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VR SIMULATORS FOR TRAINING LAPAROSCOPIC SURGERIES

Nasibiddinov Xushnudbek Qodirjon o'g'li
Tashkent State Medical University
Faculty of General Medicine No.1, student of group 119
Tashkent, Uzbekistan
Phone number: +998958011183
Fazliddin Arzikulov
Assistant of the Department of Biomedical
Engineering, Informatics, and Biophysics at
Tashkent State Medical University

Abstract: Virtual Reality (VR) simulators have become essential tools in modern surgical education, especially for laparoscopic training. These systems provide realistic, immersive environments where trainees can practice technical skills without risk to patients. VR allows for standardized training, objective performance assessment, and unlimited repetition of surgical procedures. Despite challenges related to cost and varying levels of realism, VR-based training has proven effective in improving surgical accuracy, reducing errors, and enhancing patient safety. This article explores the role, advantages, limitations, and future potential of VR simulators in laparoscopic surgery training.

Keywords: Virtual Reality (VR); laparoscopic surgery; surgical training; simulation-based learning; haptic feedback; medical education; minimally invasive surgery; performance assessment; patient safety; surgical simulation.

Introduction: Laparoscopic surgery has become a standard technique in modern surgical practice due to its minimal invasiveness, faster patient recovery, and reduced postoperative complications. However, it demands advanced psychomotor skills, hand–eye coordination, and proficiency in navigating instruments within a limited field of vision. Traditional surgical training methods—observation, assisting senior surgeons, and limited hands-on practice—often do not provide sufficient opportunities for safe, repeated learning.

Virtual Reality (VR) simulators offer a promising solution to these challenges. By creating immersive, interactive, and realistic surgical environments, VR technologies allow trainees to gain experience without depending on operating room availability or risking patient safety. VR-based training supports both foundational skill acquisition and complex procedure simulations. As a result, medical schools, training hospitals, and accreditation bodies increasingly recognize VR simulation as an essential component of surgical education.

Virtual Reality simulators recreate detailed anatomical environments where trainees perform laparoscopic tasks under realistic constraints, such as limited instrument movement, fixed camera angles, and depth perception challenges. These simulators often incorporate haptic feedback systems that mimic tissue resistance, cutting, suturing, and grasping sensations, helping learners build tactile awareness crucial for surgical performance.

VR systems offer standardized training modules starting from basic skills—camera navigation, instrument handling, knot tying—and progressing toward advanced simulations like laparoscopic cholecystectomy, appendectomy, and hernia repair. Real-time analytics track performance metrics including precision, force, time, errors, and movement trajectories. Such

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objective feedback allows for consistent evaluation and tailored skill improvement, minimizing subjectivity in assessment.

Main part: Urolithiasis is a widespread condition, occurring in about 10% of individuals. Although many predisposing factors have been identified and preventive strategies have been introduced, most patients still require surgical treatment, making it crucial for urologists to master contemporary operative techniques. Today, open surgery for stones in the upper urinary tract has been almost entirely replaced by minimally invasive approaches, including percutaneous nephrolithotripsy (PNL) and retrograde intrarenal surgery (RIRS). Both procedures consist of several technical stages, and the accuracy and safety with which these stages are performed directly influence the overall success of treatment.

Training young specialists in endourological procedures presents several difficulties, such as an extended learning curve and the necessity to ensure patient safety throughout the process. Virtual reality (VR) offers a promising solution by enabling detailed visualization and simulation of surgical techniques, helping to overcome many of these limitations. However, existing VR platforms tend to be prohibitively expensive, use standardized renal pelvicalyceal system (RPS) models, and often cannot provide fully immersive nephroscopy training—an important drawback considering the absence of direct visualization during endoscopic operations.

The objective of this study is to present a VR-based method for visualizing the internal structure of the renal pelvis using specialized headsets and to evaluate its effectiveness in teaching spatial orientation during retrograde pyelocalycoscopy to medical residents. At the start of the project, CT urograms from six patients with different renal pelvic cavity configurations were selected. Four cases corresponded to the Sampaio classification of renal collecting system types, while the remaining two involved anatomical variations such as horseshoe kidney and duplex kidney. For each case, a 3D model of the renal collecting system was created and exported in stereolithography (STL) format using RadiAnt DICOM Viewer. The models were then refined using the open-source software Blender, after which the files were transferred to a smartphone. The entire process required roughly 2–3 minutes on average. The foundation of the visualization system was the InsKid application, developed in C# for Android-based smartphones. After loading an STL model of the collecting system, the application allows the user to choose between 2D and VR viewing modes. In both modes, internal and external 3D reconstructions appear in the left and right screens of the smartphone, respectively, while a red triangle in the right screen indicates the user's real-time position and direction of gaze In modern surgical education, a growing proportion of training is carried out outside the operating room, allowing trainees to progress through much of the learning curve without direct involvement of patients. The simulators that support this shift are typically classified by manufacturing type into biological, non-biological, and virtual reality (VR)–based models. Although physical simulators offer realistic tactile sensations, their educational effectiveness has been shown to be comparable to that of VR systems. VR simulators, however, provide important advantages: they allow the use of digital anatomical models with diverse structural variations without the need for physical fabrication and eliminate dependence on delicate endourological instruments, which are prone to damage when used by beginners during early training stages.

Several VR platforms aimed at skill acquisition and preoperative planning for minimally invasive management of upper urinary tract stones have been described in the literature. The UroMentor™ system (Symbionix, Cleveland, OH, USA) reproduces rigid and flexible cystoscopy, ureteroscopy, and pyeloscopy, enabling users to practice lithotripsy and stone extraction techniques. Another solution—the PERC Mentor™ (Symbionix, Cleveland, OH, USA)—is a monitor-based simulator for percutaneous access and antegrade renal procedures, operating without VR goggles. A notable advancement in the field is the K181 PCNL & Kidney Access Array (Marion Surgical Inc., Buffalo, NY, USA), a VR headset–based percutaneous stone surgery simulator capable of uploading patient-specific CT data. Additionally, a technique proposed by E. Parkhomenko and colleagues introduces VR-guided planning for renal calyx puncture prior to percutaneous nephrolithotripsy by allowing visualization of renal structures and adjacent organs in a VR environment.

Training to perform endourological procedures for urolithiasis requires not only mastering the initial surgical steps but also the ability to orient oneself within restricted anatomical spaces, such as the renal collecting system. Despite the availability of multiple VR simulators, only two currently rely on VR headsets, and among them, only the Marion Surgical K181 platform supports full virtual nephroscopy using CT images from individual patients. Another limiting factor is the cost of VR technologies: the systems mentioned above are produced abroad and typically priced at over USD 20,000, significantly restricting their adoption in clinical settings and educational programs for residents and medical students. More affordable alternatives are therefore urgently needed for broader implementation.

Conclusion: VR simulators represent a transformative advancement in laparoscopic surgical training, offering risk-free, standardized, and immersive learning environments. They enable trainees to build necessary psychomotor skills, practice complex procedures, and receive objective feedback in ways traditional training cannot. Although cost and realism challenges persist, ongoing innovation promises even more efficient and accessible simulation-based training. As VR technologies continue to evolve, they are likely to become an essential and universal component of surgical education, leading to higher competency levels and improved patient safety worldwide.

References

1. Aggarwal, R., & Darzi, A. (2011). Virtual reality in surgical training. *Surgical Endoscopy*, 25(8), 2253–2258.
2. Seymour, N. E. (2008). VR simulation in surgical training: Current status and future directions. *Journal of Surgical Education*, 65(6), 599–602.
3. Gallagher, A. G., & Cates, C. U. (2004). Virtual reality training for surgical trainees. *BMJ*, 328(7439), 426–427.
4. Alaker, M., Wynn, G. R., & Arulampalam, T. (2016). Virtual reality training in laparoscopic surgery: A systematic review. *World Journal of Surgery*, 40(10), 2448–2456.
5. Botden, S. M. B. I., & Jakimowicz, J. J. (2009). VR, AR, and MR in minimally invasive surgery training. *Surgical Endoscopy*, 23, 140–146.
6. Grantcharov, T. P., et al. (2004). Randomized clinical trial of virtual reality simulation for laparoscopic skills training. *British Journal of Surgery*, 91, 146–150.
7. Safaeva, S. (2020). Investment in the tourism sector: the pandemic and its impact. *Архив научных исследований*, (32).
8. Rikhsibaevna, S. S., Xalilullaevna, M. D., & Farmonovna, O. H. (2020). Investment in the tourism sector: The pandemic and its impact. *South Asian Journal of Marketing & Management Research*, *10*(6), 23-29.

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https://westerneuropeanstudies.com/index.php/3
ISSN (E): 2942-1918 Open Access| Peer Reviewed

9. Rikhsibaevna, S. S. (2025). Environmental sustainability in tourism: perspectives for Uzbekistan. *Labor economics and human capital*, *4*(3), 176-185.
10. Sayyora, S. (2024). Analyzing Resource Allocation and Management in the Uzbekistan Hotel Industry Within the Context of Cloud, Distributed, and Parallel Systems. *International Journal of Biological Engineering and Agriculture*, *3*(1), 118-128.
11. Сафаева, С. Р. (2021). Основные аспекты совершенствования сферы туризма в период мировой пандемии. *Тенденции развития науки и образования*, (79), 3.
12. Safaeva, S., & Talipova, N. (2020). Problems Of Using Matrix Models In Strategic Decision Making. *Архив научных исследований*, (17).
13. Rasulova, N. F., Jalilova, G. A., & Mukhamedova, N. S. (2023). PREVENTION OF IMPORTANT NON-COMMUNICABLE DISEASES AMONG THE POPULATION. *Евразийский журнал медицинских и естественных наук*, *3*(1 Part 2), 2123.
14. Мирзаева, М. А., & Расулова, Н. Ф. (2014). Компьютеризация рабочего места медицинских сестер стационара. *Сборник статей и тезисов*.
15. Расулова, Н. Ф., & Асадова, Г. А. (2023). ИЗУЧЕНИЕ ОСОБЕННОСТИ ЗДОРОВЬЕСОХРАНЯЮЩЕГО ПОВЕДЕНИЯ И САМООЦЕНКА ЗДОРОВЬЯ СТУДЕНТОВ. *Science and innovation*, *2*(Special Issue 8), 978-980.
16. Джалилов, Э., Мамедова, Г. Б., Расулова, Н. Ф., & Назарова, Н. Б. (2015). Организация мониторинга заболеваемости органа зрения у детей от родственных браков, обучающихся в школе-интернате слепых и слабовидящих. *Молодой ученый*, (2), 58-60.
17. Мухамедова, Н. С., & Расулова, Н. Ф. (2022, May). Основы охраны материнства и детства в Республике Узбекистан. In *Биоэтика и право" Материалы международной научно-практической конференции, Ташкент* (pp. 123-127).
18. Djalilova, G., Rasulova, N., & Muxamedova, N. (2022). Hygienic, Medical and Social Aspects of Health Studies of Different Population Groups. *Science and innovation*, *1*(D4), 196-199.
19. Rasulova, N., Abdullaev, K., & Kuddusova, K. (2024). THE INTEGRATED APPROACH TO THE TREATMENT OF PATIENTS WITH ATROPHIC RHINITIS WHO HAVE COVID-19. *Science and innovation*, *3*(D7), 56-60.
20. Расулова, Н. Ф., Мухамедова, Н. С., & Максудова, Н. А. (2017). К вопросу гигиенического прогнозирования качества воды водоёмов в Узбекистане. *Проблемы науки*, (2 (15)), 89-93.
21. Rasulova, N., & Azamatova, F. (2024). Implementing Methods Of Promotion Of Healthy Lifestyle Among Adolescents. *TEXAS JOURNAL OF MEDICAL SCIENCE Учредители: Zien Journals Publishing*, *39*, 13-15.
22. Джалилова, Г. А., Расулова, Н. Ф., & Оташехов, З. И. (2024). АКТИВНЫЙ ОБРАЗ ЖИЗНИ В НАСТОЯЩЕМ–ВКЛАД В ЗДОРОВЬЕ В БУДУЩЕМ. *Eurasian Journal of Medical and Natural Sciences*, *4*(1-2), 144-146.
23. Расулова, Н. Ф., & Аминова, А. А. (2023). ЗНАЧЕНИЕ ПОЛНОЦЕННОГО ПИТАНИЯ ДЕТСКОГО ВОЗРАСТА В ПРОФИЛАКТИКЕ И ЛЕЧЕНИИ РЯДА ЗАБОЛЕВАНИЙ. *«МИКРОБИОЛОГИЯНИНГ ДОЛЗАРБ МУАММОЛАРИ» МАВЗУСИДАГИ РЕСПУБЛИКА ИЛМИЙ-АМАЛИЙ АНЖУМАНИ*, 135.

Western European Journal of Medicine and Medical Science
Volume 4, Issue 01, January 2026
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ISSN (E): 2942-1918 Open Access| Peer Reviewed

24. Файзиева, М. Ф., Расулова, Н. Ф., & Эшдавлатов, Б. М. (2023). ОРГАНИЗАЦИЯ ТРУДА И СИНДРОМ ХРОНИЧЕСКОЙ УСТАЛОСТИ. *Science and innovation*, *2*(Special Issue 8), 1982-1983.
25. Расулова, Н. Ф., Мирдадаева, Д. Д., & Одилова, М. А. (2023). РАЗВИТИЕ ПОЗНАВАТЕЛЬНОЙ АКТИВНОСТИ СТУДЕНТОВ ВУЗА В ПРОЦЕССЕ ПРОБЛЕМНОГО ОБУЧЕНИЯ. *Science and innovation*, *2*(Special Issue 8), 1979-1981.
26. Искандарова, Ш., Расулова, Н., & Аминова, А. (2023). Установление здорового образа жизни–путь к укреплению здоровья. *Science and innovation*, *2*(Special Issue 8), 1904-1907.
27. Джалилова, Г. А., Расулова, Н. Ф., & Мухамедова, Н. С. (2023). Охрана материнства и детства в республике Узбекистан. *Science and innovation*, *2*(Special Issue 8), 1971-1974.
28. Rasulova, N., Nazarova, S., Asadova, G., Otashexov, Z., Mirdadayeva, D., & Yigitalieva, R. (2023). Social and pedagogical foundations of effective adaptation of students to an educational institution. In *BIO Web of Conferences* (Vol. 65, p. 10012). EDP Sciences.
29. Rasulova, N., & Shorustamova, M. (2023). Healthy lifestyle is health through education. *Science and innovation*, *2*(D6), 24-26.
30. Rasulova, N., Aminova, A., & Ismailova, F. (2023). Improvement of early diagnosis and prevention measures of kidney stone diseases among the population. *Science and innovation*, *2*(D3), 61-66.
31. Khan, M. S., et al. (2013). Simulation-based training for laparoscopic surgery: Meta-analysis. *Annals of Surgery*, 257(2), 206–213.
32. Reznick, R. K., & MacRae, H. (2006). Simulation-based education: Past, present, and future. *Journal of the American College of Surgeons*, 202(1), 161–16