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ORIGINAL RESEARCH

Incorporating Technology Adoption in Medical Education: A Qualitative Study of Medical Students' Perspectives

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Introduction: The integration of technology into medical education has witnessed significant growth in recent years, with tools such as virtual reality, artificial intelligence, and telemedicine gaining prominence. These tool in medical education, offering immersive, experiential learning experiences.

Methods: We approached medical students currently enrolled in medical education programs and who are familiar with and actively use AI in medical education. Initially, we invited 21 random students to participate in the study; however, only 13 agreed to interviews. Some students cited their busy exam schedules as the reason for not participating. The participants were informed of the objective of the study before the commencement of the recorded interviews. Semi-structured interviews were used to guide the record interviews. Audio recordings were transcribed and analyzed using Atlas.ti, a qualitative data analysis software.

Results: Participants exhibited a diverse range of perceptions and levels of awareness regarding VR, AI, and telemedicine technologies. Learning with virtual reality was considered to be fun, memorable, inclusive, and engaging by participants. The use of virtual reality technology is seen as complementing current teaching and learning approaches, helping to build learners' confidence, as well as providing medical students with a safe environment for problem-solving and trial-and-error learning. The students reported that AI was seen as a potential game-changer in the healthcare sector. Participants hoped that telemedicine would provide healthcare services to remote and underserved populations.

Conclusion: The study conducted focus group discussions with medical students and residents in Saudi Arabia to explore their views on integrating VR, AI, and telemedicine in medical education and practice. Their insights highlight the need for informed decision-making and strategic development to optimize the benefits and address challenges like initial investments, technical issues, ethics, and regulations. These considerations are crucial for fully realizing the potential benefits of technology in medical education globally.

keywords: learning education, medical education, medical education with virtual reality, technology in medical education, qualitative research teaching technology, artificial intelligence

Introduction

The integration of technology into medical education has witnessed significant growth in recent years, with tools such as virtual reality (VR), artificial intelligence (AI), and telemedicine gaining prominence. Virtual reality has emerged as a transformative tool in medical education, offering immersive, experiential learning experiences. Medical education has demonstrated significant potential for enhancing teaching and learning through the adoption of technology. In studies by Stella et al[1] and Hyeon and Eun,[2] interactive digital platforms and virtual simulation tools were found to improve medical students' knowledge retention, clinical skills acquisition, and decision-making abilities. Electronic health records (EHRs) can also help improve documentation practices and acquaint students with healthcare systems when integrated into educational curricula.[3] VR applications in medical education encompass anatomy exploration, surgical simulations,

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and patient case scenarios. Anthony and Bipasha[4] conducted a study evaluating the use of VR in teaching anatomy and reported that VR significantly improved students' spatial understanding and engagement compared to traditional methods. In surgical education, VR simulations provide a risk-free environment for trainees to practice procedures. A study by Seymour et al[5] found that residents who received VR training in laparoscopic surgery demonstrated improved skills and reduced errors during actual procedures. These findings emphasize the positive impact of VR on skill acquisition and competence. Artificial intelligence has begun to revolutionize medical education by personalizing learning experiences, supporting diagnostic reasoning, and facilitating adaptive assessments.[6,7] Virtual reality has emerged as a powerful tool in Saudi medical education, providing immersive learning experiences. In a study conducted by Santiago et al[8] VR-based anatomy modules were found to enhance Saudi medical students' understanding of complex anatomical structures. Such applications align with Saudi Arabia's efforts to modernize medical education and promote a deeper understanding of medical concepts.[6,9] AI-driven platforms have the capacity to personalize learning experiences, assist with diagnostic reasoning, and streamline assessments. In a Saudi context, discussed the potential of AI-driven platforms to adapt to the individual learning needs of Saudi medical students, thereby enhancing comprehension and retention of medical knowledge.[6,10] Integrating AI into the curriculum equips Saudi students with skills relevant to the evolving healthcare landscape. Telemedicine has proven to be a valuable tool in Saudi medical education, especially given the country's vast geography. Telemedicine platforms enable remote clinical experiences and interactive learning. During the COVID-19 pandemic, Saudi medical schools successfully transitioned to telemedicine, ensuring continuity in education.[11] This experience highlighted the adaptability of Saudi medical education to technology-driven changes. Telemedicine also facilitates access to diverse patient populations and exposure to telehealth technologies. It enhances Saudi students' communication skills and the ability to provide patient-centered care remotely.[11,12] By integrating telemedicine experiences into the curriculum, Saudi medical education aligns with the country's vision for modernized healthcare. Despite the notable advancements in technology-enhanced medical education in Saudi Arabia, there remains a research gap in understanding the specific challenges, opportunities, and effective strategies for integrating virtual reality (VR), artificial intelligence (AI), and telemedicine into the medical curriculum to enhance learning outcomes within the Saudi Arabian healthcare system. Studies have highlighted disparities in access to devices, internet connectivity, and software platforms among medical students and educators.[13,14] Previous studies have demonstrated that many faculty members lack training in instructional design, digital pedagogy, and technology-mediated teaching methods.[13,15] There is a gap in addressing how these technologies align with Saudi Arabia's Vision 2030, which emphasizes technology-driven education and healthcare improvements. The aim of this study to identify the specific challenges and opportunities associated with the integration of these technologies into the Saudi medical curriculum and healthcare system.

Subjects and Methods

The study utilized a qualitative approach, including focus group interviews with a purposeful sample of medical students to discuss of technology integration in the medical school from Saudi Arabia. The participants were informed of the objective of the study before the commencement of the recorded interviews. Semi-structured interviews were used to guide the record interviews. This was followed by the data analysis where the participants' responses were transcribed using the Atlas.ti. The responses, once transcribed, were read and re-read multiple times for clarity, after which the software utilized for theming and coding. Ethical approval was sought from the Institutional review board.

Study Design

Our study utilized a randomized qualitative approach to investigate the perspectives on technology integration in the medical education curriculum. The qualitative methodology involved a methodical and structured analysis of textual data collected through interviews and observations.

Study Setting

This research was carried out at King Saud University, College of Medicine, in Riyadh, Saudi Arabia. The study was conducted over the period of May to September 2023.

Sample and Sampling Technique

We approached medical students currently enrolled in medical education programs and who are familiar with and actively use AI in medical education. Initially, we invited 21 random students to participate in the study; however, only 13 agreed to interviews. Some students cited their busy exam schedules as the reason for not participating. The study employed a non-probability sampling method, specifically random selective sampling, to choose participants based on their experience with and utilization of technology within the current medical school curriculum. This conscious selection process aimed to include participants who possessed the required characteristics for the study.[16]

Data Collection

After conducting an exhaustive literature review, we designed a self-administered questionnaire to fulfill the study's objectives. Our questionnaire and objectives underwent detailed discussion among a panel of ethical team members and two medical education experts, one specializing in medical informatics and the other in medical education. After receiving suggestions and clearance from the team, we proceeded with the study. The study employed semi-structured interviews to collect data. The semi-structured interviews employed open-ended questions and facilitated two-way communication between the interviewer and the respondent.[17] The participants were required to sign an informed consent form to ensure that their names and any information that can identify them will be excluded from the study's findings and the report of the research. A comfortable and healthy environment was provided to the participants to gain their confidence and trust to talk freely and share their experiences without hesitation. Each participant was interviewed for 40 to 45 minutes. The researcher had planned and agreed with the participants on the location and time for the interviews based on the convenience, pleasure and availability of each participant. Audio recordings of all interviews were carried out as evidence of what will be written in the research paper. The anonymity of the participants was implemented by allocating a number to each interview.

Data Analysis

The qualitative data obtained from the interviews were analyzed through content analyses to generate the findings of the study. This started with the generation of themes from the study. The authors employed a numbering system and colour-coding to locate texts that relate to pre-set themes. The thematic analysis method, as explained by,[18] consists of six key processes. Firstly, researchers must familiarize themselves with the data in order to fully understand its context and significance. Secondly, initial codes are assigned to various aspects of the data, allowing for a systematic categorization. Thirdly, researchers search for themes within the data, identifying patterns or connections among the initial codes. Fourthly, the identified themes are evaluated for their reliability, validity, and coherence. Fifthly, the themes are given clear names to ensure clarity and consistency throughout the analysis. Lastly, a comprehensive report is prepared, summarizing the findings and implications of the analysis. Initially, the categories and codes were developed by analysing the words, themes, phrases and concepts that were common within the transcribed records. The first batch consisted of four students, the second batch consisted of three students, the third batch consisted with three students, and the last batch with only three students, each lasting approximately 45 minutes. Participants were given the choice to communicate in either Arabic or English, fostering a comfortable and inclusive environment for all attendees. The focus group discussions were guided by a carefully constructed topic guide, aligned with the objectives of the current study. Each interview was conducted in students' academic halls. Audio recordings were transcribed and analyzed using Atlas.ti, a qualitative data analysis software. The thematic process begs with familiarization of the data by reading the data many times and getting the understudying of the content. Then coding was done to identify the important segments of the transcriptions that meet the research objectives.

Results

With 13 participants, three individual interviews and four focus groups were conducted. The participants were between the ages of 20 and 24. The focus group discussions conducted with medical students and residents in Saudi Arabia

yielded a rich array of insights into their perceptions, expectations, and concerns regarding the integration of virtual reality (VR), artificial intelligence (AI), and telemedicine into their medical education and practice (Table 1).

Perceptions and Awareness

Participants exhibited a diverse range of perceptions and levels of awareness regarding VR, AI, and telemedicine technologies. While some participants were well-versed and enthusiastic about these technologies, others displayed a limited understanding. Generally, VR was perceived as a groundbreaking tool for immersive learning experiences, AI was seen as holding the potential to enhance diagnostics and decision-making, and telemedicine was recognized as a means to bridge healthcare gaps, especially in remote or underserved areas. Some participants reported.

> I found virtual reality to be extremely helpful in understanding the clinical skills practice during the clinical section. - (FG-10)

> In virtual reality, I learned anatomy in a very exciting and fun way (FG-3).

> Internet and TV posters and videos are seen all the time, but no one pays attention to them. Through VR, you can share what you learned with someone else and I tell everyone to try learning medical skills through VR at least once. (FG-4)

> My friends and I have already seen videos showing how VR and AI are enhancing medical education in the current world (FG-11)

Expectations and Hopes

The focus group discussions revealed high expectations and hopes among medical students and residents with regards to the integration of these technologies into their educational curriculum and future medical practice.

Enhanced Learning Experiences

Many participants anticipated that VR could revolutionize medical education by providing realistic simulations of medical procedures. They believed that this hands-on, immersive approach would lead to better understanding and retention of medical concepts.

> My clinical practice can sometimes be quite shaky, especially when I'm doing something for the first time. VR would be useful in this case. Without actually being on clinical placement, I would have the opportunity to practice hands-on. (FG-13 and FG 4)

> Using VR, you were able to understand the reality of clinical scenarios in the clinical practices of medical education (FG-8)

Table 1 Themes, Sub-Themes, and Sample Codes Identified from the Study

Themes	Sub-themes	Identified from the study.
Perceptions and Awareness	Awareness	Awareness regarding VR, AI, and telemedicine technologies About diagnostics and decision-making Telemedicine
Expectations and Hopes	Learning Experiences	VR-understanding,
	Improved Patient Care	AI-driven tools to assist in diagnosis, treatment planning, and patient management
	Accessibility	Telemedicine, healthcare services to remote and underserved populations
Challenges and Concerns	Technology Readiness	Training programs, students, educators, and healthcare practitioners to adapt to and effectively utilize these technologies
	Privacy and Data Security	Concerns about patient data protection and confidentiality, privacy safeguards in the use of AI
	Cost and Infrastructure	Financial implications
Education and Training Needs	Curriculum Integration	Education and training programs to prepare medical professionals, technology-driven future of healthcare
	Continuous Training	Ongoing training, Participants recognized that technology

Improved Patient Care

AI was seen as a potential game-changer in the healthcare sector. Participants expected AI-driven tools to assist in diagnosis, treatment planning, and patient management, ultimately leading to more accurate and efficient healthcare delivery.

> Having attended the workshop about AI-driven medical education, which looked very interesting, but patient care through AI was still in its infancy. (FG- 10)

> ……, [AI] hasn't been part of our formal curriculum. it might have come up in passing in clinical or radiology lectures in the future. (FG-8)

> We should learn about AI, since I believe it will become a reality in how doctors practice medicine, provide patient care, make diagnoses, and plan treatment in the future. (FG-11, 8, and 1)

Increased Accessibility

Telemedicine was seen as a way to overcome geographical barriers in healthcare delivery. Participants hoped that telemedicine would provide healthcare services to remote and underserved populations, enhancing healthcare accessibility across the nation.

> I know that many doctors visit the clinic virtually during COVID and this practice has continued in some cases. (FG-7, and 13)

> It's something we've always done. just never repaid for it. There have always been calls at the end of the day, to discuss lab results, current management, and urgent follow-ups. There is a role for them, you know. (FG-9, and 1)

> There were many patients with data-enabled mobile phones. Most of the time, communication is not difficult. but sometimes, patients without mobile phones have difficulty communicating… (FG-2, 5 and 10)

Challenges and Concerns

Despite their optimism, participants expressed several challenges and concerns associated with the integration of VR, AI, and telemedicine:

Technology Readiness

Some participants were apprehensive about the readiness of students, educators, and healthcare practitioners to adapt to and effectively utilize these technologies. They emphasized the importance of robust training programs.

> VR and AI methods are at an early stage of development. they will require more maturity and adaptation from doctors and patients. (FG-4, and 9)

> The conversation and personal contact with my patients are being phased out, and I enjoy meeting and speaking with them. No digital or technological advantage can replace this. (FG-6, and 11)

> ……. Not All Students Have Access to VR Equipment, Particularly in Lower-Resourced or Remote Areas. (FG-13)

Participants describe challenges in integrating AI technologies seamlessly into existing medical curricula, potentially leading to fragmentation or misalignment with educational goals. Some participants showing concern about accuracy and validity of AI-generated education content. Participants, including medical students and educators, may express concerns about the reduced opportunity for hands-on clinical experience when using telemedicine for training, potentially impacting the development of clinical skills.

Privacy and Data Security

Concerns about patient data protection and confidentiality were prevalent. Participants stressed the need for stringent privacy safeguards in the use of AI and telemedicine technologies.

> The medical records of patients are very confidential, but AI and telemedicine expose them to the public all the time. (FG-9, and 13)

Cost and Infrastructure

The financial implications of implementing these technologies were acknowledged. Participants recognized the need for substantial investments in infrastructure and training.

> A VR system is not easy to install, it is expensive, and it entails a lot of maintenance and updating. The VR system is not easy to maintain and update from a student's perspective. Technology like this is great, but institutions need to fund and support all students who use it". (FG- 4, 7, 9, and 11)

Education and Training Needs

Participants highlighted the critical importance of comprehensive education and training programs to prepare medical professionals for the integration of VR, AI, and telemedicine:

Curriculum Integration

Participants advocated for the incorporation of VR, AI, and telemedicine modules into the existing medical curriculum. They believed that this would ensure that medical students and residents are adequately prepared for the technology-driven future of healthcare.

Continuous Training

The need for ongoing training and upskilling opportunities for healthcare professionals was emphasized. Participants recognized that technology is continually evolving, and medical practitioners must stay updated.

Discussion

The study findings indicate that the participants' familiarity and enthusiasm for VR, AI, and telemedicine technologies varied widely. Some participants demonstrated a robust understanding and keen interest in these technologies, while others exhibited a limited awareness. Virtual reality (VR) emerged as a highly promising tool for immersive learning experiences in medical education. Participants who had experienced VR-based medical training expressed overwhelmingly positive sentiments. For instance, one participant in Focus Group 10 (FG-10) noted, "I found virtual reality to be extremely helpful in understanding the clinical skills practice during the clinical section". The immersive nature of VR simulations provided an effective platform for participants to practice and refine their clinical skills, enhancing their overall learning experience. Additionally, comments such as "In virtual reality, I learned anatomy in a very exciting and fun way" (FG-3) underscored the engaging and enjoyable nature of VR-based learning. The latest research is in line with VR was highlighted as having several positive aspects.[19–22] Furthermore, the study revealed that participants recognized the potential of artificial intelligence (AI) to augment diagnostics and decision-making in healthcare. AI's capacity to analyze vast datasets and offer evidence-based recommendations aligns with participants' expectations for improved healthcare outcomes. In a recent systematic review, VR was found to allow for experiential learning-by-doing because of its rich, interactive, and engaging context.[23]

This aligns with the sentiment expressed in the statement,

> Internet and TV posters and videos are seen all the time, but no one pays attention to them. Through VR, you can share what you learned with someone else, and I tell everyone to try learning medical skills through VR at least once. (FG-4)

The accessibility and reach of telemedicine were perceived as vital in extending quality healthcare to populations in need. In keeping with same line with earlier research,[24–26] VR could increase student confidence in clinical care by providing a learning and safe environment that is conducive to trial and error, which is not possible with real patients. Medical records are extensively used in telemedicine.[27] In this field, it helps to capture, preserve, and distribute data, which helps to consider essential criteria.

In accordance with previously published findings, the results of this study address, the participants' anticipation of Virtual Reality (VR) revolutionizing medical education through realistic simulations of medical procedures is a significant finding with implications for the future of healthcare training. Their belief in the potential of VR to provide hands-on, immersive experiences suggests that this technology could address existing challenges in medical education and enhance the understanding and retention of medical concepts.[26,28]

The quotes provided by participants, such as

> My clinical practice can sometimes be quite shaky, especially when I'm doing something for the first time. VR would be useful in this case. Without actually being on clinical placement, I would have the opportunity to practice hands-on (FG-13 and FG-4),

highlight the perceived value of VR in addressing the common concerns of medical students and professionals. The ability to practice medical procedures in a virtual environment offers a safe and controlled space for learners to gain confidence and competence before transitioning to real clinical settings. This aligns with the principles of deliberate practice, where individuals repeatedly practice specific skills to achieve mastery.[7,26,29] VR's capacity to facilitate deliberate practice in healthcare training has the potential to improve the preparedness of future healthcare practitioners.

The findings of this study align with existing literature that underscores the potential of VR in medical education. Research has shown that VR-based simulations can improve procedural skills, reduce errors, and increase learners' confidence.[25,30] Moreover, VR's ability to provide repetitive and contextually rich experiences aligns with the principles of effective learning in healthcare education.[31,32] The statement, "Having attended the workshop about AI-driven medical education, which looked very interesting, but patient care through AI was still in its infancy" (FG-10), reflects a common sentiment in the healthcare community. AI has garnered significant attention for its potential to transform various aspects of healthcare, including diagnostics, treatment planning, and patient care.[33,34] However, as indicated by the participant, the practical implementation of AI in patient care is still in its early stages, and its full integration into clinical practice remains a work in progress. This observation aligns with the idea that while AI has immense promise, its actual deployment in healthcare settings often lags behind the enthusiasm generated by its potential.

The participant's remark in Focus Group 8, "[AI] hasn't been part of our formal curriculum. It might have come up in passing in clinical or radiology lectures in the future", underscores the need for a structured approach to integrating AI into medical education. The absence of AI-related content in the formal curriculum reflects a broader challenge in adapting medical education to the rapidly evolving field of healthcare technology.[35,36] Integrating AI into medical curricula is crucial to ensure that future healthcare professionals are prepared to work effectively with AI systems and understand their limitations and ethical considerations.

The participants' expressed hope that telemedicine could extend healthcare services to remote and underserved populations aligns with the broader goals and potential benefits of telemedicine in improving healthcare accessibility. Their comments reflect a growing awareness of the role telemedicine plays in expanding healthcare access, particularly during public health crises such as the COVID-19 pandemic. The COVID-19 pandemic accelerated the adoption of telemedicine as a means to provide safe and accessible healthcare services while minimizing the risk of virus transmission.[37–39] This shift toward virtual healthcare encounters, as observed by the participant, highlighted the potential for telemedicine to overcome geographical barriers and reach patients in remote or underserved areas.

The participants' sentiments are consistent with existing literature on telemedicine's impact on healthcare accessibility. Telemedicine has demonstrated its ability to reduce healthcare disparities by connecting patients in rural or remote locations with healthcare providers, specialists, and experts who may not be physically present in those areas.[40] It offers a practical solution to address healthcare shortages in underserved regions, helping to ensure that individuals in these areas receive timely and appropriate care. Furthermore, telemedicine can enhance healthcare accessibility for vulnerable populations, such as those with limited mobility, transportation challenges, or chronic conditions.[41,42] It provides a convenient and cost-effective means for patients to consult with healthcare professionals, potentially leading to better health outcomes. Despite the positive outlook on telemedicine expressed by the participants, it is important to acknowledge that its widespread adoption and sustainability depend on various factors, including regulatory policies, infrastructure, reimbursement models, and technology access.[43] To fully realize the potential of telemedicine in enhancing healthcare accessibility, healthcare systems and policymakers must address these challenges.

The apprehension expressed by some participants regarding the readiness of students, educators, and healthcare practitioners to adapt to and effectively utilize Virtual Reality (VR) and Artificial Intelligence (AI) technologies raises important considerations about the integration of these innovations into healthcare and medical education. While VR and AI hold significant promise, their full potential is still being realized and their practical implementation is evolving.[33,44] This means that healthcare professionals, including doctors and nurses, may require additional training and education to effectively leverage these technologies in clinical practice. Successful technology adoption hinges on healthcare professionals' ability to navigate and use these tools effectively.[45,46] Comprehensive training programs can bridge the gap between theoretical knowledge and practical application, helping healthcare practitioners build confidence in using VR and AI technologies in various clinical settings.[47] The concerns expressed by participants regarding the readiness of students are also noteworthy. While the current generation of students may be more technologically savvy, they still require structured guidance and education on how to apply VR and AI tools effectively in clinical practice.[30,35,48] Training programs for students should encompass not only the technical aspects of these technologies but also their clinical relevance and considerations. It is important to acknowledge the limitations of this study. The research was conducted within a specific time frame, and the technology landscape is rapidly evolving. Additionally, the generalizability of findings to all medical schools and healthcare facilities in Saudi Arabia may be limited due to variations in resources and infrastructure.

Limitations

A limitation of the study is its relatively small sample size of only 13 participants. Nevertheless, the findings might not fully represent the perspectives of the diverse population within Saudi Arabia based on the focus groups with medical students and residents. Furthermore, the study was limited to a preliminary exploration of VR, AI, and telemedicine integration in medical education and practice. Future research endeavors will address these limitations by conducting a more extensive analysis with a larger sample size. This upcoming research will allow for a more comprehensive understanding of the topic and enable us to draw more robust conclusions. Furthermore, it will be conducted after gaining more experience with AI use in medical education, which will enhance the validity and generalizability of the findings.

Conclusion

The advancements in technology and their integration into medical education are not unique to Saudi Arabia; they reflect a global trend towards leveraging innovative solutions to enhance healthcare training and delivery. The integration of technology, including virtual reality, artificial intelligence, and telemedicine, in medical education in Saudi Arabia has shown substantial promise in enhancing learning experiences, improving clinical skills, and expanding healthcare access. The focus group discussions provided valuable insights into the perceptions, expectations, and concerns of key stakeholders in the Saudi medical context regarding the integration of VR, AI, and telemedicine. These discussions underscore the significance of embracing technological innovations in medical education to advance healthcare delivery and achieve the goals outlined in Saudi Arabia's Vision 2030. These findings are essential for informed decision-making and shaping future policies and educational strategies in Saudi Arabia's medical education and healthcare delivery systems. Embracing a worldwide perspective and fostering international cooperation, the global community can collectively harness the transformative power of technology to advance medical education and improve healthcare outcomes for populations around the world. However, challenges related to initial investments, technical issues, ethical considerations, and regulatory frameworks need to be addressed for the full realization of the potential benefits of technology in medical education within the Saudi and world.

Abbreviations

VR, Virtual reality; AI, Artificial intelligence; FG, Focus group; COVID-19, coronavirus disease- 2019; IRB, Institutional review board.

Data Sharing Statement

All datasets used and/or analyzed in this study are available upon request from the corresponding author.

Ethics Approval and Consent to Participate

This study was approved by the Institutional Review Board (IRB) at King Saud University (KSU) in Riyadh, Saudi Arabia. Before participating, all participants signed a consent form. All participants provided informed consent prior to data collection. Participation was voluntary. The methods used were in accordance with all relevant guidelines and regulations.

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Consent for Publication

Participants signed a consent form before participating in the study. All participants agreed to participate and allow publication. Each author involved in the method has given his or her consent.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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