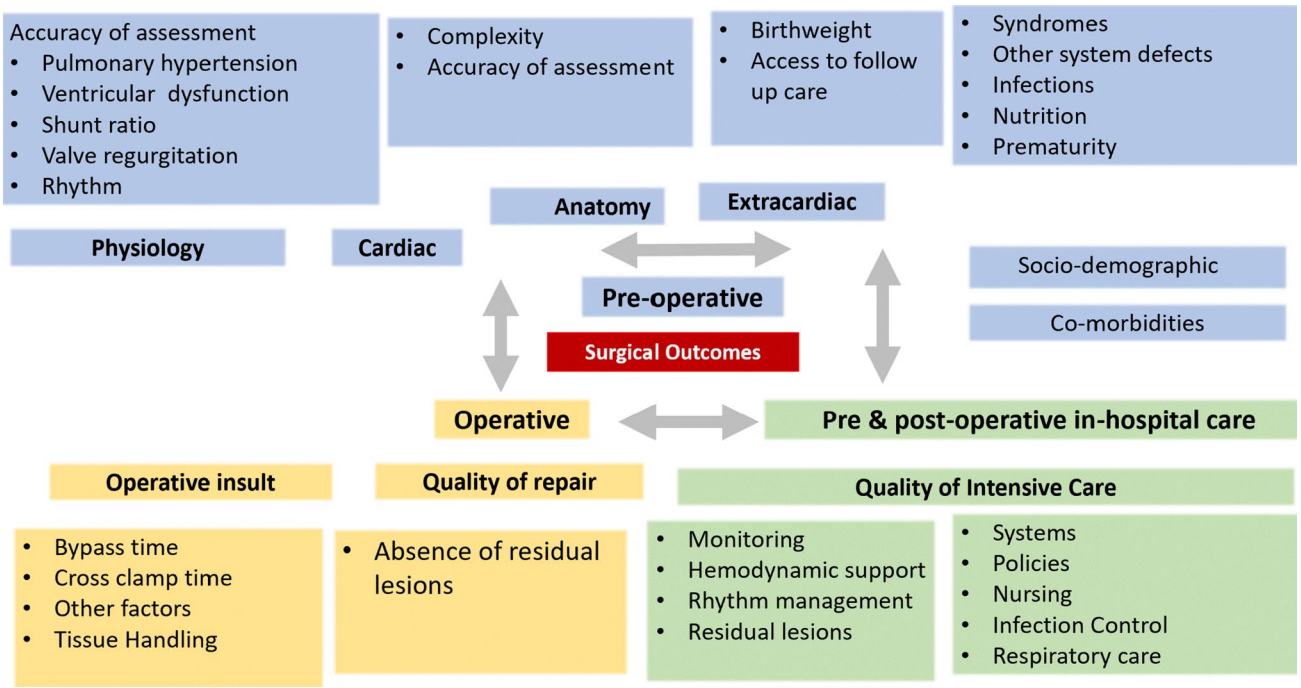

Fig. 2 Elements that determine outcomes after cardiac surgery in children

Individual/Single Institution-Based QI Initiatives

- The impact of a QI initiative in an echocardiography (ECHO) laboratory in a low resource setting was studied by Mohsin et al. A key driver diagram (KDD)-based QI change strategy was used to drive improvement in all the processes, and the overall quality of the ECHO lab without any substantial increase in resources or cost [19].
- A reduction in radiation dose of cardiac computed tomography angiography (CCTA) and cardiac catheterization laboratory was demonstrated using a KDD-based change strategy [20, 21].

Multi-institutional QI Collaboratives

Initiated in 2007, International Quality Improvement Collaborative (IQIC) is the best known multi-institutional QI effort for congenital heart care in LMICs. This collaborative collects data from LMIC CHD programs, provides detailed reports including risk-adjusted outcomes and using a KDD-based change strategy actively promotes QI initiatives across the participating sites. At present, 74 sites from 27 countries have enrolled in IQIC. Clinical outcomes tracked in the database are risk-adjusted mortality (in-hospital and 30-day post-surgery) and major post-operative infections (surgical site and bloodstream) [22]. Recently, major post-operative morbidities such as tracheostomy, diaphragm paralysis, need for pacemaker placement, and reintubation are also being tracked. Over years, cumulative IQIC data, along with single-center experiences have demonstrated significant improvement in outcomes [23, 24].

Table 1 provides an overview of the challenges encountered by each QI initiative, along with the corresponding solutions. These challenges encompass issues such as the availability of tools and resources for collecting actionable data, a deficiency in knowledge regarding QI methods, the strain on healthcare systems, and the relatively low priority assigned to QI by hospital administration or health ministries [25]. These examples have also demonstrated improved outcomes and underscored the importance of standardization and the development of systems that ensure consistent QoC.

Guiding Principles for Delivery of Quality PCHD Care

The guiding principles for providing high-quality PCHD care in resource-constrained setting have previously been documented [26]. The following salient features are worth reiterating:

- *Advocating for the patient and family:* All caregivers must have a strong commitment to serving every child in the region. A thorough understanding of each family's economic situation in relation to the cost of care enables implementation of cost-effective management strategies, including QI initiatives.
- *Focus on simple QI measures that significantly impact outcome*: Highly effective QI measures that lead to improved outcomes are not necessarily costly. For example, investing in infection control estimated to have a return on investment of up to $236 by preventing healthcare-associated infections (HAIs)) [27]. Another simple and highly effective QI intervention is the implementation of the surgical safety checklist.
- *Reluctance to accept expensive new technology without proof of incremental benefits*: New technology in healthcare can be expensive, and in a number of countries with limited public health funding, there is often insufficient consideration of cost versus benefits when acquiring advanced equipment, like, Hybrid Cath lab-operation theater suites and three dimensional mapping and printing. While these technologies may be presumed to be superior, achieving excellent outcomes may not always depend on them. Maintenance costs are also a significant financial burden [28].
- *Systematic documentation of practices, challenges, and outcomes through contextually relevant research*: Documentation through peer-reviewed publications introduces considerable rigor and consistent reporting in multiple centers enables wider spread of change [29].
- *Cultural changes in the work environments through introduction of collective data driven introspection*: Traditional hierarchies may need to be dissolved through education and empowerment of all caregivers. This is especially true for nurses. It is also critical to develop and nurture leadership that resonates with the new paradigm of multidisciplinary care.
- *Consistently communicating a comprehensive shared vision* that encompasses all these elements is necessary to garner the necessary administrative, governmental, and funding support.

Metrics for QI Framework in LMIC

A comprehensive quality framework encompassing standard of care, patient safety and satisfaction, and outcomes for different levels of PCHD care is essential to ensure consistent and high-quality healthcare delivery. QMs and performance indicators are the fundamental components of this framework [30] and we suggest introducing QM at each level of PCHD care facility as described in detail in Table 2 and Fig. 1. Several of these QMs have been derived or adapted from sources, such as the Adult and Congenital Pediatric Cardiology Quality Network (ACPC QNET), the IQIC, and the Congenital Cardiac Catheterization Project Outcome (C3PO) [31]. These metrics can be implemented

Table 1 Lessons learnt from quality initiatives in low- to middle-income countries

Intervention	Challenges/limitations	Solution	Outcomes/paper
Comprehensive transthoracic echoes, reported timely with high diagnostic accuracy	- Poorly developed health systems, no EHR, reporting /archiving server - Lack of incentive to sustain QI work - High volume of patient and less monetary benefit - Skewed clinic volumes - Sedation was not done with safety	- Employee engagement - Incentive through endowment fund - Standardization of protocols and Pre-surgical meeting pattern - Regular Echo quality audits - Sedation adverse event reporting	Decrease in diagnostic errors from 7.5% to 3.5%. Sedation adverse events from 6.8% to 0% Mohsin et al. [19]
Radiation hazard in CT angiography A key driver-based QI to reduce radiation dose during CTA for CHD using protocol optimization, communication, and training and implementation of CTA protocols as the drivers for intervention	- No standard protocols for pediatric cardiac CT scanning - Lack of training of staff in performing pediatric cardiac CT - Inefficiency in resource utilization	- Creating and teaching pediatric cardiac CT protocols - Clear communication regarding the indication of the scan and questions to be answered - Buy in from both radiology and pediatric cardiology - Appropriate planning with discussion	Radiation dose decreased from median of 12 mSV to 2.0 mSV. Over a period of 5 years Ali et al. [21]
Reduction of radiation hazard in Cath lab (C3PO)	- Lack of radiation knowledge - Inadequate procedural documentation - No preprocedural team huddle - No quality audits	- Promotion of safe radiation practices - Adequate staff education - Documentation optimization - Sustainability of standard practices	Improvement in the percentage of cases that met the established benchmark of 'Ideal documentation' (35% vs 95%, $p=0.001$) Ali et al. [20]
IQIC Infection control Nurse empowerment	- Lack of teamwork - Ineffective hand hygiene - Limited involvement of nurse quality improvement practices	-Point person for IQIC was chosen from CICU nurses - Improved hand hygiene practices	Significant decrease in surgical site infections and bacterial sepsis in the post-IQIC versus pre-IQIC period (1% vs 30%, $p=0.0001$, respectively Kumar and Shrivastava [25]
The impact of IQIC on post-operative outcomes after CHD surgery	- Lack of database - Lack of learning and QI opportunities	- Telemedicine platform to facilitate distance learning, dialogue, and to disseminate knowledge and skills - Key driver diagram-based change strategies for QI	Over the three years, there was a significant decline in bacterial sepsis (from 15.1 to 9.6%, $p<0.001$), Surgical site infection (11.1 to 2.4%, $p<0.001$) Duration of ICU stay from 114(8–999) hours to 72 (18–999) hours ($p<0.001$). The decline in mortality from (4.3 to 2.2%) did not reach statistical significance Jenkins et al. [22]; Sen et al. [23]

CHD congenital heart disease, *CTA* computed tomography angiography, *EHR* electronic health record, *IQIC* International Quality Improvement Collaborative, *QI* quality improvement

Table 2 Metrics for QI framework in LMIC

Metric	Definition	Numerator	Denominator	Target*	Assigned person
Pediatric and congenital cardiac services level (PCCSL) 2/First-level Hospital					
Diagnostic accuracy rate (DAR)	The proportion of potentially preventable and clinically important inaccurate diagnoses among congenital heart surgical patients Minor: No change in patient plan Moderate: Change in plan but no harm Severe: Catastrophic event/death	Number of inaccurate diagnoses (These errors will be identified by reviewing other imaging modality or in the operating room by surgeon)	Number of Congenital heart disease CHD Transthoracic scans done	Minor = < 5% Moderate = < 2% Severe = 0%	Lead pediatric cardiologist with technical lead sonographer. They will collaborate with level 4 and 5 PCCSL to receive feedback on Diagnostic errors
Stabilization rate	Appropriate presurgical management like timely prostaglandin (PGE1) or oxygen initiation depending on the lesion	Number of neonates who received PGE1 within 6 h of prescribing (the time period can be according to each programs resources)	Number of neonates who received prostaglandin infusion	> 80%	Pharmacy in charge will be responsible and program coordinator will collect data and update the system
PCCSL 3/ Referral Hospital (second level) (in addition to above metrics)					
Sedation adverse event rate	This metric will track any adverse events which will be categorized as minor, moderate, and severe according to ACPC QNET definition	Number of sedation adverse events	Total number of sedated studies for echo	Moderate adverse events < 2% Severe adverse events should be 0%	Sedation nurse will be responsible to collect the data The Echo technical lead sonographer will collect data and upload
Mean comprehensive score (MCS)	Average completeness score as measured by the comprehensiveness exam assessment worksheet of initial transthoracic echo (TTEs) designated as complete studies (either inpatient or outpatient)	Sum of the comprehensiveness exam assessment worksheet scores for all TTEs	Total number of initial TTEs designated as complete studies during the measurement period for patients with structurally normal hearts	28 (Sum of MCS) 20 studies per quarter will be randomly selected and assessed by sonographers and reading physicians	Lead pediatric cardiologist with technical lead sonographer
Transport rate	Ability to transport in timely and efficient manner	Number of patients accepted as urgent who are transported within 24 h of request	Total number of patients accepted as urgent who are transported	> 80%	Pediatric cardiology program coordinator will be responsible

Table 2 (continued)

Metric	Definition	Numerator	Denominator	Target*	Assigned person
PCCSL 4/ Referral Hospital (third level) (in addition to above metrics)					
Prenatal detection of critical CHD	This metric will serve as a means for centers to track and report rates of prenatal detection of critical CHD, defined as lesions requiring surgical or catheter intervention within first 28 days of life	Number of patients who had a prenatal diagnosis of structural CHD in which intervention was expected or possible	Fetuses born during the quarter with prenatal CHD diagnosis needing intervention within first year of life	> 80%	Pediatric cardiology program coordinator will ensure the data is collected quarterly
Fetal diagnostic error rate	This measure provides a mechanism for fetal echocardiography laboratories to record and analyze diagnostic discrepancies between fetal and postnatal findings	Number of fetal patients with a moderate or severe discrepancy between prenatal & postnatal diagnosis	Fetuses born during the quarter with prenatal CHD diagnosis needing intervention within first year of life	< 5%	Comparison of prenatal imaging findings and reports with postnatal investigations and reports or repeat fetal echocardiogram Maternofetal and pediatric cardiology nurse coordinators will collect the data
Residual lesion score (RLS) [50]	To keep a record of residual lesion based on pre-discharge echocardiogram	Number of procedures with RLS category 3 or more	Total number of surgeries performed	< 10%	Lead pediatric cardiologist with technical lead sonographer
Multidisciplinary team (MDT) meetings	Shared understanding and situational awareness of surgical procedures	Cases discussed in MDT meetings	Total number of surgeries	100%	Lead pediatric cardiologist with technical lead sonographer
Intensive care unit (ICU) & inpatient complications rate	CAUTI, CLABSI, VAP, soft tissue infections	Number of patients who developed complication	All patients discharged from hospital or ICU	10%	Programs can report per 1000 patient days or can use IQIC reports to track these metrics
	Crude mortality rate	Number of mortalities	Number of patients admitted	< 10%	Targets can be set internally with a focus on consistent improvement
	ICU length of stay (LOS)	Mean LOS in ICU	Expected LOS in ICU according to lesion	–	
Emergent cardiac catheterization procedure outcomes	Crude mortality rate in hospital after emergent cardiac catheterization	Number of mortalities during the procedure	Number of emergent procedures performed in a year	< 10%	Individual data collection or IQIC registry by nurse coordinator
Regular morbidity & mortality (M&M) meetings	Number of M&M meetings conducted per year		–	> 2	Cardiothoracic surgery with intensive care
PCCSL 5/ National Children's Hospital (in addition to above metrics)					
Trans-esophageal echocardiogram (TEE) accuracy rate	Accuracy of pre-operative diagnosis based on TEE	Total number of pre-operative TEEs with one or more major discrepancies identified within 24 h of surgery	Total number of pre-operative TEEs performed	0%	Pediatric cardiology, noninvasive imaging ream
TEE adverse events rate	Rate of adverse events associated with TEE	Number of TEEs with adverse events, identified during a TEE assessment	Total number of TEEs performed	< 2%	

in resource-limited settings without the requirement for additional resources, as demonstrated by examples from LMIC in Table 1.

While this might appear ambitious, with strong leadership, thorough planning, and efficient resource allocation, achieving high-quality healthcare, especially in LMIC through contextually relevant, cost-effective, and innovative change strategies is attainable. *Low cost, by no means should be equivalent to low quality.*

Strategies for Ensuring the Implementation of the QI Framework in LMIC

QI is a systematic approach to improve healthcare delivery requiring continuous efforts to reduce variation and sustain the improved outcomes. Despite the relatively modest impact of healthcare improvement initiatives, it remains crucial to customize QI to identify particular gaps and incorporate them into facility-level processes [13, 32]. The main gap is lack of planning the implementation change [33]. Implementation strategies can enhance patient care and outcome by clear goal setting, stakeholder engagement, resource allocation, and continuous monitoring. A well-designed implementation plan is essential for seamlessly and sustainably integrating a QI framework and QMs into the healthcare system. It should also address potential obstacles and challenges.

- Leadership commitment: Stable leadership, with vision and commitment, is the most important piece in sustainability of QI efforts [34]. Effective institutional leadership plays a crucial role in promoting teamwork and improving QI practices within a multidisciplinary healthcare team [35]. Leaders can facilitate training of support staff to acquire and maintain QI skills, create organization support structures, and align systems/workflows to support improvement. Importantly, leadership is vital in creating a culture that promotes and values innovation and improvement. It is imperative that healthcare leaders understand how to develop, drive, and sustain change strategy. Communicating a clear roadmap for change will help these leaders develop QI-focused teams, keep track of progress, and improvise to ensure effective and efficient QI initiatives [36]. Essential considerations that healthcare leaders should make to drive continuous QI include
    - o *Developing a cohesive team.* A cohesive multidisciplinary healthcare team is essential for improving patient outcomes. Effective teamwork involves collaboration and acknowledging the contributions of all team members, including those in less obvious roles, such as housekeeping staff [37]. Training

Table 2 (continued)

Metric	Definition	Numerator	Denominator	Target*	Assigned person
ICU bounce back rate	Rate of readmissions to ICU	Number of patients shifted back to ICU within 24 h	Number of patients shifted from ICU to ward	< 2%	Nurse coordinator
Neurodevelopmental outcome	Ensuring high-risk CHD patient are followed on long-term basis for neurodevelopmental outcomes	Number of high-risk CHD patient's referral to cardiac neurodevelopmental programs	Total number of high-risk CHD surgeries done	> 80%	Outpatient clinical psychologist

*Target: The target benchmarks suggested by the authors can be employed as key performance indicators for each program, with feasible target values tailored to individual programs

ACPC QNET Adult Congenital & Pediatric Quality Network, *CAUTI* Catheter-associated Urinary Tract Infection, *CLABSI* Central line-associated bloodstream infections, *IQIC* The International Quality Improvement Collaborative, *VAP* Ventilator-associated pneumonia

programs can enhance team cohesion and shared responsibility among medical staff, particularly in surgical programs where structured and effective communication is crucial. This has been illustrated by examples from collaborations between Uzbekistan and Seoul National University College of Medicine in Korea, as well as Mongolian CHD programs [38, 39]. Within the proposed QI framework (Table 2), various healthcare professionals, ranging from primary healthcare workers to cardiologists, nurses, and support staff, collaborate to enhance patient care.

- *Specific role assignment and effective communication*: Clear roles and responsibilities, firm guard rails for scope of work, well-defined escalation pathways, and communication standards help QI teams to function optimally. Early and frequent conversations for conflict resolution between team members through formal or informal meetings is essential. Previous research has shown that nurses can play the roles of effective communicators in multidisciplinary team (MDT) meetings in addition to communicating with patients and families [40]. Regular MDT meetings where patient details are shared between the team members can improve shared situational awareness, which is key to QoC. With increasing patient complexity in maturing surgical programs, these meetings acquire even greater significance.
- *Culture:* Leaders that create an institutional culture that values all team members taking responsibility "to do their jobs and improve upon them," promote internal drive for improvement [41]. The leadership should endeavor to always promote team harmony and proactively address potential threats that could disrupt the team's integrity. A social media-based encouragement strategy from LMIC has successfully shown employee engagement in a productive manner [42].
- *Empowerment of team members*: Empowerment in the workplace occurs when employees are enabled to perform effectively and recognize their contributions. This involves providing learning opportunities to enhance knowledge and skills, boosting confidence and competence [43]. Achieving this entails offering educational material, training for complex scenarios, adequate resources, staffing, feedback, and mentorship [44]. Such an environment is essential for staff mental well-being, promoting self-improvement and a sense of psychological safety [45]. Empowered workplaces enhance motivation, productivity, and organizational commitment among employees [46].

- Developing shared accountability: Promoting accountability among healthcare team members is a crucial element for sustainable QI [47]. To develop accountability within a healthcare system, four parameters can be used: competence, information accessibility, awareness, and gratification.
  - *Competence* involves enhancement of the individual's knowledge, clinical reasoning, skill set, and communication.
  - *Information accessibility* emphasizes patient-centered care and transparency and requires information to be shared within all domains of healthcare, including primary care centers and ancillary staff. Using QM as described in Table 2 to share patient outcomes is an illustration of promoting information accessibility.
  - *Awareness* highlights the need for prudent decision-making and understanding the implications of medical action.
  - *Gratification*: As physicians improve their skills and achieve better patient outcomes, they earn the trust of both patients and the healthcare system. This trust brings about professional satisfaction, inculcate gratification, and drives intrinsic motivation.

- Data-driven approach:
  - Timely collection of accurate data, frequent validation, and auditing of data used for QI purposes can help with a transparent and objective approach to continuous QI. This instills trust among the team members which in turn leads to a collective improvement effort.
  - QM data collection can play a crucial role in procurement of funds to support clinical services and health research. Reliable and accurate QM enables funders or regulatory agencies to see how their funds are being utilized and empowers them to make informed decisions based on evidence. Resources can be allocated according to the outcomes shown by the QM comparison analysis [28].

- Adaptation of implementation science principles to drive sustainable QI initiatives: There is a significant gap between knowledge of interventions and their dissemination and implementation [48]. Implementation science is the scientific study of methods to stimulate the incorporation of evidence-based contextual research findings into routine clinical practice [49]. High-quality implementation science is needed to improve effectiveness of research and guidelines and to improve healthcare outcomes.

Conclusion and Future Directions

PCHD care in resource poor health environments of LMICs are likely to respond well to systematic efforts to improve QoC. In this review, we have sought to present a framework for implementation for QI in LMICs across the different level of PCHD care keeping in mind the care continuum for children with heart defects. These interventions are probably cost-effective and essentially require a cultural transformation through systematic and collective efforts from all stakeholders. The cost-effective interventions leading to improved outcomes can also be deployed globally irrespective of geographical location. The realities of each environment are unique, and interventions need to be tailored to each situation. It is essential for the efforts to be overseen by leadership that constantly seeks to develop and nurture a culture of unflinching commitment to QoC that is embraced by all the team members. Given their unique challenges, quality networks or collaborative like IQIC are valuable to LMICs. These networks can greatly facilitate shared learning and enable substantial improvements in care across multiple institutions in the region and potentially dramatically improve outcomes over time. Regulatory agencies also need to mandate that institutions share their QM in the public domain. This is especially needed when government or other funding agencies provide financing for congenital heart care.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00246-023-03351-2.

Acknowledgements The Authors wish to acknowledge Dr. Aarti Bhat from the department of Cardiology at the Seattle Children's Hospital and Ms. Muneera Rasheed Implementation scientist for her valuable inputs in the Manuscript.

Author Contributions SM drafted the manuscript and coordinated the changes. BH and BZ made crucial contributions in content at multiple stages of the preparation process. RKK conceptualised the document, drafted the outline and made critical changes in content at various stages of the manuscript preparation.

Declarations

Conflict of Interest The authors declared no competing interests.

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