Commentary

Medicine

What Could We Expect When Quantum Meets Medicine?

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The convergence of quantum physics and medicine has the potential to transform healthcare in unprecedented ways. Quantum computers can process vast quantities of data with unmatched velocity, facilitating more precise diagnoses and customized treatment strategies aligned with each individual's distinct genetic profile. Quantum sensors can identify diseases in their initial stages, facilitating preemptive measures prior to the manifestation of symptoms. Quantum encryption technology guarantees the utmost preservation of patient privacy and data security. Additionally, quantum concepts like superposition and entanglement may soon be utilized for innovative medicines that precisely target individual molecules, hence reducing side effects and enhancing efficacy. As researchers investigate the intersection of quantum mechanics and medicine, we anticipate a future in which healthcare is proactive, preventive, and genuinely individualized rather than merely reactive.

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QUANTUM mechanics is a discipline of physics that has transformed our comprehension of the essential elements of nature (Dowling & Milburn, 2003). It pertains to occurrences at the minute scales of energy levels of atoms and subatomic particles (Lewis, n.d.; Lopez et al., 2022). The implementation of quantum mechanics has resulted in significant advancements in technology and research (OpenLibrary.org, 1961). A particularly intriguing domain where quantum mechanics may exert a substantial influence is medicine (Bisiani et al., 2023).

The convergence of quantum mechanics and medicine has the capacity to transform the healthcare sector (Pulipeti & Kumar, 2022). Quantum mechanics facilitates the manipulation and control of individual atoms and molecules, potentially resulting in the advancement of more precise and effective therapies for many ailments (Raghunandan et al., 2019). Quantum computing may facilitate the simulation of intricate biological processes and the analysis of extensive genomic data to tailor treatments for specific patients (Flöther, 2023; Santagati et al., 2024). Besides, quantum mechanics presents opportunities for the advancement of novel imaging techniques that may transform medical diagnosis (Haga, 2024; Pal et al., 2023). Quantum sensors may facilitate the detection of biomarkers within the body with unparalleled sensitivity and specificity, enabling the early identification of diseases like cancer (Aslam et al., 2023; Chugh et al., 2023; Haga, 2024; Zhang et al., 2024). Quantum imaging methodologies may yield enhanced resolution images of the body, facilitating more precise diagnostics and targeted therapies (Altıntaş & Tothill, 2015; Aslam et al., 2023; Pericleous et al., 2012).

The concepts of quantum mechanics may be utilized in medicine development and delivery. Quantum computing may facilitate the design of novel pharmaceuticals with precise molecular architectures that specifically target and interact with pathogenic molecules with exceptional accuracy (Flöther, 2023; Kulkarni et al., 2018; Raghunandan et al., 2019). Quantum dots, tiny particles exhibiting quantum characteristics, may serve as drug carriers to transport medications directly to specific cells within the body, therefore reducing side effects and enhancing therapeutic efficacy (Abdellatif et al., 2022; Azzazy et al., 2007; Banerjee & Verma, 2011; Delehanty et al., 2009; Hussain et al., 2024; Iga et al., 2007; Kulkarni et al., 2018; Probst et al., 2012; Samia et al., 2003; Santra, 2012; Zhao & Zhu, 2016).

Quantum physics may profoundly influence the domain of regenerative medicine. Quantum bioengineering may facilitate the manipulation of stem cells at the atomic level, enabling precise control over their differentiation into specific cell types for tissue regeneration and repair (Facchin et al., 2018; Hameroff, 2004; Jacobson, 2016; Solanki et al., 2008). This may result in the advancement of novel therapies for diseases including spinal cord injury, cardiovascular disease, and diabetes.

The use of quantum physics into medicine presents ethical and cultural ramifications (Facchin et al., 2019; Jacobson, 2016; Tsonis, 2002). The advancement of quantum technologies in healthcare may intensify existing health disparities, as access to these innovative treatments could be restricted to individuals with sufficient financial resources (Rasool et al., 2023; Wang & Alexander, 2020). Policymakers and stakeholders must solve these concerns to guarantee equal access to quantum-based medicinal innovations. Furthermore, the security and privacy of personal health data must be meticulously evaluated when integrating quantum technologies into healthcare (Bida et al., 2023). Quantum cryptography may be employed to safeguard patient data and defend against cyberattacks, thereby maintaining the security and integrity of medical information (Gupta et al., 2024; Selvarajan & Mouratidis, 2023). Nonetheless, these security protocols require ongoing updates and surveillance to remain proactive against new threats.

The integration of quantum mechanics and medicine presents significant potential for revolutionizing illness detection, treatment, and management. Utilizing quantum technology, healthcare practitioners could deliver more tailored and effective patient care, resulting in enhanced health outcomes and quality of life. The future of medicine is expected to be influenced by the principles of quantum physics, creating new opportunities for medical innovation and transforming the practice of medicine.■

References

Abdellatif, A. A., Younis, M. A., Alsharidah, M., Rugaie, O. A., & Tawfeek, H. M. (2022). Biomedical Applications of Quantum Dots: Overview, Challenges, and Clinical Potential. International Journal of Nanomedicine, 17, 1951-1970. DOI: https://doi.org/10.2147/ijn.s357980

Altintas, Z., & Tothill, I. E. (2015). Molecular biosensors: promising new tools for early detection of cancer. Nanobiosensors in Disease Diagnosis, 1. DOI: https://doi.org/10.2147/ndd.s56772

Aslam, N., Zhou, H., Urbach, E. K., Turner, M. J., Walsworth, R. L., Lukin, M. D., & Park, H. (2023). Quantum sensors for biomedical applications. Nature Reviews Physics, 5(3), 157-169. DOI: https://doi.org/10.1038/s42254-023-00558-3

Azzazy, H. M., Mansour, M. M., & Kazmierczak, S. C. (2007). From diagnostics to therapy: Prospects of quantum dots. Clinical Biochemistry, 40(13-14), 917-927. DOI: https://doi.org/10.1016/j.clinbiochem.2007.05.018

Banerjee, H., & Verma, M. (2011). Quantum dots and their potential applications in cancer detection and therapy. International Journal of Biomedical Nanoscience and Nanotechnology, 2(1), 33. DOI: https://doi.org/10.1504/ijbnn.2011.038465

Bida, M. N., Mosito, S. M., Miya, T. V., Demetriou, D., Blenman, K. R. M., & Dlamini, Z. (2023). Transformation of the Healthcare Ecosystem in the Era of Society 5.0. In Society 5.0 and Next Generation Healthcare (pp. 223-248). DOI: https://doi.org/10.1007/978-3-031-36461-7_10

Bisiani, J., Anugu, A., & Pentyala, S. (2023). It's Time to Go Quantum in Medicine. Journal of Clinical Medicine, 12(13), 4506. DOI: https://doi.org/10.3390/jcm12134506

Chugh, V., Basu, A., Kaushik, A., & Basu, A. K. (2023). Progression in Quantum Sensing/Bio-Sensing Technologies for Healthcare. ECS Sensors Plus, 2(1), 015001. DOI: https://doi.org/10.1149/2754-2726/acc190

Delehanty, J. B., Boeneman, K., Bradburne, C. E., Robertson, K., & Medintz, I. L. (2009). Quantum dots: a powerful tool for understanding the intricacies of nanoparticle-mediated drug delivery. Expert Opinion on Drug Delivery, 6(10), 1091-1112. DOI: https://doi.org/10.1517/17425240903167934

Dowling, J. P., & Milburn, G. J. (2003). Quantum technology: the second quantum revolution. Philosoph-

ical Transactions of the Royal Society a Mathematical Physical and Engineering Sciences, 361(1809), 1655-1674. DOI: https://doi.org/10.1098/rsta.2003.1227
Facchin, F., Bianconi, E., Canaider, S., Basoli, V., Biava, P. M., & Ventura, C. (2018). Tissue Regeneration without Stem Cell Transplantation: Self-Healing Potential from Ancestral Chemistry and Physical Energies. Stem Cells International, 2018, 1-8. DOI: https://doi.org/10.1155/2018/7412035
Facchin, F., Canaider, S., Tassinari, R., Zannini, C., Bianconi, E., Taglioli, V., Olivi, E., Cavallini, C., Tausel, M., & Ventura, C. (2019). Physical energies to the rescue of damaged tissues. World Journal of Stem Cells, 11(6), 297-321. DOI: https://doi.org/10.4252/wjsc.v11.i6.297
Flöther, F. F. (2023). The state of quantum computing applications in health and medicine. Research Directions Quantum Technologies, 1-21. DOI: https://doi.org/10.1017/qut.2023.4
Gupta, K., Saxena, D., Rani, P., Kumar, J., Makkar, A., Singh, A. K., & Lee, C. (2024). An Intelligent Quantum Cyber-Security Framework for Healthcare Data Management. IEEE Transactions on Automation Science and Engineering, 1-12. DOI: https://doi.org/10.1109/tase.2024.3456209
Haga, A. (2024). Quantum annealing-based computed tomography using variational approach for a real-number image reconstruction. Physics in Medicine and Biology, 69(4), 04NT02. DOI: https://doi.org/10.1088/1361-6560/ad2155
Hameroff, S. R. (2004). A new theory of the origin of cancer: quantum coherent entanglement, centrioles, mitosis, and differentiation. Biosystems, 77(1-3), 119-136. DOI: https://doi.org/10.1016/j.biosystems.2004.04.006
Hussain, S., Packirisamy, G., Misra, K., Tariq, M., & Sk, M. P. (2024). Editorial: Quantum dots for biological applications, volume II. Frontiers in Bioengineering and Biotechnology, 12. DOI: https://doi.org/10.3389/fbioe.2024.1389974
Iga, A. M., Robertson, J. H. P., Winslet, M. C., & Seifalian, A. M. (2007). Clinical Potential of Quantum Dots. Journal of Biomedicine and Biotechnology, 2007, 1-10. DOI: https://doi.org/10.1155/2007/76087
Jacobson, J. I. (2016). A quantum theory of disease, including cancer and aging. Integrative Molecular Medicine, 3(1). DOI: https://doi.org/10.15761/imm.1000200
Kulkarni, N. S., Guererro, Y., Gupta, N., Muth, A., & Gupta, V. (2018). Exploring potential of quantum dots as dual modality for cancer therapy and diagnosis. Journal of Drug Delivery Science and Technology, 49, 352-364. DOI: https://doi.org/10.1016/j.jddst.2018.12.010
Lewis, P. J. (n.d.). Quantum Mechanics, Interpretations of | Internet Encyclopedia of Philosophy. Internet Encyclopedia of Philosophy. Available at: https://iep.utm.edu/int-qm/
Lopez, A., Kelly, P., Dauer, K., & Vitali, E. (2022). Fermionic superfluidity: from cold atoms to neutron stars. European Journal of Physics, 43(6), 065801. DOI: https://doi.org/10.1088/1361-6404/ac8707
OpenLibrary.org. (1961). Quantum mechanics. by Albert Messiah | Open Library. Open Library. Available at: https://openlibrary.org/books/OL5843556M/Quantum_mechanics
Pal, S., Bhattacharya, M., Lee, S., & Chakraborty, C. (2023). Quantum Computing in the Next-Generation Computational Biology Landscape: From Protein Folding to Molecular Dynamics. Molecular Biotechnology, 66(2), 163-178. DOI: https://doi.org/10.1007/s12033-023-00765-4
Pericleous, P., Gazouli, M., Lyberopoulou, A., Rizos, S., Nikiteas, N., & Efstathopoulos, E. P. (2012). Quantum dots hold promise for early cancer imaging and detection. International Journal of Cancer, 131(3), 519-528. DOI: https://doi.org/10.1002/ijc.27528
Probst, C. E., Zrazhevskiy, P., Bagalkot, V., & Gao, X. (2012). Quantum dots as a platform for nanoparticle drug delivery vehicle design. Advanced Drug Delivery Reviews, 65(5), 703-718. DOI: https://doi.org/10.1016/j.addr.2012.09.036
Pulipeti, S., & Kumar, A. (2022). Secure quantum computing for healthcare sector: A short analysis. Security and Privacy, 6(5). DOI: https://doi.org/10.1002/spy2.293
Raghunandan, R., Voll, M., Osei, E., Darko, J., & Laflamme, R. (2019). A review of applications of principles of quantum physics in oncology: do quantum physics principles have any role in oncology research and applications? Journal of Radiotherapy in Practice, 18(4), 383-394. DOI: https://doi.org/10.1017/s1460396919000153
Rasool, R. U., Ahmad, H. F., Rafique, W., Qayyum, A., Qadir, J., & Anwar, Z. (2023). Quantum Computing for Healthcare: A Review. Future Internet, 15(3), 94. DOI: https://doi.org/10.3390/fi15030094
Samia, A. C. S., Chen, X., & Burda, C. (2003). Semiconductor Quantum Dots for Photodynamic Therapy. Journal of the American Chemical Society, 125(51), 15736-15737. DOI: https://doi.org/10.1021/ja0386905
Santagati, R., Aspuru-Guzik, A., Babbush, R., Degroote, M., González, L., Kyoseva, E., Moll, N., Oppel, M., Parrish, R. M., Rubin, N. C., Streif, M., Tautermann, C. S., Weiss, H., Wiebe, N., & Utschig-Utschig, C. (2024). Drug design on quantum computers. Nature Physics, 20(4), 549-557. DOI: https://doi.org/10.1038/s41567-024-02411-5
Santra, S. (2012). The Potential Clinical Impact of Quantum Dots. Nanomedicine, 7(5), 623-626. DOI: https://doi.org/10.2217/nnm.12.45
Selvarajan, S., & Mouratidis, H. (2023). A quantum trust and consultative transaction-based blockchain cybersecurity model for healthcare systems. Scientific Reports, 13(1). DOI: https://doi.org/10.1038/s41598-023-34354-x
Solanki, A., Kim, J. D., & Lee, K. (2008). Nanotechnology for Regenerative Medicine: Nanomaterials for Stem Cell Imaging. Nanomedicine, 3(4), 567-578. DOI: https://doi.org/10.2217/17435889.3.4.567
Tsonis, P. A. (2002). Regenerative biology: The emerging field of tissue repair and restoration. Differentiation, 70(8), 397-409. DOI: https://doi.org/10.1046/j.1432-0436.2002.700802.x
Wang, L., & Alexander, C. A. (2020). Quantum Technology: Advances and Trends. American Journal of Engineering and Applied Sciences, 13(2), 254-264. DOI: https://doi.org/10.3844/ajeassp.2020.254.264
Zhang, Y., He, Z., Tong, X., Garrett, D. C., Cao, R., & Wang, L. V. (2024). Quantum imaging of biological organisms through spatial and polarization entanglement. Science Advances, 10(10). DOI:

https://doi.org/10.1126/sciadv.adk1495
Zhao, M., & Zhu, B. (2016). The research and applications of quantum dots as nano-carriers for targeted drug delivery and cancer therapy. Nanoscale Research Letters, 11(1). DOI: https://doi.org/10.1186/s11671-016-1394-9

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