RESEARCH PAPER

Implementation Intelligence in Cardiology: Real-World Use of AI Tools and Barriers to Uptake

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Abstract

Background:

Artificial intelligence (AI) has also proliferated at a very fast rate in the fields of cardiology where it aids in diagnostics, risk forecasting, and imaging analysis, along with workflow automation. Although the pace of technological change is increasing, its application in practice varies, and the unique obstacles affecting the adoption by the clinician are not comprehensible.

Objective:

To determine the current issues of AI tools use by professionals in cardiology in practice, determine the facilitators and obstacles to their implementation, and understand the willingness to expand use to more aspects of clinical practice.

Methods:

Eight cardiology centers have been considered in the case of a mixed-methods study performed in 2021-2023. The survey on 512 clinicians (cardiologists, fellows, nurses, and imaging specialists) was used to gather quantitative data. The survey evaluated the familiarity of AI, its usage frequency, perceived utility, and institutional support. The semi-structured interviews that were provided as a part of the qualitative research on the problem of workflow and trust-related issues involved 46 participants. The descriptive statistics and the thematic analysis were used to summarize these findings.

Results:

One-third of the participants said that it have regularly been using AI tools with the most frequent ones being cardiac imaging and risk stratification. The most perceived to be the key facilitators were accuracy, workflow effectiveness and enabling institutional infrastructure.

The lack of training (62%), fears of transparency of algorithms (54%), workflow disruption (49%), and medicolegal uncertainty (41%) were the greatest barriers. Interview stories contributed the theme of mistrust in black-box models and lack of integration with any of the existing electronic health systems.

Conclusion:

Although there is wide excitement, adopting AI into cardiology is limited in reality due to knowledge gap in training, transparency issues, and workflow mismatch. Overcoming these obstacles by designing clinical-based application platforms, better model clarity and unified integration systems will play a critical role in managing scalable and responsible AI practice in cardiovascular healthcare.

Keywords: Cardilogy, AI, digital health, clinical adoption, clinician trust

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Introduction

Artificial intelligence (AI) has become one of the most novel trends in contemporary cardiovascular medicine, altering the clinician diagnostic process, risk-stratification, monitoring, and management of cardiovascular disease patients throughout the spectrum. The AI is currently used to interpret electro-cardiograms, echocardiograms, and cardiac imaging automatically; issues clinical deterioration in real-time; and automates clinical workflow with decision-support systems [1]. Incorporating AI algorithms in medical specialties is an upcoming development that has placed cardiology at the forefront of the specialties that are well-positioned to be in the favor of the innovations.

Even though the pace of the technological advancement is rapidly increasing, the practical implementation of AI in clinical cardiology is uneven. According to early implementation reports, even though most institutions have AI-enabled tools, very few clinicians apply to them regularly in their everyday practice [2]. This digital capability to clinical integration gap, as it is commonly referred to as the artificial intelligence implementation gap, can be said to contain challenges that are not limited to model performance. The acceptance of clinicians, compatibility with workflow, institutional preparedness, and trust in AI outputs are the important elements of successful adoption (3).

An accumulating research emphasizes the perceived advantages of AI systems, such as better diagnostic performance, less interpretation variability, quicker workflow, and patient triage [4]. The cardiac imaging field has become one of the most popular, and AI results in automated segmentation, chamber measurement, and valvular evaluation with the same level of performance as the expert reader [5]. Similarly, machine- learned risk prediction models have shown high potential to determine hearth- failure worsening, risk of arrhythmia, or unfavorable coronary events in patients [6]. Nonetheless, these tools have not been translated into practice as fast as they should be.

A number of obstacles have been identified severally. Clinicians also mention the lack of training regarding the nature of AI basics, and they are not clear on how to use, interpret, and restrict the boundaries of the algorithm outputs [7]. This is because worries about the so-called black-box-opacity of some choice paths and the resulting reluctance of engaging with AI models are guided by concerns about the reliability of their use on high-stakes tasks like acute coronary syndrome care or arrhythmia detection [8]. Impairment of the workflow also posits the impediments to implementation, tools that cannot penetrate the current electronic health records (EHR) are perceived to be more cumbersome rather than supporting.

The uptake is also influenced by institutional and systemic factors. Such inconsistency of the digital infrastructure, inconsistency of the regulatory rules, and medicolegal ambiguities of the person making AI-aided decisions are still an issue in regard to organizations that weigh the risks and benefits of implementing AI [9]. The other problem is fair access since not every AI system might be able to treat different patients relatively, and this dilemma can be posed in the framework of fairness and safety, which is conditional on the nature of the data to train them.

With the active evolution of AI technologies, there is need to have a current image of the application of such devices in the sphere of cardiology by specialists and the impediments affecting them. The experiences regarding the attitudes of the clinicians, patterns of real-life implementation, and the perceived barriers will be important in designing successful implementation policies that should be clinician-oriented. The discontinuity between the AI implementation presupposes not only the technical advancement themselves, but also the usability, transparency, training, as well as the support of the institution.

In the present study, actual application of AI in clinicians of cardiological facilities will be evaluated, the primary enablers and impediments will be outlined, and the willingness to embrace AI further elaborated on. The combination of quantitative surveys with qualitative interviews conducted in different cardiology facilities provides this research with a detailed assessment of the current level of intelligence in implementation and the potential directions of the action that can be taken to render AI-based findings accountable and generalizable in cardiovascular care.

2 **Literature Review**

The rapid development of artificial intelligence (AI) in the cardiovascular sphere has served to introduce new concepts in the areas of diagnostics, risk detection, and optimization of clinical process. According to the original study, AI-assisted information systems can enhance accuracy in echocardiography, cardiac MRI, and coronary CTA with automatic chamber segmentation, valve inspection, and the occurrence of subtle structural abnormalities that would have otherwise remained unnoticed due to human evaluation [11]. The instruments have particularly been useful in reducing interobserver errors as well as helping to mentor novice clinicians in the demanding environments.

Other than imaging, machine-learning-made risk models have emerged as a powerful foreteller of heart failure worsening, arrhythmias and serious adverse heart failure events. These prediction models utilize high-dimensional clinical and physiologic measures to ascertain deterioration patterns several years prior to their clinical emergence in numerous conventional risk measures [12]. Despite such technological advancement, it has been discovered that the entire process of translating to the real world has been behind the science breakthrough.

It has been reported numerous times that the digital preparation of clinicians through the cultivation of sleep has led to the manifestation of transparency as essential in the implementation of AI tools in the bedside setting. The surveys arranged by the various cardiology departments show that although most of the clinicians acknowledge AI has the potential to work to their advantage, only a few of them have confidence to read AI data or to understand the weaknesses of the algorithm [13]. Other problems have been worry over other black-box models and medicolegal liability, and possible bias of the training data, especially in such life and deaths cases, such as acute coronary syndromes.

Adoption is also influenced by organizational and infrastructural factors. The dismal combination of AI platforms with electronic health records as well as the absence of standardized implementation frameworks and the presence of insufficient training resources often limit the workflow integration. Recent studies of implementation highlight the fact that successful adoption must not solely be based on technical correctness, but an user-friendly design, explainability, and institutional training and assessment support [14].

3 Materials & Methods

Study design

The current research used the mixed-methods design with both a quantitative survey analysis and qualitative semi-structured interviews to assess the application of artificial intelligence (AI) tools to cardiology clinical practice in real-world scenarios and as well as barriers that affect adoption. This research was carried out in eight cardiology practices, including both Academic hospitals and regional cardiovascular centers and community-based cardiology networks between June 2021 and December 2023. Parallel design was done in a convergent manner that enabled the simultaneous collection and quantitative and qualitative analysis of data then integrating them later.

The given figure 1 reviewsumes the utilization of AI tools in the cardiology field and the key obstacles to their implementation. The existing uses are risk assessment, interpretation of images and clinical decision support. Nevertheless, it can be broadly used only due to the limitations of its integration into a clinical workflow, finding regulatory compliance, and the cost parameters of deploying this technology into a practice.

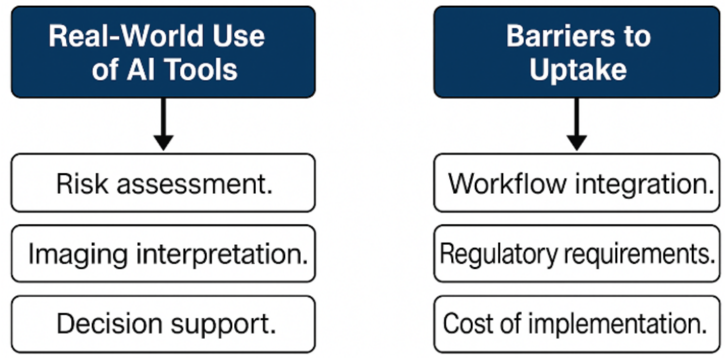

Fig.1. Proposed structural model

Population and Recruitment of the study.

The eligible subjects were cardiologists, cardiology fellows, advanced practice provider (NPs), nurses, and cardiac imaging personnel, as well as, clinical technologists with a minimum of 6 months of experience in a cardiology department. The recruitment was conducted through the email invitation and departmental meetings. The process in which it was carried out was voluntary and anonymous. The quantitative survey was administered to 512 clinicians and purposive sampling of 46 clinicians was done to take into consideration the representation of roles, levels of experience, and institutional settings.

Survey Instrument Development.

The survey used was a structured 42-item survey, which was previously built according to the current implementation science frameworks and previous literature regarding clinical AI adoption. There were four domains in the survey:

a. AI acquaintance and training experience.
b. Existing use of AI (e.g., imaging automation, risk prediction, triage systems, etc.)
c. Perceived benefits/ barriers.
d. Organizational preparedness and computer network.

The type of questions utilized Likert scale, binary and open-ended questions. The survey underwent pilot testing on 15 clinicians to determine its clarity, content validity and time of completion.

The procedures of qualitative interviews involve the use of interview methods and procedures.<|human|>Qualitative Interview Procedures Qualitative interviews are interviewing approaches and procedures.

The studies focused on clinician perspectives about AI usability, trust, workflow integration, perceived risks, and organizational support are examined using semi-structured interviews. The interview guide used contained flexible questions, which prompted the participants to elaborate on personal experiences and organizational issues. Interviews were recorded on tape and all transcribed verbatim and lasted 25-45 minutes. The sampling was continued until thematic saturation, which was three consecutive interviews and no new conceptual information has developed.

Data Collection and Data Management.

The survey data was gathered electronically in a safe site and saved on an encrypted database within an institution. Qualitative analysis software was used to analyze interviews and code them as de-identified files. All data was not accessible to any party, except the research team, and was analyzed in the aggregate form.

Quantitative Analysis

The demographic characteristics, the frequency of AI use, the perceived usefulness, and barriers were summarized using the descriptive statistics. Chi-square tests for categorical variables and independent-sample t tests for non-ratio variables were used to conduct group comparisons (i.e., e.g. across role, or level of experience, etc.). The predictor variables addressed by logistic regression models are the years of practice, AI training level, perceived transparency, and institutional support. The findings were expressed in terms of odds ratios and confidence intervals. Any analysis was conducted using SPSS (version 28) and R (version 4.2).

Qualitative Analysis

Thematic analysis was used in the analysis of the interview transcripts. Initial open coding was done by two independent coders then later axial coding was done to refine the categories. The controversies were addressed by consensus. Inductive derivation of themes and mapping on established implementation science constructs, such as trust, workflow alignment, perceived risk, and organizational readiness.

Mixed-Methods Integration

A triangulation matrix was used in integrating quantitative and qualitative findings to locate convergent, complementary and conflicting insights. Themes were summarized to obtain a condensed perception on the facilitators and obstacles to the adoption of AI.

Ethical Considerations

All the centers provided institutional review board approval. The informed consent was obtained by means of written consent to the interview and implied consent to surveys.

Work flow model

Fig 2 Study flow model

This figure 2 represents the recruitment and inclusion process of the study indicating the amount of clinicians invited to participate in the study, those who of course fill out the quantitative survey and those who will undergo a qualitative interview. Exclusion causes and the ultimate analytic samples of both quantitative and qualitative elements are presented.

4 Results and Discussion

The survey was done on 512 cardiology clinicians including 46 respondents in a follow-up qualitative interview, which constitutes a comprehensive data to assess the practice of AI in the real world and the conditions under which it is adopted. The sample of respondents was highly varied in clinical position, experience, and institutional location, which made it possible to make the comparison between the subgroups robust. Quantitative and qualitative analysis were conducted simultaneously after verifying completeness and internal consistency of responding.

The Results section has three huge sections:

a. Disciplinary factors, such as demographics, clinical exposure, training exposure, and institutional factors;
b. Patterns of AI use, summary frequency of usage by imaging, Ecg analysis, tools to predict risk, and workflow;
c. Obstacles and enablers of AI implementation, including not only survey results but also thematic findings of interviews.

The results are presented in a quantitative form at the beginning and the tables indicate patterns of usage, perceived usefulness and predictors of regular use of AI. Self-reported barriers are then analyzed such as lack of training, transparency, disruption of work flow and medicolegal issues. Qualitative themes are subsequently encompassed in order to give a deeper understanding and visualization of how clinicians go through these barriers in their daily practice. All these outcomes can provide a multi-dimensional insight into the potential and challenges associated with the implementation of AI in modern cardiology.

1. Participant Characteristics

Of all 512 clinicians who filled the survey (response rate: 68%), 512 met the criteria. The respondents had different clinical roles where cardiologists were the majority (38% as indicated in the tabular 1). The weighted average clinical experience was 11.4 +- 7.2 years. There were particular qualitative interviews with forty-six clinicians.

Table 1. Survey Respondent Characteristics.

Variable	n (%) or Mean ± SD
Total participants	512
Age (years)	41.3 ± 8.9
Years in clinical practice	11.4 ± 7.2
Clinical role	
– Cardiologists	195 (38.1%)
– Cardiology fellows	102 (19.9%)
– APPs/Nurses	128 (25.0%)
– Imaging technologists	87 (17.0%)
Prior formal AI training	96 (18.7%)
Works in academic center	301 (58.8%)

2. AI Utilization Patterns

Just a third of patients indicated that they used AI daily in clinical activities. The most common areas of AI application were identifying images (echo/CT/MRI) and automated analysis of ECGs as presented in the table 2. Workflow assistance and diagnostic augmentation were considered by the clinicians as the most useful features.

Table 2. Application of AI by Clinical Domain.

AI Application Area	Routine Use (%)	Occasional Use (%)	Rare/Never (%)
Echocardiography automation	44.8	32.0	23.2
Cardiac CT/MRI analysis	38.5	28.4	33.1
Automated ECG interpretation	52.1	26.3	21.6
Risk prediction tools	29.7	34.9	35.4
Workflow triage systems	18.4	27.0	54.6

The regression analysis indicated that institutional digital infrastructure, AI training, and perceived transparency were all important predictors of routine AI use (OR 2.18, 1.76, and 1.55 respectively; all $p < 0.01$).

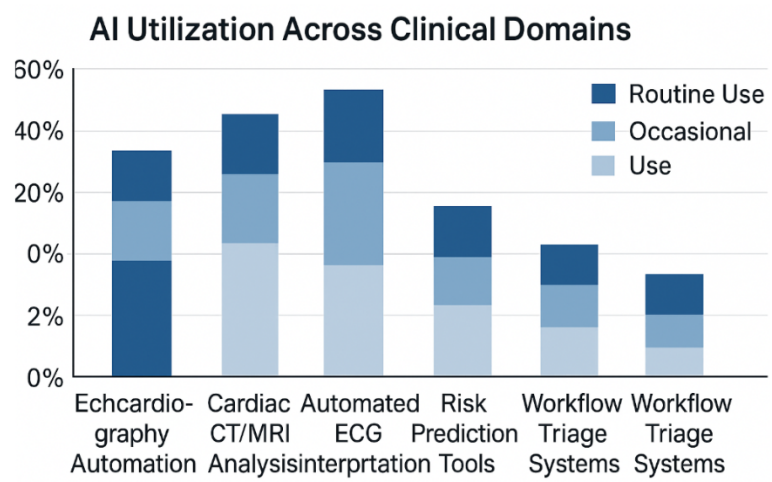

Figure 3. AI Utilization Across Clinical Domains

This Figure 3 provides a brief overview of common, purposeful, and uncommon application of AI tools in five cardiology areas, namely, the automation of echocardiography, cardiac CT/MRI analysis, ECG interpretation, risk prediction models, and workflow triage systems. IGestational Uptakes ECG and echo automation use is most frequently used, and predictive and triage tools are less frequently used.

3. Barriers to Adoption

The most common reason cited was the lack of training (62%), just above the issues of the transparency and reliability of algorithms (54%) as shown the table 3. These concerns were supported by the themes of the interviews, with workflow disorder and medicolegal problem in the spotlight.

Table 3. There were also reported Barriers to AI Adoption.

Barrier Category	n (%)
Lack of training / insufficient skills	318 (62.1%)
Algorithm transparency ("black box" concerns)	277 (54.1%)
Workflow disruption / poor EHR integration	252 (49.2%)
Medicolegal uncertainty	209 (40.8%)
Bias or fairness concerns	166 (32.4%)
Limited institutional support	158 (30.8%)

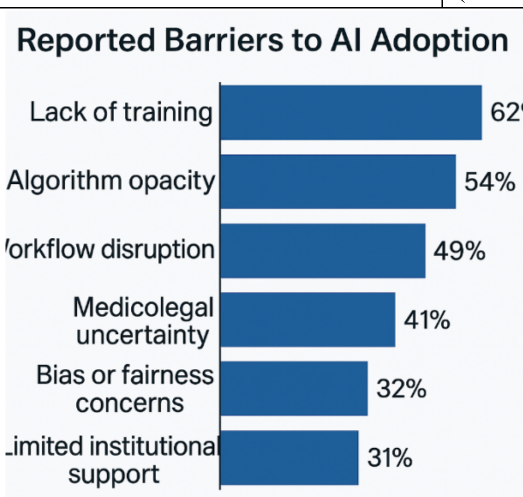

Figure 4. Stated Obstacles to AI Adoption.

This figure 4 shows the most significant obstacles to the adoption of AI, such as inadequate training, the lack of understanding of the algorithm, disruption of the workflow, medicolegal uncertainty, bias issues, and institutional support deficiencies. The most supported barriers are lack of training.

5 Discussion

The article is a mixed-methods study that offers a thorough analysis of the existing use, perception of the potential benefits, and obstacles that still restrain the widespread usage of artificial intelligence applications by the cardiology clinicians. Even though AI technologies are becoming more common and present in cardiology centers, our findings project that real-world adoption is still low, with only 38 percent of clinicians claiming to use them regularly. In line with other researchers, the uses of AI were greatest in imaging and ECG interpretation because the performance of algorithms is well-defined, and integration into a workflow is more established there. Nevertheless, the few applications of predictive analytics and triage systems suggest that less integrated or more complex AI applications experience more difficulties in becoming part of clinical practices.

One of the findings is the high impact of training and transparency on patterns of adoption. Clinicians who received training in AI previously were over twice as improbable to utilize the tools. Thought qualitative interviews corroborated this point by showing that a good portion of clinicians continue to be confused about interpreting AI-generated advice or identifying the limitations of the algorithms. The problem with the algorithmic transparency (more so-called black-box models) continues to be the source of mistrust, particularly when it comes to high-stakes choices such as the ones made in arrhythmia detection or coronary disease risk profiling.

Workflow and infrastructural issues are also very critical roles. Approximately, nearly five of ten respondents indicated that AI tools disrupt the normal clinical practices when they are not integrated well with electronic health records. This is in line with the general implementation research observation that the most appropriate models would never be anticipated to care unless there is interoperability and institutional support. The additional causes of clinician reluctance are medicolegal uncertainty and accountability issues which were considered in the quantitative and qualitative outcomes.

6 Conclusion

This paper demonstrates how although artificial intelligence instruments are increasingly being utilized in the cardiology practice setting, there is still a lack of practical use of its application because of training gaps, integration of workflow and trust. Clinicians are aware of the potential benefits of AI, and the familiarity and perceived transparency and institutional infrastructure are among the major factors of influence. The fact that the problems associated with the black-box algorithms, Medicolegal uncertainty and lack of smooth integration of the EHRs that are in focus suggests that the technical performance is not sufficient to render the clinical uptake effective.

Our combined-method findings indicate the need to have a structured implementation system, which will put into consideration the user and system-level barriers. The main key to designing responsible and scalable AI use in cardiovascular care lies in the necessity in creating clinician education, improving explainability controls, simplifying workflow connectivity, and designing improved regulatory and accountability protocols. The alignment of the technological advancement to the clinical needs and the reality of the current reality functioning in the working process will become one of the key concerns regarding the achievement of the potential of this solution in improving patient outcome in connection with the continuous development of AI.

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