ADVANCES IN VIRTUAL REALITY AND 3D PRINTING TECHNOLOGIES APPLIED TO GENERAL SURGERY: A LITERATURE REVIEW

Tais Moreno Borges
Centro Universitário de Belo Horizonte (UniBH)
Belo Horizonte - MG
https://orcid.org/0009-0003-2503-9411

Laura Garcia
Fundação Educacional do Município de Assis (FEMA)
Assis - SP
https://orcid.org/0009-0009-2328-5049

Maria Francisca de Jesus Melo Serra
Universidade Federal do Maranhão (UFMA)
São Luís - MA
https://orcid.org/0000-0003-3736-9242

Luísa Della Líbera Murari
Faculdade de Medicina de Catanduva (FAMECA)
Catanduva - SP
https://orcid.org/0009-0000-5146-150X

Clarissa Formigheri Moretto
Universidade do Vale do Itajaí (UNIVALI)
Itajaí - SC
https://orcid.org/0000-0002-0095-1709

Lucas Thomé Cavalheiro
Universidade Franciscana (UFN)
Santa Maria - RS
https://orcid.org/0009-0002-4922-1691

Laila Rosa
Centro Universitário Max Planck (UNIMAX)
Indaiatuba- SP
https://orcid.org/0009-0007-7010-2634

Sara Cristina Barbosa Ribeiro
Centro Universitário de Caratinga (UNEC)
Caratinga - MG
https://orcid.org/0009-0003-5877-7648

Raiane Alvarenga Ranieri
Faculdade Evangélica Mackenzie do Paraná
(FEMPAR)
Curitiba - PR
https://orcid.org/0000-0002-4537-1687

Kênia Scarton Tomazelli Ferreira
Faculdade Multivix de Cachoeiro de
Itapemirim (MULTIVIX)
Cachoeiro de Itapemirim - ES
https://orcid.org/0009-0007-9265-6179

Isabela Adélia de Amorim Ferreira
Centro Universitário Unifacisa
(UNIFACISA)
Campina Grande - PB
https://orcid.org/0009-0004-6355-6425

Josenil Bezerra Nascimento Neto
Universidade Estadual do Piauí (UESPI)
Teresina - PI
https://orcid.org/0000-0001-7893-7803

Abstract: Objective: To analyze advances in Virtual Reality (VR) and 3D Printing technologies applied to general surgery, as well as their clinical implications and the learning curve required to use them. Methodology: We performed a narrative review of the literature. Studies published from 2018 to 2023 were included and inclusion and exclusion criteria were applied, resulting in the analysis of 18 studies. Discussion: Objects printed by 3D printers, created from digital models, have been integrated into surgery in a beneficial way for medical practice. The tactile and three-dimensional visualization provided by these objects allows a better understanding of the procedure, both for the medical team and for the patient, which positively impacts all surgical phases, from planning to the postoperative period. The use of Virtual Reality also brings benefits, as it allows safer surgical planning and provides the patient with greater adherence to the procedure. The combination of these technologies generates a perfect integration between the real and virtual surgical environment, resulting in a significant improvement in the training of professionals and in the performance of procedures. However, it is important to emphasize that these technologies still have limitations, such as the high financial cost and the lack of well-established evidence in more invasive scenarios. Despite this, we recognize the impact on the learning process. Although the incorporation of these technologies into curricula is still limited, projections indicate a possible improvement in the quality of care and a reduction in ethical, financial, legal and cultural concerns related to future studies in human beings. Conclusion: The use of VR and 3D Printing applied to general surgery has favorable advantages for both medical practice and patients. Despite the considerable financial costs, these technologies have the potential to significantly contribute to

the improvement of surgical processes in a comprehensive way.

Keywords: Three-dimensional; General surgery; Security; Virtual reality.

INTRODUCTION

Virtual reality (VR) is a technology on the rise in the area of laparoscopic surgery, which provides the simulation of a virtual operating room environment. There is a growing number of studies on the application of VR in this field, arousing great interest on the part of the surgical team (JIN et al., 2021). On the other hand, 3D printing technology has been used to create simulation models of organs and lesions, allowing surgeons to realistically visualize the internal details of these structures. These models offer surgeons the opportunity to practice and become familiar with the patient's anatomy before actual surgery, providing repetitive training (LI et al., 2020).

However, the use of these technologies in the surgical environment is still questionable. The need for a more comprehensive reassessment of the application of virtual reality in relation to the learning curve was identified, due to several observed shortcomings (JIN et al., 2021). Schmidt et al. (2021) noted the possibility of acquiring surgical skills through robotic simulators, which can be transferred to the operating room, but it is still unclear to what extent this can be applied.

In this context, the objective of this bibliographic review is to analyze the advances in surgical technology, with emphasis on 3D printing and virtual reality, and to investigate their clinical implications in general surgery, considering aspects of safety, efficacy and mastery of these new technologies in the surgical process.

METHODOLOGY

This study corresponds to a narrative review of the literature carried out from April to May 2023 through the implementation of the PVO research strategy (population or research problem, variables and outcomes). The guiding question was to investigate "how does the implementation of technologies such as 3D printing and virtual reality affect the surgical process and clinical implications in general surgery?". The search in the databases was carried out in Scientific Electronic Library Online (SciELO) and in PubMed Central (PMC). The search strategy was applied by combining descriptors with Boolean operators: Printing, Three-Dimensional AND General Surgery AND Safety AND Virtual Reality. In association, inclusion criteria were established that considered articles in English and Portuguese, published between the years 2018 to 2023, exploring the research theme. Observational studies, narrative reviews, systematic reviews, meta-analyses, randomized and non-randomized clinical trials, and scoping reviews were included. Exclusion criteria were based on duplicate articles, abstracts and research that did not address the proposed theme. After applying the descriptors and inclusion and exclusion criteria, 18 studies were identified and selected to compose the collection.

RESULTS

BENEFITS OF NEW TECHNOLOGIES

The 3D printing technique applied to medicine and the surgical environment is a current revolutionary project, consisting in the construction of objects from a digital model (EMILE; WEXNER, 2018). Numerous benefits were perceived from this innovation, related to medical training, surgical procedures and hospital costs (CORNEJO et al., 2022). This technology allows the conversion of two-

dimensional structures viewed on a flat screen into three-dimensional and tactile structures that can be manipulated (MEYER-SZARY et al., 2022). In addition, these models collaborate in explaining and demonstrating techniques and procedures to patients, facilitating communication and understanding of the disease, procedure and possible complications, which improves adherence to surgical treatment (BASTAWROUS et al., 2018; EMILE; WEXNER, 2018).

The continuous advancement of this technique in the surgical environment allows for changes and adaptations both in the pre-surgery and intraoperative period. 3D printed models help surgeons in surgical planning, enabling the choice of the most appropriate approach, prior training through simulation in models similar to the patient's anatomy, and the prevention and management of possible complications (EMILE; WEXNER, 2018; BASTAWROUS et al., 2018). This allows for the recreation of the patient's anatomy, with a detailed analysis of the involvement of the pathology, such as location, size, morphological characteristics and relationship with other structures, which makes the procedure faster and safer (CORNEJO et al., 2022; BASTAWROUS et al, 2018; EMILE; WEXNER, 2018; MEYER-SZARY et al., 2022).

Similarly, this technology promotes evolution in the learning curve of medical students and surgeons in training (EMILE; WEXNER, 2018; MEYER-SZARY et al., 2022; SALIBA; BARROS, 2021). It also enables surgeons to train in skills essential to improving their confidence, reducing errors and improving outcomes. In addition, printed models are easier to replicate, store and have a lower cost (SALIBA; BARROS, 2021).

It is important to emphasize the increase in patient safety undergoing a given procedure, since performing the surgical technique in the field is preceded by training in realistic simulation, resulting in reduced surgical time and blood loss (RADI et al., 2022). In this context, 3D printing and virtual reality technologies can be combined, allowing the association of models and virtual environments with physical structures, which contributes to better training of surgeons and planning of the operation to be performed (CORNEJO et al., 2022). Virtual reality technology can also be used to reduce patients' anxiety and fear before surgery, increasing adherence to these procedures (VOGT et al., 2021).

There is a positive impact on the safety of patients undergoing specific procedures, since performing the surgical technique in the field is preceded by training in realistic simulation, resulting in reduced surgical time and blood loss (RADI et al., 2022). In this context, the combination of 3D printing and virtual reality technologies enables the integration of models and virtual environments with physical structures, providing a significant improvement in surgeon training and operation planning (CORNEJO et al., 2022). Furthermore, virtual reality technology has the potential to mitigate the anxiety and fear of presurgical patients, increasing adherence to these procedures (VOGT et al., 2021).

APPLICATION LIMITATIONS AND CHALLENGES

The applicability of 3D printing and virtual reality in large centers requires a high financial investment, since it involves not only the cost of materials, but also the training required for their use. As an alternative to this cost limitation, academic centers seek to train professionals through digital platforms, in which it is possible to expose and prepare professionals to use these innovations through training with simulators. In this sense, RADI et al. (2022) conducted a study analyzing the results obtained in two groups

of residents who used a simulator to improve their techniques. Comparing the results of a pre- and post-test, it was possible to observe that 83% of the residents were able to perform all tasks with mastery after training, with a time interval between the pre- and post-test ranging from 14 days to 10 months.

In addition to the significant variation in training time reported by RADI et al. (2022), there are difficulties in assessing the benefits of reproducing these surgical skills, since studies carried out in the last 5 years have highlighted the use of small samples as a fragility (SHEIK-AL et al., 2019).

With regard to studies on the applicability of virtual reality and 3D printing in real scenarios, we found divergent results regarding the length of hospital stay, which can either increase or decrease, directly interfering with the patient's recovery. According to TAYLOR et al. (2021), the use of virtual reality in conjunction with local anesthesia and sedation to perform minor pediatric procedures, such as removal or replacement of hormonal implants, resulted in shorter hospital stays and faster recovery.

On the other hand, XIONG et al. (2019) and AREZZO et al. (2019) state that the use of these practices in more invasive scenarios, such as orthopedic surgeries and videolaparoscopies, still requires further studies to assess the complications resulting from a longer hospitalization time compared to conventional surgeries.

The possibility of three-dimensional printing allows the construction of individualized physical models for the patient, which can be evaluated for more effective preoperative planning. The use of these models during surgery can bring several benefits, not only in terms of better results, but also in terms of surgical effectiveness, time reduction, re-approaches and costs (CORNEJO et al., 2022).

The simulation of initial robotic surgery techniques in specific centers, instead of being performed directly in operating rooms, has a positive impact on surgeons' learning. This also reflects on the safety of the procedure, with less surgical time and reduced costs. Therefore, technological advancement requires innovation in the training of professionals, being a relevant investment in medical education (RADI et al., 2022; ZHANG et al., 2023).

Despite the expansion of the use of technologies applied in the surgical area and the benefits brought to both physicians and patients, their incorporation into the curricula of academic training for surgeons is still limited. This new form of learning is, in some respects, superior in its ability to convey certain information. However, it is fundamental to develop a structure that allows the implementation of a surgical curriculum for the use of these new technologies, considering aspects such as structure, responsibility, transparency, cost and impact. This will allow expanding the practical and theoretical knowledge of medical students (LIN et al., 2019; GASPERIN et al., 2018).

Regarding financial aspects, both academia and health benefit. The future expansion of 3D printing availability will likely result in reduced healthcare costs, as well as promoting a higher quality of patient care. In addition, the use of 3D anatomical models in academia facilitates access, reducing financial, ethical, legal and cultural concerns associated with studies in humans (SPENCER; WATTS, 2020).

FINAL CONSIDERATIONS

The implementation of technologies such as 3D printing and virtual reality has proven to be favorable in the clinical context of general surgery. 3D printing enables an improved visualization of the patient's

anatomy during the intraoperative procedure, resulting in greater speed and safety. In addition, virtual reality has shown benefits in training surgeons, leading to procedures with a lower incidence of complications and reduced operative time. It was also observed that virtual reality contributes to the reduction of anxiety and fear of pre-surgical patients, promoting greater adherence to procedures. In short, 3D printing and virtual reality have an extremely positive impact on the surgical environment, improving surgeons' training, procedural safety and patients' quality of life. Although cost is a current limitation, it is clear that the use of these technologies will make a significant contribution to improving contemporary surgical processes.

REFERENCES

AREZZO, A. et al. The use of 3D laparoscopic imaging systems in surgery: EAES consensus development conference 2018. **Surgical endoscopy**, v. 33, p. 3251-3274, 2019.

BASTAWROUS, S. et al. Principles of three-dimensional printing and clinical applications within the abdomen and pelvis. **Abdominal Radiology**, v. 43, p. 2809-2822, 2018.

CORNEJO, J. et al. Anatomical Engineering and 3D Printing for Surgery and Medical Devices: International Review and Future Exponential Innovations. **BioMed Research International**, v. 2022, 2022.

EMILE, S. H.; WEXNER, S. D. Systematic review of the applications of three-dimensional printing in colorectal surgery. **Colorectal Disease**, v. 21, n. 3, p. 261-269, 2019.

GASPERIN, B.D. et al. A realidade virtual pode ser tão boa como o treinamento em sala cirúrgica? experiências de um programa de residência em cirurgia geral. **Arquivos Brasileiros de Cirurgia Digestiva**, v. 31, 2018.
JIN, C. et al. The application of virtual reality in the training of laparoscopic surgery: A systematic review and meta-analysis. **International Journal of Surgery**, v. 87, p. 105859, 2021.

LI, H. et al. Three-dimensional printing: the potential technology widely used in medical fields. **Journal of Biomedical Materials Research Part A**, v. 108, n. 11, p. 2217-2229, 2020.

LIN, C. et al, When to Introduce Three-Dimensional Visualization Technology into Surgical Residency: A Randomized Controlled Trial. **Journal of Medical Systems**, v. 43, n. 3, p. 71, 2019.

MEYER-SZARY, J. et al. The role of 3D printing in planning complex medical procedures and training of medical professionals—cross-sectional multispecialty review. **International Journal of Environmental Research and Public Health**, v. 19, n. 6, p. 3331, 2022.

RADI, I et al. Feasibility, effectiveness and transferability of a novel mastery-based virtual reality robotic training platform for general surgery residents. **Surgical endoscopy**, v. 36, n. 10, p. 7279-7287, 2022.

SALIBA, T.V.; BARROS, R.M. Development and validation of a 3D laryngeal model in surgical skills training. **Brazilian Journal of Otorhinolaryngology**, v. 89, p. 128-135, 2023.

SCHMIDT, M. W. et al. Virtual reality simulation in robot-assisted surgery: meta-analysis of skill transfer and predictability of skill. **BJS open**, v. 5, n. 2, p. zraa066, 2021.

SHEIK-ALI, S. et al. Next-generation virtual and augmented reality in surgical education: a narrative review. **Surgical technology international**, v. 33, 2019.

SPENCER, S.R.; WATTS, L.K. Three-dimensional printing in medical and allied health practice: a literature review. **Journal of Medical Imaging and Radiation Sciences**, v. 51, n. 3, p. 489-500, 2020.

TAYLOR, J. et al. Small surgeries, big smiles: using virtual reality to reduce the need for sedation or general anesthesia during minor surgical procedures. **Pediatric Surgery International**, v. 37, n. 10, p. 1437–1445, 2021.

VOGT, L. et al, Virtual Reality Tour to Reduce Perioperative Anxiety in an Operating Setting Before Anesthesia: Randomized Clinical Trial. **Journal of Medical Internet Research**, v. 23, n. 9, p. e28018, 2021.

XIONG, L. et al. The efficacy of 3D printing-assisted surgery for traumatic fracture: a meta-analysis. **Postgraduate medical journal**, v. 95, n. 1126, p. 414-419, 2019.

ZHANG, J et al. The impact of extended reality on surgery: a scoping review. **International orthopaedics**, v. 47, n.3, p 611-6121, 2023.