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Can Simulation-Based Training Address the Challenges of Residents' Training in Cardiology? A Combination of a Survey and a Literature Review

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Abstract **Original Research Article**

Simulation has become an essential pedagogical tool in medical training, providing a safe environment for acquiring and refining clinical skills. Our study explores the impact of simulation in the training of cardiology residents by combining a literature review and a survey of cardiology residents regarding the obstacles in their learning. Articles published between 2014 and 2024 were selected based on specific criteria, and a survey with a 16-question questionnaire was conducted. The results show that simulation significantly improves the technical and non-technical skills of cardiology residents, while also increasing their confidence and reducing medical errors. However, limitations such as the high cost and lack of realism of simulators were identified. Despite a generally positive satisfaction with the quality of their training, residents reported obstacles such as the absence of structured programs and lack of supervision. The conclusion emphasizes that simulation offers unique opportunities to improve skills and patient safety, but it is necessary to enhance simulation technologies, increase methodological rigor, and standardize evaluation tools to fully benefit from it.

Keywords: Simulation Training, Medical Training, Cardiology Residents, Benefits of Simulation, Technical Skills, Non-technical Skills, Simulation Technologies.

INTRODUCTION

Cardiology, a rapidly evolving medical specialty, demands advanced expertise and skills in various diagnostic and therapeutic procedures, as cardiovascular diseases remain the leading cause of morbidity and mortality worldwide [1]. Traditional training methods, which rely on theoretical learning, supervised practical workshops, and real-time patient interactions, often fall short in providing a safe and controlled learning environment. Since the 1990s, simulation-based training has emerged as a transformative approach, offering a risk-free setting where trainees can practice procedures, make clinical decisions, and manage complications without endangering patients. This is made possible through advanced technologies such as high-fidelity mannequins and virtual reality [2]. Despite its promise and proven positive outcomes in various medical specialties, the integration of simulation in cardiology has been slow. Contributing factors include high costs, the need for specialized equipment, and the requirement for trained personnel. However, the potential benefits of simulation in cardiology are substantial. It allows for repeated practice of high-risk procedures, enhances understanding of complex cardiovascular pathophysiology, and improves teamwork and communication skills, thus better preparing trainees for rare critical scenarios. This background underscores the need for a detailed exploration of the effective integration of simulation in cardiology training, addressing current gaps and paving the way for future advancements.

Current cardiology training programs face several significant challenges, particularly in the area of invasive skill training [3]. The complexity and high-risk nature of procedures such as left and right heart catheterization require extensive practical experience and high precision. Traditional training methods, heavily reliant on real clinical encounters, often provide inconsistent exposure to these critical procedures, potentially leaving trainees with insufficient practice and confidence. Furthermore, the inherent risks of invasive procedures limit opportunities for learners to practice

through direct patient care, as any error can have serious consequences for patient safety. In Morocco, cardiology training faces additional challenges due to the evolving public university hospital structures and the growth of private and semi-private facilities, which have made Moroccan patients more demanding in terms of quality and safety of care. These constraints further highlight the crucial need for innovative and safe educational methods, such as simulation, to complement and enhance traditional clinical training.

The main objective of our study is to explore the impact of integrating simulation into cardiology resident training. This involves analyzing the theoretical and practical benefits of simulation, identifying the challenges and obstacles faced by residents through a survey focusing on practical training, workload, and psychological aspects, and assessing the potential use of simulation to address these challenges.

MATERIALS AND METHODS

Literature Review:

A comprehensive literature review was conducted, encompassing studies published between 2014 and 2024 in both English and French. The databases utilized for the search included PubMed and Google Scholar. Inclusion criteria comprised randomized controlled trials, observational studies, systematic reviews, and meta-analyses, while articles with only abstracts were excluded. The search terms used included "Simulation-based training," "Cardiovascular training," and "SBT Impact."

Survey:

An online survey was administered to cardiology residents in various university hospitals across Morocco. The survey consisted of 16 questions, incorporating both open-ended and closed Likert scale questions, aimed at identifying the obstacles and challenges faced during their training.

Data Analysis:

Quantitative data from the survey responses were analyzed using SPSS and R software. Descriptive and inferential statistical analyses were performed to interpret the data. Qualitative responses to open-ended questions were analyzed using NVivo software, employing thematic analysis to identify key patterns and themes.

RESULTS

1. Systematic review of literature:

This initial research identified 239 articles on the topic of our study. Out of these, 62 articles were selected for further analysis based on their relevance, methodological quality, and contribution to understanding the benefits and challenges of using simulation in cardiology training. The selected articles included randomized controlled trials, observational studies, systematic reviews, and meta-analyses, ensuring comprehensive and diverse coverage of the subject. Figure 1 presents a flowchart describing the article selection process for our thesis according to the PRISMA standards (Preferred Reporting Items for Systematic Reviews and Meta-Analyses):

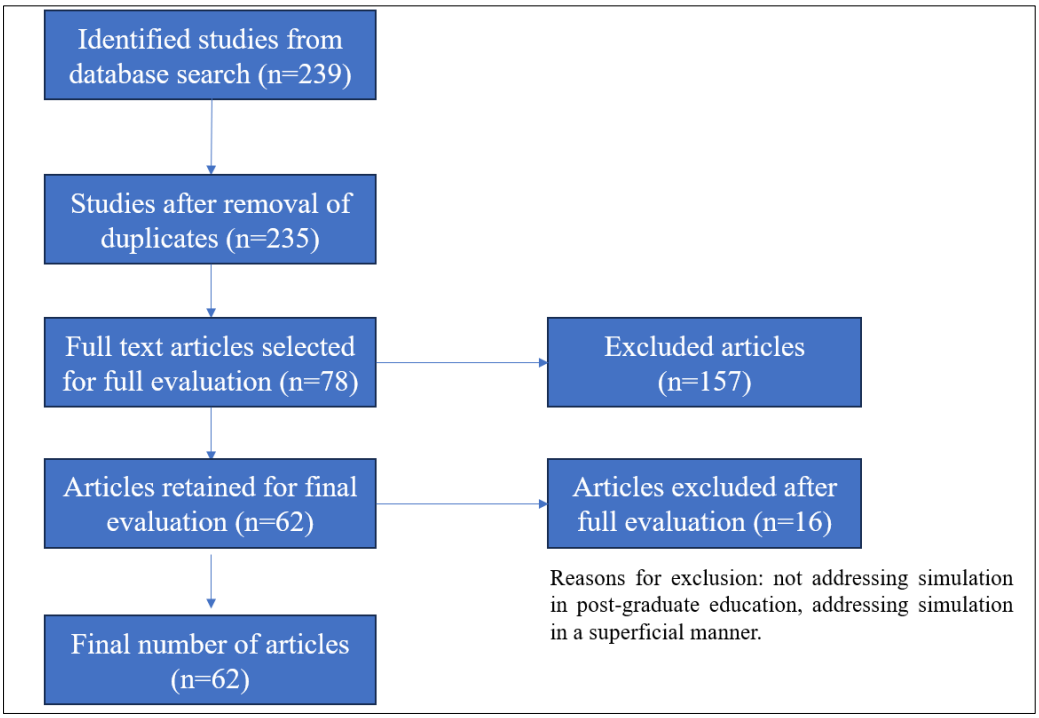

Figure 1: Flowchart describing the article selection process according to the PRISMA standards

- **Benefits of simulation-based training:**

The reviewed articles highlight several significant benefits of using simulation-based training in the education of healthcare professionals across various specialties, and specifically in cardiology. Through The Simulation Teaching Commission (COMSI) of the French Society of Cardiology, Théo Pezel et al, 2021 provided a comprehensive state-of-the-art review of simulation training in cardiology to evaluate the effectiveness of simulation methods in cardiologist training [4]. The article reviews various simulation methods, including high-fidelity mannequins, virtual simulators, and augmented reality. Studies cited in this work show that cardiology residents trained through simulation achieve better practical and theoretical exam results compared to those trained by traditional methods [5,6,7]. Simulation is particularly effective for teaching critical and rarely encountered procedures. These benefits can be grouped into two main categories: improvement of technical skills and development of non-technical skills:

- **Simulation and cardiology technical skills:** The articles in our review highlight three main areas of benefits from simulation-based training:
  - **Precision and Speed of Procedures**: Residents trained with realistic simulators perform invasive procedures, such as cardiac catheterization, with greater precision and speed. The integration of virtual and augmented reality improves the understanding of cardiac anatomy, reduces procedure time, radiation exposure, and overall healthcare costs [8].
  - **Error Reduction**: Simulation allows residents to practice complex technical procedures without risk to patients, reducing errors during real interventions. It plays a crucial role in decreasing adverse events, including medication errors [9].
  - **Management of Emergency Situations:** Simulation is beneficial for training in the management of cardiac emergencies, enabling residents to practice their technical skills for responding quickly and effectively to critical situations. Residents trained in simulation show a better ability to handle emergencies and make technical decisions under pressure [4].

The most simulated technical procedures studied in our literature review were Left heart catheterization (11 articles), Transesophageal echocardiography (TEE) (10 articles), and rhythmology invasive interventions (9 articles). The main outcomes of the selected studies, organized by technical procedures and cardiology sub-specialties, are summarized in Tables 1, 2, and 3.

Table 1: Summary of the results of studies on the impact of simulation on the learning of left cardiac catheterization

Principal Author	Study Type	Date of Study	Study design	Type of procedure studied	Main outcomes
Voelker W, *et al.,*[10]	Randomized study	2016	Randomization of participants between simulation and classical training	Angioplasty	Significant improvement in procedural skills after simulation training
Prenner SB, *et al.,*[11]	Randomized controlled trial	2018	Controlled test evaluating the impact of simulation on the use of fluoroscopy	Coronary angiography	Reducing the Use of Fluoroscopy in Simulation-Trained Residents
Fischer *et al.,*[12]	Randomized controlled trial	2018	Randomization of participants between simulation and classical training	Coronary angiography	Simulation could potentially improve learners' clinical and anatomical skills
Kelly RF *et al.,*[13]	Cohort study	2020	Longitudinal follow-up of simulation-trained vs. traditional residents	Coronary angiography and angioplasty	Improved performance scores and reduced procedure times in simulation-trained residents
El-Andari R, *et al.,*[14]	Literature review	2021	Summary of studies on the use of simulators	Angioplasty	Confirmation of the usefulness of simulators in improving revascularization skills
Lee *et al.,*[15]	Randomized controlled trial	2022	Randomization of participants between simulation with classical training and classical training alone	Coronary angiography	Simulation is a good complement to traditional teaching for the interpretation of coronary images
Popovic B, *et al.,*[16]	Clinical study	2022	Comparison of radiation exposure before and after training	Coronary angiography and angioplasty	Significant reduction in radiation exposure through simulation training
Ahmed M, *et al.,*[17]	Prospective study	2022	Longitudinal follow-up of cardiology residents using simulation	Angioplasty	Continuous improvement of the technical and decision-making skills of simulation-trained residents

Principal Author	Study Type	Date of Study	Study design	Type of procedure studied	Main outcomes
Hammami R, *et al.,*[18]	Cross-sectional study	2023	Cross-sectional survey on the contribution of simulation	Angioplasty and coronary angiography	Improving the procedural skills of beginners through simulation training
Chan JF, *et al.,*[19]	Randomized controlled trial	2023	Randomized Resident Readiness Assessment	Coronary angiography and angioplasty	Significant improvement in technical skills and complication management
Bagai A, *et al.,*[20]	Clinical Trial	2023	Randomized trial on the impact of simulation on performance	Angioplasty	Significant improvement in technical skills and resident confidence after simulation training

Table 2: Summary of the results of studies on the impact of simulation on the learning of invasive gestures in rhythmology

Principal Author	Study Type	Date of Study	Study design	Type of procedure studied	Result of the study
Talbot et al [21]	Development and validation study	2014	Simulator testing by experienced learners and operators	Cardiac pacing and ablation	The Cardiac Electrophysiological Procedure Simulator can be part of a computerized medical learning curriculum
Young MN *et al.,*[22]	Cohort study	2018	Prospective assessment of skills after simulation training	Temporary Transvenous Pacing Lead	Improving the skills and performance of fellows in cardiovascular medicine
Young TP *et al.,* [23]	Pre-post simulation survey	2019	Comparison of pre- and post-simulation confidence levels by a paired-pair Wilcoxon test	Temporary Transvenous Pacing Lead	Improved trainee confidence after simulation
Mohyuddin GR *et al.,* [24]	Interventional, Comparative and Randomized Study	2020	Pre-post evaluation simulation with comparison to the control group	Temporary Transvenous Pacing Lead	High-fidelity simulation is no better than similar interactive learning without the use of high-fidelity simulation tools.
Smith AW *et al.,* [25]	Pre-post simulation survey	2021	Assessing learners' confidence by the modified Likert scale	Defibrillation and Temporary Transvenous Pacing Lead	Effectiveness of Simulation in Improving Trainee Confidence in the Management of Severe Arrhythmias
Jeilan M *et al.,* [26]	Literature Review	2023	Article review and proposal of training frameworks	Cardiac pacing device implantation	Simulation can close gaps in cardiac implantation training in low- and middle-income countries
Mascheroni *et al.,* [27]	Randomized Trial	2023	Comparison of results between implanters trained by simulation based on validated performance metrics, and those trained by traditional methods	Cardiac pacing device implantation	Fewer intraoperative errors in simulation-trained novice implanters
Kozlik M *et al.,* [28]	Study by survey	2024	Questionnaire and survey after simulator test by participants	Analysis of electrophysiology traces	Simulation is an effective solution for the training of young electrophysiologists
Klemz FK *et al.,* [29]	Development and validation study	2024	Modified Likert questionnaires before and after simulation	ECG-guided Temporary Transvenous Pacing Lead	High rate of acceptance among experts and a significant improvement in cardiology residents' learning after simulation

Table 4: Summary of the results of studies on the impact of simulation on echocardiography learning

Principal Author	Study Type	Date of Study	Study design	Type of procedure studied	Result of the study

Biswas M *et al.,* [30]	Review study and narrative analysis	2016	Narrative analysis	TTE and TEE	Simulation is an excellent tool for acquiring motor and cognitive skills in the early stages of learning echocardiography
Winchester D *et al.,* [31]	Pre-post simulation survey	2017	Comparison of pre- and post-simulation confidence levels by a Wilcoxon test	TEE	Cardiology fellows report increased value and confidence in ETO skills after completing a simulator-based training program.
Nazarnia S *et al.,* [32]	Review study and narrative analysis	2017	Narrative analysis	Perioperative TEE	Simulation is a good starting point and can play a major role in developing cognitive and psychomotor skills in echocardiography training if properly integrated into a training curriculum.
Bloch A *et al.,* [33]	Prospective, randomized, controlled study with blinded outcome assessment	2017	Comparison of performance on a real patient between trainees trained by simulation and control group	TEE in intensive care	Simulation improves novice operators' ability to perform targeted transesophageal ultrasound in critical care compared to lecture-based training
Chenkin J *et al.,* [34]	Prospective interventional study	2019	Theoretical and practical evaluation pre-post simulation	TEE in the emergency department	The short simulation training sessions have proven effective in teaching an ETO protocol in five shots to residents
Zhao Y *et al.,* [35]	Randomized controlled experimental study	2021	Comparison of 4th year medical students trained by simulation with control group, through theoretical and practical tests	TEE	The simulation-based training significantly improved the performance of medical students in interpreting transesophageal echocardiographic views compared to video training
Jujo S *et al.,* [36]	Systematic review and meta-analysis of randomised controlled trials	2021	Comparison of the learning effects of TEE training for beginners with and without simulator	TEE	Simulator training resulted in higher post-training test scores of skills and knowledge
Pezel T *et al.,* [37]	Randomized multicenter clinical trial	2023	Comparison of cardiology interns trained by simulation for 3 months with control group, through theoretical and practical tests	TEE	Significant improvement in cardiology trainee knowledge, skills and self-assessment of skills
Koenig P *et al.,* [38]	Prospective interventional study	2023	Theoretical and practical evaluation pre-post simulation	Pediatric TEE	Simulation-based mastery-based learning is a powerful medical educational strategy for achieving high and consistent learning outcomes in pediatric OTE among trainees of different levels and pathways.
Su Y *et al.,* [39]	Systematic review and meta-analysis of randomised controlled trials	2024	Selection, Analysis and Synthesis of Articles	TEE	The simulation significantly improves the learning of transesophageal echocardiography compared to traditional training.

- **Simulation and cardiology non-technical skills:** In addition to improving technical skills, simulation plays a crucial role in developing non-technical skills essential for clinical practice in cardiology:
  - **Communication and Teamwork:** The German team of Freytag *et al.,* (2017) showed that the integration of realistic simulation and structured debriefings improves communication and the

performance of medical teams by focusing on crisis resource management (CRM) principles [40]. We identified three areas of impact regarding communication and teamwork:

- Emergency Training and Reduction of Hierarchical Barriers: Simulation allows teams to practice emergency situations, improving coordination and collaboration, and reducing hierarchical barriers [9].
- Development of a Safety Culture: Simulation programs raise awareness among teams about the importance of reporting potential issues without fear, thereby improving communication and collaboration [41].
- Training Clinical Leaders and Engaging Team Members: Simulations provide opportunities to develop leadership skills and increase the engagement and accountability of team members [42].

- **Stress Management and Self-Confidence:** Simulation develops the self-confidence of cardiology professionals, allowing them to master technical and clinical skills in a risk-free environment. Studies show that simulation training significantly improves the confidence of cardiologists in training [20,23,25,31]. For example, Kovach *et al.,* (2021) revealed that residents felt more confident in performing complex procedures after simulation sessions [43]. The systematic review by Arjomandi Rad *et al.,* (2023) also showed an increase in confidence, clinical knowledge, and technical skills after simulation sessions [44].
- **Clinical Decision-Making:** Simulation helps residents develop critical decision-making skills [8,45]. By recreating realistic clinical scenarios, residents learn to quickly assess situations, identify problems, and implement appropriate solutions, thereby improving their ability to make informed and rapid clinical decisions in real-life situations.

- **Limits of simulation-based training:**
  - **Cost and Resources Required**

Implementing and maintaining cardiology simulation programs require significant investments in equipment, maintenance, and staff training. High-fidelity simulators are expensive, and recurring costs add to the financial burden [46]. Limited availability of simulators necessitates careful planning to maximize their use.

  - **Perception by Learners and Application of Skills**

Learners' perceptions of simulation can impact its effectiveness. Some view it as less realistic than clinical experiences, which can reduce engagement [45]. The artificial nature of simulation may hinder the transfer of skills to real clinical situations [47]. Applying simulation-acquired skills in real settings can be challenging due to the inability of simulators to fully replicate real-life complexities.

  - **Acceptance by Educators and Students**

Acceptance of simulation varies among educators and students. Some educators prefer traditional methods and may lack training in simulation, reducing its effectiveness [48]. Students who do not see the value of simulation may be less engaged. Structured debriefings and clear demonstrations of skill transfer can improve acceptance and engagement [49].

  - **Technical Limitations of Simulators**

Simulators have technical limitations, such as limited physiological responses and lack of realistic haptic feedback, which can reduce the authenticity of the learning experience [50]. Technological advancements are addressing these issues, but progress is slower in cardiology compared to other fields [49]. Regular updates to simulation software are needed to keep up with clinical and technological advances, posing logistical and financial challenges [4].

2. SURVEY AMONG CARDIOLOGY RESIDENTS:

62 residents in cardiology, from 5 different university hospitals participated in our survey. The majority age group was 25-30 years old with 61.3% (n=38), followed by the 31-35 years old group with 29.0% (n=18). Participants under 25 years old represent 6.5% (n=4), while those over 35 years old constitute 3.2% (n=2). he distribution was balanced between the sexes, with a slight predominance of male participants. Men represent approximately 58% of the sample, while women constitute about 42%. The distribution of the 62 participants across the four years of residency shows a majority in the 2nd and 3rd years. Specifically, the 2nd year of residency has 20 participants (32.3%), and the 3rd year has 18 participants (29.0%). The 1st and 4th years each have 12 participants, representing 19.4% of the total for each year. The overall satisfaction with the quality of cardiology training, based on a Likert scale, was predominantly rated as "neither satisfied nor dissatisfied" by 28 participants (46.7%), "satisfied" by 22 participants (36.7%), "very satisfied" by 6 participants (10.0%), "dissatisfied" by 2 participants (3.3%), and "very dissatisfied" by 2 participants (3.3%). The calculated overall satisfaction score is approximately 3.47 out of 5, which corresponds to an overall satisfaction of about 69.33%.

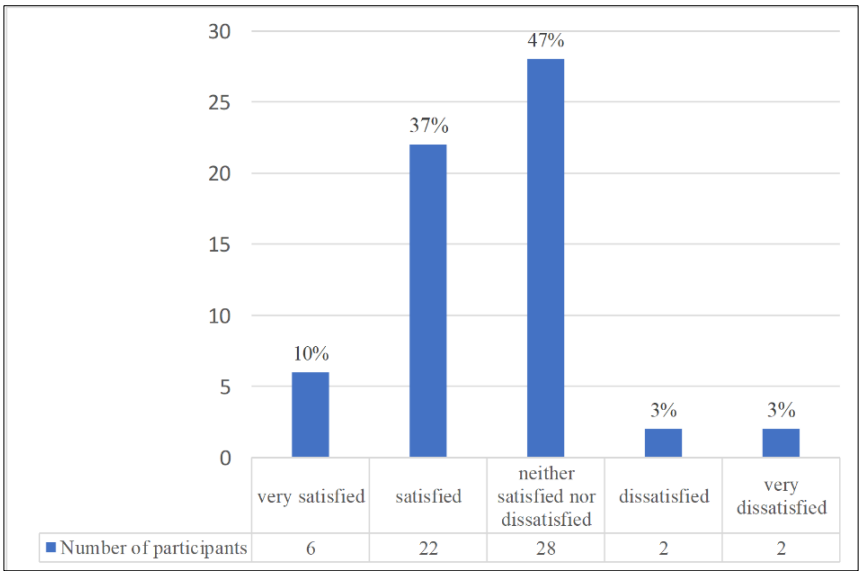

Figure 2: Overall Evaluation of the Quality of Cardiology Training by Participants

The most difficult skills to acquire during cardiology training, according to the residents, were as follows: Invasive technical skills (left heart catheterization, TEE, temporary or permanent pacemaker implantation) were identified by 87.1% of participants (n=54). Non-technical skills (communication, leadership, self-confidence, decision-making) and stress echocardiography were each mentioned by 45.2% of participants (n=28). Reading Holter ECG and ABPM was noted by 35.5% of participants (n=22). Exercise stress testing was identified by 16.1% of participants (n=10), and transthoracic echocardiography by 9.7% of participants (n=6).

In an open-ended question regarding the challenges and obstacles related to acquiring technical and non-technical skills in cardiology, in order of importance, the lack of structured programs for learning invasive procedures was identified as the main obstacle by 83.9% of participants (n = 52). The lack of supervision and feedback during training was also highlighted, affecting 71% of participants (n = 44), followed by limited access to invasive procedures (67.7%, n = 42). Additionally, the absence of structured training programs for complex non-invasive techniques was frequently reported (61.3%, n = 38).

Our participants also ranked the obstacles they personally encountered during the learning of complex invasive or non-invasive technical procedures, in order of frequency. The most frequently reported obstacle was the refusal by seniors to allow hands-on practice during complex technical procedures. This was followed by a lack of supervision by seniors, difficulty in accessing technical platforms, the absence of structured training programs, and lastly, a lack of self-confidence.

Only 29% of our participants (n=18) used simulation during their cardiology training, while 71% (n=44) never benefited from simulation training. Among participants with simulation experience in cardiology, 16 had sessions on invasive procedures, 8 had simulation of complex non-invasive procedures, and two participants experienced scenarios on emergency management in cardiology and decision-making. A large majority of participants (83.87%) believe that simulation improves technical skills. Additionally, 74.19% highlighted that simulation offers opportunities for repeated practice without risk to patients. Reduced stress during real-life situations was also cited by 67.74% of participants. The development of self-confidence during real-life procedures was mentioned by 61.29% of respondents, while 45.16% emphasized the immediate and constructive feedback provided by simulation. Conversely, a minority of 3.23% of participants saw no benefit in simulation for cardiology. Our survey also revealed that 96.8% of participants want the integration of simulation sessions into the cardiology training curriculum, with only one participant against it.

DISCUSSION

We combined a literature review with a survey among cardiology resident to evaluate the potential impact of simulation on their training challenges. With 62 participants among more than 500 cardiology trainees currently in Morocco, the size of our sample remains very modest. Although this allows for preliminary conclusions, a larger sample size would increase the precision and generalizability of the results. The majority of participants were in the 2nd year and 3rd year of residency. At this stage of their training, residents have acquired enough clinical experience to critically assess their training and identify their specific learning needs. The results of training quality evaluation indicate a moderate to high general satisfaction. Satisfaction studies among resident physicians regarding their training quality are rare and difficult to compare due to the significant variability in training resources, curriculum structures, and socio-economic conditions

from one country to another. A study by Babandi *et al.,* (2020) characterized the satisfaction of residents in 15 hospitals in Northwestern Nigeria as very poor, mainly due to stress, disappointment with residency training not meeting expectations, and the desire to leave training to practice abroad [51]. These conclusions further confirmed the results of Peter *et al.,* (2018), demonstrating the same level of frustration among Nigerian residents [52]. A study in Pakistan described an overall satisfaction rate of 60%, and was more specific in its evaluation with varied results according to different educational aspects of their training [53]. The best-rated areas included regular clinical case discussions, supervision by a consultant during interventional procedures, and regular journal clubs. Conversely, the less well-rated areas included constructive feedback from supervisors, role modeling by consultants, and learning from the faculty. In the United Kingdom, Gregory *et al.,* (2017) demonstrated, through multiple regression analysis on a large sample of residents (173,652 participants), an overall satisfaction estimated at 80%, with the main determinants being rigorous clinical supervision, frequent and useful feedback meetings, an adequate workload, and a supportive environment [54].

The study of difficulties and obstacles during training of Moroccan cardiology residents was particularly interesting, as it highlighted commonly found results among the majority of cardiology trainees worldwide. The prominence of acquiring invasive technical skills as the top training challenge was predictable, stemming from a global trend towards early attention of residents to subspecialty choice and future projections. The emergence of TEE and stress echocardiography among the difficult-to-learn skills seems logical, as these often require prior mastery of performing and interpreting standard transthoracic echocardiography. Nevertheless, the fact that techniques such as exercise testing and reading Holter ECG and Ambulatory Blood Pressure Monitoring data appear among the main learning difficulties for residents raises serious questions, as these techniques are part of the general cardiologist's daily diagnostic arsenal. This is explained by the absence of structured training programs for these skills in most cardiology training institutions in Morocco, where the educational architecture revolves more around theory without clear objective means tracing the technical learning. There is a significant contrast in the technical training approach between our programs and those of more developed countries, notably the United States, where trainees must structure their general training to meet the COCATS (Core Cardiology Training Symposium) requirements and where it is imperative for all cardiology trainees to reach at least level I in all categories to graduate [55]. This missing technical axis in the educational architecture in Morocco is strongly felt by the participants in our survey, who ranked it as the top obstacle in terms of importance. Our universities do not currently offer university diplomas (DUs) addressing subspecialties and invasive procedures such as cardiac catheterization or electrophysiology, leaving residents with the obligation to turn to foreign countries, for training, with access to training being far from evident. The involvement of seniors in the practical training of complex technical procedures also requires significant improvement, especially in subspecialties generally marked by competition and knowledge retention. Our survey highlights the refusal of seniors to allow hands-on practice for younger residents during complex technical procedures, as well as the lack of supervision by seniors during these procedures, as the most frequently encountered obstacles during training, impacting the self-confidence of residents throughout their learning journey.

Finally, despite the limited simulation training experience among our survey participants, residents seem well aware of the usefulness of simulation tools to address their gaps and mitigate the difficulty of technical learning. The possibility of performing and repeating complex procedures in a stress-free and patient-safe environment is seen by participants as an effective way to improve their technical skills, receive immediate and constructive feedback, and develop their self-confidence before engaging in real-life procedures. These expectations regarding simulation are fully aligned with the objectives and demonstrated benefits of simulation training.

The data from our literature review met the primary objective of this study, which was to demonstrate the importance of simulation tools in cardiology training. The overall benefit of this tool is clearly evident in the development of medical and paramedical training programs in general, and in cardiology specifically, which is perfectly suited for the integration of simulation in terms of technical procedures, communication, and team management [4].

Based on the feedback and expectations of the cardiology residents who participated in our survey, the identified positive impacts of simulation present a tremendous potential for improving the quality of training. Given the recent development of healthcare services in our country and the increased awareness of Moroccan patients, it is undeniable that patient safety should be the priority in health visions. Practicing on patients without prior skill acquisition is increasingly abandoned, and the demand for practitioner safety and expertise is a right that cannot be denied to patients, even in university hospitals. Reducing error rates among residents in procedures is a significant gain that simulation can proudly showcase, especially for invasive procedures such as cardiac catheterization, temporary pacing wire insertion, and intracardiac device implantation, where iatrogenic complications can be fatal [4,10,25,41]. Simulation training programs thus find their value in the learning of invasive procedures; a

value demonstrated through multiple reliable randomized clinical trials.

The non-technical aspect of simulation training is equally important as technical skills. Stress management, self-confidence development [20,23,27,39], responsibility, and leadership development are all strengths that any training program should highlight. Certainly, simulation can never replace practical learning, but it has a significant role in reinforcing therapeutic decision-making and prescribing habits through scenarios that closely resemble cases encountered in the hospital.

Our literature review identified several limitations of using simulation in cardiology training that can impact its effectiveness and adoption in Moroccan training institutions, despite its proven advantages. The establishment of sustained simulation programs in developing countries requires substantial investments in costs and resources, including the design, construction, and maintenance of simulation centers. Additionally, human resources for managing simulation programs are a significant consideration, requiring qualified personnel to operate equipment and supervise training sessions, adding financial burden.

Acceptance of simulation by faculty and students is also a challenge; some instructors may prefer traditional teaching methods and lack training to use simulators effectively. Students might not see the added value of simulation, though our survey indicated otherwise among Moroccan cardiology residents.

CONCLUSION

Our study deeply explored the interest and implications of using simulation in cardiology training and its ability to meet the needs and challenges of Moroccan residency curriculum. The study of various aspects of simulation, from technical training to enhancing non-technical skills such as communication and team decision-making through the main simulation technologies, demonstrated the benefits of improving patient safety, acquiring precision and speed in performing technical procedures, and developing self-confidence, communication, collaboration, and crisis management. The integration of simulation in cardiology training is crucial for several reasons. It offers a complementary approach to traditional teaching methods, providing practical experience that is not always possible in real clinical environments. Moreover, simulation prepares residents to handle rare and critical situations, thereby increasing their overall readiness and ability to respond effectively to medical emergencies.

In conclusion, simulation represents a significant advancement in cardiology training. It offers unique opportunities to enhance practitioners' skills and confidence while ensuring patient safety. Its systematic and well-planned integration into training programs is essential for preparing future cardiologists to meet the complex challenges of modern clinical practice.

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