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Transforming simulation in healthcare to enhance interprofessional collaboration leveraging big data analytics and artificial intelligence

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Abstract
Simulation in healthcare, empowered by big data analytics and artificial intelligence (AI), has the potential to drive transformative innovations towards enhanced interprofessional collaboration (IPC). This convergence of technologies revolutionizes medical education, offering healthcare professionals (HCPs) an immersive, iterative, and dynamic simulation platform for hands-on learning and deliberate practice. Big data analytics, integrated in modern simulators, creates realistic clinical scenarios which mimics real-world complexities. This optimization of skill acquisition and decision-making with personalized feedback leads to life-long learning. Beyond clinical training, simulation-based AI, virtual reality (VR), and augmented reality (AR) automated tools offer avenues for quality improvement, research and innovation, and team working. Additionally, the integration of VR and AR enhances simulation experience by providing realistic environments for practicing high-risk procedures and personalized learning. IPC, crucial for patient safety and quality care, finds a natural home in simulation-based education, fostering teamwork, communication, and shared decision-making among diverse HCP teams. A thoughtful integration of simulation-based medical education into curricula requires overcoming its barriers such as professional silos and stereo-typing. There is a need for a cautious implantation of technology in clinical training without overly ignoring the real patient-based medical education.

Keywords Simulation, Healthcare, Big data analytics, Augmented reality, Virtual reality, Artificial intelligence, Medical education

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Transforming simulation in healthcare to enhance interprofessional collaboration leveraging big data analytics and artificial intelligence

Simulation in healthcare, powered by big data analytics (BDA) and artificial intelligence (AI), stands at the forefront of transformative innovations with a promise to facilitating interprofessional collaboration (IPC). This convergence of technologies towards educational philosophies not only revolutionizes medical training but also enhances the quality of care and patient safety in an IPC climate for an efficient delivery of healthcare system [1]. Simulation in healthcare showcases a controlled, versatile, and safe environment for healthcare professionals (HCPs) from diverse disciplines to engage in hands-on learning with deliberate practice [2]. Learners are engrossed in immersive, iterative, and interactive climate which can nurture opportunities for the acquisition of transferable psychomotor and cognition-based skills [3]. A simulated environment nurtures the real jest of life-long learning where learners can be trained by deliberate practice till the acquisition of their skills.

BDA, embedded in modern cutting-edge simulators, can utilize enormous healthcare data for clinical training and skills acquistion [4]. For instance, Bateman and Wood employed Amazon's Web Service to accumulate a complete human genomic scaffold including 140 million individual base pairs by adopting an advanced hashing algorithm [5]. Later, a BDA platform successfully matched patients' data of children in hospital to their whole-genome sequencing for the management of potentially incurable clinical conditions [6]. From another perspective, leveraging clinical scenarios with realism, BDA can be a valuable tool in reflecting the complexities of the real-world medical practice. This data-driven approach diligently mimics the variability and inconsistency encountered in real clinical settings, preparing HCPs for diverse patient encounters and crisis management. Artificial intelligence (AI) with its machine learning algorithm (MLA) and natural language processing (NLP) further fortifies the impact of simulation by enabling adaptive learning experiences [7]. Moreover, AI-powered patient simulators with automated interfaces can demonstrate high fidelity realistic physiological responses such as pulse, blood pressure, breathing patterns, and facial expressions to allow learners to practice decision-making in lifelike scenarios. By analyzing simulation data, institutions can identify trends, best practices, and areas for improvement, ultimately enhancing patient outcomes and advancing medical knowledge.

Applications of BDA harness the experimental usage of electronic health records, medical imaging, genetic information, and patients' demographics. By aggregating and analyzing this data, simulation platforms can create realistic scenarios that can be used by learners for clinical reasoning and critical decision-making. Additionally, MLA and NLP have the ability to predict disease prognosis, treatment efficacy, and unwanted outcomes, thereby offering a reliable hub for interactive and immersive learning for HCPs [8]. MLA and NLP encourage adaptive learning experiences by analyzing learner interactions and performance in real-time. This unique opportunity of acquiring skills mastery with personalized feedback either by simulator, peer, or facilitator makes simulation a master-class educational and training tool for all HCPs. For instance, if a learner consistently makes errors in decision-making or a procedural skill, a smart simulator can tailor further exercises to provide targeted practice opportunities for individual learners.

Clinical training is interposed at the crossroads of adopting AI, virtual reality (VR), and augmented reality (AR) technologies. Beyond training, simulation-driven medical education holds immense potential for quality improvement and research in healthcare [9]. VR and AR technologies offer immersive experiences that simulate clinical settings with unprecedented realism. VR headsets transform learners into a cyber space where they deal with animations, digital images, and a host of other exercises in virtual climate [10]. AR overlays digital information onto the physical world, allowing learners to visualize anatomical structures, medical procedures, or patient data in real-time. Moreover, VR and AR can be used to perform high risk medical procedures till the complete acquisition of skill mastery. Such opportunity is not possible due to threats to patient safety and limited time for learners' training in real-world workplaces [11]. At the same time, the mapping of learners' needs with the curriculum is possible only in simulated environment where learners' expectations can be tailored to meet their learning styles [11]. AI, VR, and AR technologies in healthcare simulators essentially empower learners to develop clinical expertise, enhance patient care, and drive innovations in healthcare delivery.

An example of integration of AI, NP, ML, and certain other algorithms in simulation is the sepsis management of a virtual patient being managed by a team of HCPs from different healthcare disciplines. A patient presents with fever, confusion, and rapid breathing in the emergency room. AI platform creates a detailed medical record of the patient with past hospital visits, medications, allergies, and baseline health metrics. AI simulates patient's symptoms in real-time with tachycardia, tachypnea, hypotension, and fever. The trainees interview the virtual patient and AI responds, using NLP, by providing coherent and contextually appropriate answers. The trainees order a set of tests, including blood cultures, a complete blood count, and lactate levels. AI presents realistic test results where blood cultures show a bacterial infection, leukocytosis, and elevated lactate levels. Based on the diagnosis of sepsis, the trainees plan treatment which typically includes oxygen, broad-spectrum antibiotics, and intravenous fluid. AI then adjusts the patient condition based on the trainees' actions which may lead to improvement in clinical parameters. However, a delayed treatment could lead to worsening symptoms such as septic shock. Furthermore, AI can introduce complications if initial treatments were ineffective or if the trainees commit errors. Thereupon, AI provides real-time feedback on the trainees' decisions which can highlight missed signs, suggest alternative diagnostic tests, or recommend adjustments to treatment plans. Lastly, AI would generate a summary report of the performance with a breakdown of diagnostic accuracy, treatment efficacy, and adherence to clinical guidelines. MLAs analyze patterns in patient data to assist in diagnosis. In this context, decision trees and neural networks of MLAs analyze vast datasets of patient records to create realistic virtual patients with diverse medical histories and clinical conditions.

There has been a proliferation of empirical research about the powerful role of IPC in medical education [12, 13]. IPC fosters shared decision-making, role identification and negotiations, team coherence, and mitigates potential errors [14]. Through simulated scenarios, HCPs learn to navigate interdisciplinary challenges, appreciate each other's roles, and develop a shared approach to patient care. Additionally, simulation in healthcare faces the challenges of costs, access, development, and ethical considerations. Nevertheless, the integration of simulation, BDA, VR, AR, and AI heralds a new era of IPC in healthcare, where learning, practice, and innovation converge to shape the future of medicine.

The overarching goal of all healthcare systems focuses on patient safety as reiterated by the World Health Organization (WHO) sustainable development goals [15]. General Medical Council, Irish Medical Council, Canada MEDs, Accreditation Council for Graduate Medical Education, and EmiatesMEDS are also in agreement with WHO and, in this context, IPC can potentially enhance the quality of care and patient safety [16]. Though the role of IPC is widely accepted, there is a lukewarm response from medical institutions about its integration into the existing curricula. Professional silos, stereotyping, bureaucratic inertia, and resistant mindsets are some of the deterring factors [17]. In the era of simulation in healthcare, IPC can be efficiently embedded into this technology-powered educational tool for impactful collaborative teamwork. By harnessing the technological power of VR, AR, and AI, simulation platforms can leverage the indigenous advantage of IPC in clinical training. Once skills acquisition is accomplished in the simulated platform, its recreation in the real world would be a seamless transition of transferable skills.

To sum up, despite an exponential growth in the use of technology-driven simulation in healthcare, educators should be mindful of its careful integration in medical curricula. Clinical training on real patients cannot be replaced by any strategy or tool regardless of its perceived efficiency or effectiveness. Bearing in mind the learning styles of our learners with a preference toward fluid than crystalloid verbal comprehension and fluid reasoning, technology-driven simulation plays a vital role in medical education. A thoughtful integration of simulation pitched at certain courses and modules spiraled across the curriculum will enhance the learning experience of medical and health sciences students and HCPs [18].

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