Virtual Reality Simulator Enhances Ergonomics Skills for Neurosurgeons

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ABSTRACT

This paper aims to assess the needs of neurosurgical training in order to strategize the future plans for simulation and rehearsal. The main objective is to investigate the ability of virtual reality to enhance the training. An online questionnaire has been conducted among surgeons practicing in different countries across the globe. The study shows significant differences in rehearsal methods and surgical teaching methods practiced by the respondents. Among respondents, 90% did believe that virtual reality technology can serve surgical training, and almost all respondents agreed that there is a gap in the existing neurosurgical training in terms of operating room ergonomics. Adequate education on surgical ergonomics might lead to an improvement in the outcomes for both surgeon and patient. The contribution of the paper is twofold. One side investigates the new requirements for the enhancement of neurosurgeon training and adoption on a virtual reality simulator. The other side contributes to the body of knowledge related to the required ergonomics skills.

KEYWORDS

Ergonomics, Simulation, Surgery, Training, Virtual Reality
1. INTRODUCTION

1.1. Challenges in Neurosurgical Training

In the recent years, medical training has been challenged by the introduction and adoption of various sophisticated technologies including Virtual Reality, Robotics, Artificial Intelligence and others. The objective of this paper aims to assess the needs of neurosurgical training believe their physical health is affected by operating environment (Cavanagh et al., 2012). Adequate education on surgical ergonomics might lead to an improvement in the outcomes for both surgeon and patient.

Medical education is a key step in the acquisition of clinical skills and improvement in overall patient care. As the amount of medical information steadily increases, the complexity of treatment options also increases. Therefore, it is essential that medical practitioners and other health care professionals continuously improve their skills and stay informed with the innovations in their field. An important factor in the progress of surgical education and training is the technical solutions that determine the standards of competence in the performance of surgical procedures (Atesok et al., 2017). Therefore, systems that allow consistent evaluation of skills, in a risk-free, controlled manner, are of imperative importance. In this context, the simulation-based techniques are “go-to tools” for a variety of medical and surgical specializations. Medical education has increasingly begun to incorporate virtual reality (VR) as a key method in the training of students in the past decade. It has been observed that VR has taken on a basic role in medical and, more clearly, surgical training as a method that can be used both for its cognitive task analysis and training for technical skills (Konakondla et al., 2017).

Neurosurgical training programs share certain limitations with other surgical training programs, specifically when it comes to residency education. Most significantly, educators must balance the optimization of learner education against the objective of patient safety with properly graduated learner autonomy (Konakondla et al., 2017). To achieve improvements of a surgical resident abilities, surgical training, whether in the form of observation or as practice in and out of the operating room (OR), is crucial. By using repetition and objective observation, a virtual human body enhances learning. Thus, in simulation, computers are replacing patients in surgical preparation. Surgeons can learn and transfer their virtual abilities into the OR with virtual instruments and patients. In general, studies show that VR and other simulations decrease operative time and error by increasing the surgeon’s confidence and minimizing wasted movements (Bernardo, 2017).

Neurosurgery is one of the most challenging medical professions that engages a high level of expertise. It is a very challenging surgical specialty where new techniques and technologies are continually emerging. A recent increase of interest in neurosurgical simulation has emerged. This is primarily due to the decreased exposure of trainees to surgical cases based on constraints on residency duty-hours, and technical developments in the area of simulation imaging, computing, virtual reality (VR), and 3D printing (Rehder et al., 2016).

In the field of neurosurgery, there has been an interest in exploring and using medical simulation and VR for preparation, maintenance of expertise, development, demonstration, and evaluation purposes (Konakondla et al., 2017). Nowadays, there are several commercial neurosurgical simulation technologies that aim to help trainees improve their skills. However, most of the available technologies are not fully validated and are underutilized by trainees (Atesok et al., 2017).

Several Neurosurgical simulators have been available in the market such as ImmersiveTouch (Lemole et al., 2007), NeuroTouch (NeuroVR ™) (Delorme et al., 2012), Dextroscope (Stadie et al., 2008), and Surgical theater (Zhalmukhamedov & Urakov, 2019) as well as others. These simulators were made available in the past 2 decades but never gained enough widespread adoption in neurosurgical education. Some were not updated and others are no longer on the market. This may have been because most of the simulators available so far do not represent advanced micro-neurosurgical cases, hence recently a roadmap was proposed to developed and validate complex neurosurgical scenarios (Sabbagh et al., 2020).
Rather than only assessing surgical procedures, existing simulation models can be used to assess other aspects. The NeuroTouch (NeuroVR ™) 

(bajunaid et al., 2017) to build and validate a set of methods for testing technical skills that can assess bimanual psychomotor performance skills and aimed to explore the effect of a simulated stressful virtual reality tumor resection scenario. They simulated acute stress and explored its effect on psychomotor performance in safe environments.

1.2. Ergonomics Foundations in Neurosurgical Training

Ergonomics, also called human factors, is the study of the actions of individuals in relation to their working environment and the mechanical and electronic equipment operated by the worker. The role of ergonomics professionals is to design or improve workers’ workplaces, equipment and procedures, not only to ensure their health and safety, but also to ensure efficient performance and results (Berguer, 1997).

The risks of ergonomics in the OR may be divided into three groups: Risks from physical ergonomics, Risks of cognitive ergonomics and, Risks from organizational ergonomics. Risks from physical ergonomics in the operating room are related to physical activity, as such physical ergonomics concerns with human anatomical, anthropometric, physiological, and biomechanical characteristics. Risks to cognitive ergonomics in the operating room are related to mental processes such as perception, thinking, and motor response, as they influence human experiences and other elements of a system. As for risks from organizational ergonomics are related with the enhancement of technical frameworks, including their organizational structures, strategies and procedures (Vural & Sutsunbuloglu, 2016).

In addition, the risk factors for injury are both an absence of surgical experience and inadequate ergonomic preparation. Surgery residents may also have specific occupational injury risk indicators, since they have less experience and are often expected to perform tasks that are physically challenging. Moreover, with less focus on their own physical status, surgical configuration, or other ergonomic factors, their primary intraoperative emphasis would be on the surgical procedure. Therefore, ergonomic education during residency can Luckily be mitigated (Ronstrom et al., 2018).

Many surgeons, as a result to a bad posture or as a due to the instruments they use, will continue to feel pain and discomfort while performing operations at work, unless they have adequate training to improve their working practices or until the ergonomics of surgery is considered by departments in their organizations. Neurological surgery, in particular, is characterized by technically complex procedures that require long hours of training in order to minimize the patient’s risk. Therefore, training and education improvement is essential for both neurosurgeons and their patients. According to a study by Soueid et al. (Soueid et al., 2010), 80% of neurosurgeons (8 out of 10) have a prevalence of musculoskeletal pain that has been attributed to operating environment. For surgery residents, an injury may have direct consequences on their training. Therefore, the aim of this study is to understand the current perspectives and future vision and the need for simulation in neurosurgical training and practice.

1.3. Complementary Aspects of Our Research Problem

More aspects of the research phenomenon have been integrated to the literature. In Table 1, we provide an overview of key complementary approaches that have an impact in our research.

In their recent research study (Ritter et al., 2020) Ritter et al discussed the effects of varied surgical simulation Training schedules on Motor-Skill Acquisition. In their research they performed laparoscopic training tasks to learning sessions and they analyzed the efficiency and the earned learning curved proving that the more training leads to less time for completion of tasks. Rodrigues et al (Rodrigues Armijo et al., 2020) also performed recently an Ergonomics Analysis for Subjective and Objective Fatigue between Laparoscopic and Robotic Surgical Skills Practice among Surgeons. In their experiment and study two standardized surgical tasks (peg transfer (PT) and needle passing
(NP)) were performed twice in each surgical skills’ practical environments: (1) laparoscopic training-box environment (Fundamentals of Laparoscopic Surgery (FLS)) and (2) Mimic dV-trainer (MIMIC). A key finding in their research proved that ergonomics settings and related disadvantages have an overall impact on the efficiency of the operations. In this research context the training of surgeons is also a critical success factor for robotic surgery. In their research work Wu et al (Wu et al., 2021) they deployed sensors technology to establish indicators for the performance on training sessions of robotic surgery. They key results associated significant changes in performance between sessions to various metrics related to behavior and cognition. This implies that effective training for surgery training requires to also integrate these factors as complementary enhancement components. The concept of validation of ergonomics instructions was discussed in the research of Mertens et al (Van’t Hullenaar et al., 2018) with an emphasis in robot-assisted surgery simulator training. The deployment of DaVinci skills simulator and the methodological experiment of researchers proved that instruction on ergonomics leads to better scores and performance on ergonomics. This is a key indication that also the integration of VR and simulation platforms has to take into consideration the ergonomics design.

Similar works in the literature study the aspects and benefits of simulation training in neurosurgery (Bernardo, 2017; Konakondla et al., 2017) with a comparative analysis of available tools and techniques related to medical simulation and virtual reality as it is applied to neurologic surgery. Some of the benefits highlighted are related to their capacity to reduce the learning curve to improve the understanding of human anatomy and to develop surgery skills.

More focused studies (Ciporen et al., 2018), emphasize on crisis management simulations promoting unique training experiences for domains like dual neurosurgery and anesthesia. The support of a team for handling intraoperative crisis challenges the design and specifications of a training simulation environment. A key finding was associated to the need for continuous integration to routine training practices of simulations. Such a key requirement also implies the enhancement of Surgical Ergonomics to training. In their study Ronstrom et al discuss the critical role of ergonomics specialists as educators. As a key implication the research highlights that residents should be trained to the use of ergonomics in the operating room (Ronstrom et al., 2018).

The complexity of tasks related to surgery also demands the design and deployment of multi-procedural simulators powered by Virtual Reality (De Luca et al., 2019), (Teodoro-Vite et al., 2020) with emphasis on interactivity and integration.

Yadav et al (Yadav et al., 2016) analyze the concept of Micro-neurosurgical Skills Training and they conclude among other key findings that the knowledge of ergonomics can improve surgical skills significantly while Azarnoush et al (Azarnoush et al., 2016) analyze the impact of “force” in VR for brain tumor resection. With the deployment of NeuroVR (formerly NeuroTouch), they understood that force application and utilization in neurosurgeon combined with ergonomics data significantly improve the patient safety.

New areas of interest in the literature are also related to the deployment of high-definition three-dimensional exoscope (Beez et al., 2018), the integration of ergonomics as a critical element for ETS (Mattogno et al., 2020), deployment of 3D microscopy to microsurgery (Mendez et al., 2016), and ergonomic evaluation of prototype consoles for robotic surgeries and simulations with digital human manikins (Fan et al., 2018). (Overview of literature on Table 1).

Basically, the principles of ergonomics can be learned rather than training someone in ergonomics, which requires physical activities. Most ergonomic practices are used in the design of equipment, devices, or instruments. Using a simulator to teach the principles of ergonomics with negative and positive examples of ergonomics or interactive programs on a computer or in VR can be applied. The application would be based on the selected ergonomics skills that can be measured during the practice. These measures can be read through the simulator device, for example, the neck angle of the user or hand movements.

A summary of the emphasis on the studied literature in provided in Table 2.

In the next section we provide the materials and methods of our research.
Table 1. An overview of critical literature review on the research phenomenon under study

| Author(s) | Title of article                                                                 | Key contribution                                                                 | Aspects of the research phenomenon under study                  |
|-----------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------------------------------------------------------|
| (Ritter et al., 2020) | Effects of Varied Surgical Simulation Training Schedules on Motor-Skill Acquisition. | This study examined learning on a laparoscopic surgery simulator using a set of procedural or perceptual-motor tasks with some declarative elements. | Impact of Simulation training                                    |
| (Rodrigues Armijo et al., 2020) | Ergonomics Analysis for Subjective and Objective Fatigue Between Laparoscopic and Robotic Surgical Skills Practice Among Surgeons. | Our aim was to determine how self-reported and objectively measured fatigue of upper limb differ between laparoscopic and robotic surgical training environments. | Relation of Ergonomics and Robotics Surgical Skills              |
| (Wu et al., 2021) | Sensor-based indicators of performance changes between sessions during robotic surgery training. | The objective of this study was to measure changes in trainees’ cognitive and behavioral states as they progressed in a robotic surgeon training curriculum at a medical institution. | Use of sensor technology for measuring efficiency of robotics training sessions |
| (Van’t Hullenaar et al., 2018) | Validation of ergonomic instructions in robot-assisted surgery simulator training. | The aim of this study was to assess whether a brief explanation on ergonomics of the console can improve body posture and performance. | Assessment of Ergonomics instructions for robotics surgery       |
| (Konakondla et al., 2017) | Simulation training in neurosurgery: advances in education and practice. | Explore the development, availability, educational taskforces, cost burdens and the simulation advancements in neurosurgical training, discuss various aspects of neurosurgery disciplines with specific technologic advances of simulation software, analyze concurrent concept overlap between PubMed headings and provide a graphical overview of the associations between these terms. | Benchmarks of simulations training and tools assessment          |
| (Bernardo, 2017) | Virtual Reality and Simulation in Neurosurgical Training. | For developing neurosurgeons, such tools can reduce the learning curve, improve conceptual understanding of complex anatomy, and enhance visuospatial skills. | Understanding the impact of Surgical VR on learning curve       |
| (Ciporen et al., 2018) | Crisis Management Simulation: Establishing a Dual Neurosurgery and Anesthesia Training Experience. | This study establishes a first of a kind simulation experience in a neurosurgery/anesthesia resident (learners) team working together to manage an intraoperative crisis. | Simulation and Ergonomics for Intraoperative Crisis events     |
| (Ronstrom et al., 2018) | Surgical Ergonomics, Surgeons as Educators | Musculoskeletal discomfort is common among surgeons. Surveys show that 77–100% of laparoscopic surgeons experience physical symptoms or discomfort attributed to operating, but few seek treatment. | The role of Surgical ergonomics as Educators                   |
| (De Luca et al., 2019) | A Multi-procedural Virtual Reality Simulator for Orthopaedic Training. | This paper presents a prototype of a multi-procedural VR platform accommodating three different anatomical sites. | The case of multi-procedural VR simulator as a response to requirements |
| (Teodoro-Vite et al., 2020) | A High-Fidelity Hybrid Virtual Reality Simulator of Aneurysm Clipping Repair With Brain Sylvian Fissure Exploration for Vascular Neurosurgery Training. | The design, implementation, and assessment of a new hybrid aneurysm clipping simulator are presented. It consists of an ergonomic workstation with a patient head mannequin and a physics-based virtual reality simulation with bimanual haptic feedback. | VR simulator application for Vascular Neurosurgery Training.     |
| (Yadav et al., 2016) | Microneurosurgical Skills Training. | This article is based on a review of the literature on the principles of microsurgical techniques and the personal experience of senior neurosurgeons with > 25 years of experience and provides practical tips to improve surgical skills. Residents and young surgeons may not get sufficient clinical case volume or opportunity during routine operative hours at the beginning of their career. | Lessons learnt from the experience and practice of last years   |

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2. MATERIALS AND METHODS

In our research methodology, we have three complementary research objectives:

**Research Objective 1:** To investigate the complementary educational methods adopted for teaching surgical skills.

**Research Objective 2:** To explore ways and suggested interventions for the enhanced training performance related to surgical training.

**Research Objective 3:** To understand perceptions related to the use of virtual simulation as a training and assessment tool in neurosurgery.

**Research Objective 4:** To identify the gaps in existing neurosurgical training and to propose reflective actions for enhanced neurosurgical training with the use of ergonomics and VR.

An online questionnaire was conducted using the SurveyMonkey platform distributed through WhatsApp from January 2019 to February 2019 and sent to neurosurgery residents, specialists, and consultants (as well as a control group made up of other surgical specialties) who are practicing globally. This questionnaire was conducted by the authors in a group of several fields, including neurosurgeons, computer scientists, and biomedical engineers. The questionnaire investigates different aspects of the available methods that educational programs offer for teaching surgical skills at different institutions, and explores better ways of assessing surgical training performance from the respondents’ point of view.

Furthermore, this questionnaire was designed to obtain responses with regard to experiences and perceptions of virtual simulation as a training and assessment tool in neurosurgery, as well as to explore the gaps in existing neurosurgical training. In this paper, we use a descriptive statistical method to observe and summarize the collected data in a graph, which can help us in selecting the
Table 2. A summary of the emphasis on the studied literature

| Author                                      | Key emphasis                                                                 |
|---------------------------------------------|------------------------------------------------------------------------------|
| (Ritter et al., 2020)                       | Surgery                        | Simulation                     | Ergonomics | Training                          | Virtual reality | Traditional surgery |
|                                             | X Laparoscopic surgery         | X Laparoscopic surgery simulator | X Human factors study | x Training schedules Surgical education | | |
| (Rodrigues Armijo et al., 2020)             | X Laparoscopic surgery         |                               | X Human factors study | X Surgical education | | x |
| (Wu et al., 2021)                           | X Simulated training           |                               | X Human factors study | X Simulated training | X Robotic surgery | |
| (Van’t Hullenaar et al., 2018)              | X Minimally Invasive surgery   |                               |                               |                               | X robots | |
| (Konakondla et al., 2017)                   | X neurosurgery                 |                               |                               | X residency education neurosurgery training | | x |
| (Bernardo, 2017)                            | X neurosurgical                |                               |                               |                               | X Stereoscopic digital visualization Augmented reality Robotics in surgery | |
| (Ciporen et al., 2018)                      | X Anesthesia neurosurgery      |                               |                               | X Crisis management Cavernous carotid injury | | |
| (Ronstrom et al., 2018)                     | X operating room               |                               | X Humans factors posture | | | |
| (De Luca et al., 2019)                      | X Orthopedic                   | X Interactive simulation haptics | X Psychomotor skills | X Education and training | | X Neuro vr |
| (Teodoro-Vite et al., 2020)                 | X Aneurysm repair vascular neurosurgery | X surgery simulation hybrid simulators | X Skill metrics gestures exerted forces | X surgery training | | |
| (Yadav et al., 2016)                        | X microneurosurgery            |                               | X motor skills physiology | X microsurgery education | | x |

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training tool needed. We have highlighted and discussed the most important questions that we believe are related, to plan our next step and construct the implementation.

Additionally we run a qualitative research with a population of 14 surgeons on the use of ergonomics and VR simulation for surgical practice including six key parameters of analysis:

- The key limitations of current approaches in Surgery, with an emphasis in technological support.
- Their experience in the use of technological tools in Surgery.
- Their opinion on the potential of Virtual Reality in Surgery?
- The ergonomics considerations in Surgery with emphasis on best and worse practice.
- Their own belief for the evolution of emerging technologies and their adoption in Surgery.
- Their recommendations for some new processes and actions for the integration of Virtual Reality, Simulations etc. in Surgery?

### 3. RESULTS AND KEY FINDINGS

In this section we provide the key facts and empirical data that were analyzed through our research tool. We elaborate on the key findings and we provide some initial interpretations. In the next section we will integrate them with the implications of our research and key discussion.

#### 3.1 Quantitative Investigation

The questionnaire gathered data from 77 respondents practicing in different countries, including Saudi Arabia, USA, UK, Pakistan, Egypt, and many other countries. Board-certified surgeons had the greatest representation at 73.6% (56) surgeons, followed by 9.2% (7) senior residents, 9.2% (7) junior residents, 7.8% (6) specialists, and one more respondent didn’t mention their education level. Responders represent a total number of 68 males and 7 females (two responders skipped this question).
Of the total, 57.33% worked at tertiary hospitals, 32% of the respondents worked at university hospitals, and the other 10.6% worked at community hospitals. Residency programs are available in the hospitals of 79% of the respondents. This question was asked in order to identify the background of respondents based on their work environments. In our cohort, the top three neurosurgical subspecialties practiced by the board-certified neurosurgeons were spinal surgery, neuro-oncology, and pediatric neurosurgery. The respondents’ characteristics and demographic data are shown in Table 3.

When asked about different rehearsal habits, 44% of respondents said they rehearse before operations, while 35% sometimes rehearse before operations, and 19% don’t rehearse before operations.

Regarding which method they practiced for rehearsal, as shown in Figure 1, reviewing medical imaging of the patient (MRI, CT, ultrasound, X-ray) was practiced by 97% of respondents, followed by reviewing the anatomy (86%), discussion (77%), mental rehearsal (73%), while a review of navigation-generated images was practiced by the lowest number (55%). However, most of the respondents (97%) agreed that reviewing medical imaging of the patient (MRI, CT, ultrasound, x-ray) is an essential method of rehearsal. Basically, it supports medical and surgical treatment planning as well as guiding medical personnel as they insert catheters, maneuver other devices inside the body, or remove blood clots and other blockages.

Referring to the methods that programs offer for teaching surgical skills at the doctors’ institutions, an “apprenticeship model (learning by doing)” was most commonly offered (71%), followed by “training on live surgery” (68%), followed by “scheduled surgical lectures” (55%). However, the apprenticeship model is based on the theory of situated learning, which states that a skill must be learned in the authentic context where it is to be applied. In terms of defining better ways of assessing surgical training performance, results show that 71% of responses suggested operating on cadavers as a better method, 67% of respondents suggested deploying virtual reality models, and 51% suggested synthetic models and scheduled surgical lectures.

The questions designed to discover how much doctors know about virtual reality technology showed that 61% of respondents hadn’t experienced virtual reality surgical simulation in training, while 90% of total respondents did believe that virtual reality technology can serve surgical training.

When the respondents were asked whether they had explored any of the existing virtual reality neurosurgical simulators, their responses indicated that 57% hadn’t explored any kind, while 30% had tried the NeuroTouch (NeuroVR™) simulator, 13% had tried Surgical Theater’s simulator, and 11% had tried the Immersive Touch simulator.

Regarding the preoperative phase, which is an important phase that many doctors may not pay that much attention to, almost all respondents (98%) agreed that there is a gap in existing neurosurgical training in terms of operating room ergonomics skills.

When asked about the gap in existing neurosurgical training in the preoperative phase, in order to identify which gaps are common among the majority of respondents, 60% of residents agreed on “identifying the interface between tumor and brain and use as operating plane for tumor resection”, and most of the board-certified surgeons (63%) felt the gap was in “identify anatomic landmarks, functional regions, and major structures”. This indicates that board-certified surgeons have more comprehensive thinking toward the existing gaps than the trainees.

When asked about how important the body positioning technique is when compared with the other skills, 89% of them thought that it is essential, as shown in Figure 2.

Regarding gaps in existing neurosurgical training, the respondents were given a wide selection of neurosurgical skills to choose from: scalp incision, bone flap removal, dural opening, open and close scalp incisions, etc. The answers were variable between the different types of surgical skills. Shown in Table 4 are the top five skills where respondents felt there were gaps.
Table 3. Respondents’ characteristics

| Variables                      | Cohort |
|--------------------------------|--------|
| **Gender**                     |        |
| Male                           | 90.79% | 69    |
| Female                         | 9.21%  | 7     |
| skipped                        |        |
| **Age**                        |        |
| 25-34                          | 29.33% | 22    |
| 35-44                          | 26.67% | 20    |
| 45-54                          | 29.33% | 22    |
| >55                            | 14.67% | 11    |
| skipped                        |        |
| **Educational level**          |        |
| Junior resident                | 9.21%  | 7     |
| Senior resident                | 9.21%  | 7     |
| Specialist                     | 7.89%  | 6     |
| Board-certified surgeon        | 73.68% | 56    |
| skipped                        |        |
| **Region of practice**         |        |
| North America                  | 10.3%  | 8     |
| South America                  | 2.5%   | 2     |
| Europe                         | 7.79%  | 6     |
| Asia                           | 70.12% | 54    |
| MENA                           | 5.19%  | 4     |
| skipped                        |        |
| **Type of institution**        |        |
| Tertiary Hospital              | 57.89% | 44    |
| Community Hospital             | 10.53% | 8     |
| University Hospital            | 31.58% | 24    |
| skipped                        |        |
| **Do you have residency program in your hospital?** |        |
| Yes                            | 78.95% | 60    |
| No                             | 21.05% | 16    |
| skipped                        |        |
| **For how many years have you been practicing at your current level (resident, specialist, or consultant)?** |        |
| 0-1                            | 15.58% | 12    |
| 2-5                            | 27.27% | 21    |
| 6-10                           | 18.18% | 14    |
| 11-15                          | 11.69% | 9     |
| 16-20                          | 12.99% | 10    |
| >20                            | 14.29% | 11    |

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3.2 Qualitative Investigation

In this section we provide the additional insights collected from the focused survey that reached 14 surgeons. The key findings provide additional insights to our investigation and research approach.

In the first focused question we tried to understand the key limitations of current approaches in Surgery, with an emphasis in technological support.

As it is indicated in the overview these are some of the key perceptions of our respondents:

- **Reaching Deep Structures, Light during Operation**: It is critical to deploy new methods and more sophisticated approaches to reach deep structures and to improve lighting during operations and realistic representations.
More time for training: Time for training seems to be a key limitation factor. From this perspective simulation tools and VR enhanced surgical practice capability combined with ergonomics will add value.

High Prices of simulation devices: The development of cost effective simulation environments for surgery is a key requirement.

Confidence and Experience: The deployment of technology needs to be based on increased confidence and experience. The availability of simulation environment will allow the development

Training and IT skills: The effective deployment of surgical VR requires enhanced training and development of IT skills. This requires a detailed analysis of training modules and design for integrated curricula.

Budget: The required investment in technological tools for surgery is a limitation factor. In this context new approaches bringing into operation fully functional cost efficient environments for simulations and surgical VR or robotics is a significant milestone.
- **Limited broadcasting:** Technical difficulties related to connectivity and broadcasting capabilities is operation rooms is also a key factor for investigation and improvement.
- **Skills and competencies:** The required skills for technological innovations in surgery need integrated training programs and extensive practice.

In Table 5, we provide an overview of key limitations.

In the next question our respondents were requested to summarize their own experience in the use of technological tools in Surgery. From there statements it is resulted a rather adequate deployment of tools and relevant skills and competencies. As is is shown in Table 6, some key areas include: Endoscopic surgeries, Microscopic surgeries, Visualization techniques, Tristappler in powel anastomosis, Laparoscopic Devices, anastamosis, stapling and thermocoagulatory devices. Also technology adoption related to Utilization, Navigation studies, Endoscopy 3D viewing, VR trials, Laparoscopic Surgery, 3D screens and Robotic Surgery.

### Table 5. Key limitations of current approaches in Surgery, with an emphasis in technological support

| Open-Ended Response | Key issue revealed | Contribution to our methodological framework |
|----------------------|--------------------|---------------------------------------------|
| Reaching deep structures without causing injury to the outside structures, light during operation, Focusing | Reaching Deep Structures, Light during Operation | Light & Reaching of deep structures |
| Need more time for learning and to get more chances from the seniors for learning | More time for training | Time for Training |
| High price of surgical simulation devices and lack of availability | High Prices of simulation devices | Cost |
| Some long operations “like Wipple” requires multiple major steps that can be done in other operations but together they make the name, so training and simulation sessions targeting these individual steps build the confidence of this operations “and other operations may share the same step”, the experience and build up of learning curve | Confidence and Experience | Learning Curve |
| We need more training | Training | Time for Training |
| Need large budget | Budget | Budget Resources |
| Most of the Current surgical approaches are based on exploratory procedures where a longer surgical incision is made to look and reach for pathologic or diseased part. Technology may help us in pin pointing the location of bleaders, tumors, cysts, masses, stones etc. It can help in easing up positioning during surgery. Good healing and less risks may be achieved with technology. | Easing up positioning | Good Healing, |
| Minimally invasive with less with less exposure Long learning curve | Less exposure | Long learning curve |
| IT employees | IT skills | IT skills and employees |
| There is not enough broadcasting for laparoscopic surgery to outside the OR room so even if someone is not attending can observe the approach. Robotic surgery is not available in most hospitals. | Limited broadcasting | Robotic Surgery |
| Old generation can’t cope with the new advances especially that relates to technology | Skills and competencies | Skills |
In the next questions we tried to understand the key perceptions of our respondents on their thoughts about the potential of Virtual Reality in Surgery. Some key aspects of their opinions are summarized as follows:

- **Limited Use, Promising Technology:** “I didn’t use it before, but I think it would be a wonderful experience and promising field in medicine one day, especially when practicing for the junior physicians and interns to understand the anatomy properly” or “No I didn’t try it, if available it will be soooo beneficial.”
- **Concerned attitude:** “it has some limitations such as losing the real sensation.”
- **Confident positive opinion:** “Its good.”
- **Non users:** “Never used it before.”
- **Awareness build:** “We have read about it but still not used it.”
- **Advocates:** “VR surgery is a great medium to access patients with minimal contact especially in the presence of this pandemic in addition to being able to help patients who are not able to be present in the same place as the surgeon.”

Another critical question of our qualitative approach is related to the Responders’ opinion about ergonomics considerations in Surgery. Below is a summary of key ideas communicated:

- **Resistance to change:** “The main issue with the advanced or technological instruments and approaches in the surgery that it got fought by senior and old physicians that got used to limited approaches and hate the idea of changing their concepts and refusing to give a chance for novel techniques in practice, meanwhile in the other hand it sometimes benefit the patient when there is a pack up approach that is not fully forgotten and vanishes when needed mostly.”

### Table 6. Responders’ experience in the use of technological tools in Surgery

| Provide your experience for the use of technological tools in Surgery | Key issue revealed |
| --- | --- |
| Endoscopic surgeries in Otolaryngology field shown to be better for visualization when compared to microscopes especially in ear surgeries, which would save operative time, and save skin incisions that would scar and cause pt inconvenience | Endoscopic surgeries |
| Microscopic surgeries |
| Visualization |
| Using tristappler or circular stappler in bowel anastomosis | Tristappler in powel anastomosis |
| Laparoscopic device | Laparoscopic Devices |
| Actually my answer “as well as others” maybe biased in here because some hospitals “including the one I’m working at” is mainly dealing with one company than others so we don’t have that much of choices to prefer one product to another, but dealing with Covidine Company in regard of it’s anastamosis, stapling and thermocoagulatory devices is great and I’m comfortable using them in the field | anastamosis, stapling and thermocoagulatory devices |
| Utilizing minimal invasive surgeries will decrease overall complications | Utilization |
| Use of endoscopes, microscopes, navigation studies have helped in our field of neurosurgery. | Endoscopes |
| Microscopes |
| Navigation studies |
| Endoscopy 3d viewing for difficult access structure | Endoscopy 3d viewing |
| VR trials | VR trials |
| Not much experience apart from laparoscopic surgery | Laparoscopic Surgery |
| Most of our new surgeries depends on new technology including 3D screens, robotic surgery | 3D screens |
| Robotic Surgery |
Key contribution of Ergonomics / Pillar of efficiency: “Ergonomics are a must in surgery specially in Laparoscopic procedures for instance. I have seen in my practice so far some examples of applying the ergonomics and stressing on them and the results were excellent on the surgeon, procedural time and result on the patient. some surgeons were the opposite of not paying attention to them and they had some difficulties.”

More practice: “It is need more practice.”

Improve Discomfort: “Surgeon discomfort has potential negative consequences on surgeon performance and patient outcomes, resulting in lost revenue and surgeon burnout. Improving surgical ergonomics can reduce discomfort and mitigate negative downstream consequences. In the operating room, this includes awareness of body posture and proper operating room setup. Other strategies include a warm-up prior to the first case and taking scheduled breaks during surgery. Outside of the operating room, surgeons can reduce discomfort by improving the ergonomics of their office environment and maintaining good health through routine exercise and stretching. Surgeon educators should teach residents ergonomic principles as well as model their implementation in the operating room.

Positioning issues: “Long standing with wrong posturing.”

Lack of expertise: “As i’ve mentioned, there are not enough expertise in VR.”

Core component of success in surgery: “Most of our surgeries depends on it and it is efficient.”

Additionally one of our key efforts was to reveal the qualitative aspects of attitude of surgeons on the evolution of emerging technologies and their adoption in Surgery. Below are some of the characteristic opinions that add into the rich picture of our research:

Many examples we could use to highlight over what technology helped us in, for example robotic surgeries used nowadays in oropharyngeal surgeries saving time and ugly scars in the face to reach a point that is tiny compared to the damage it took when approaching patient surgically, also endoscopic ear surgeries nowadays is the favorable approach with newly graduated physicians with an outcome is fascinating when compared to the traditional microscopic surgeries.

Its upcoming future.....need more learning curve and more teaching centers.

Virtual reality whole body anatomy, that surgeon can work on any body part like real patient.

Actually as I’m still a resident and the fact that I haven’t worked yet in any robotic surgeries, I lack the knowledge and informations needed to discuss this mater.

Treat the sport knee.

Using robotics surgeries would be the near futures for most operations.

Emerging of new technologies is a wonderful progress. I wish that I have technologies to pinpoint bleeders, tumors exactly on operating table and we can directly manage them without cutting a lot of tissues.

I believe future it is all about technoliges that helps as do less invasive and more effective surgery but with good exposure and virtual reality for better learning.

None

Robotic surgery is the best example for future potential in accessing everyone. Technology and medicine should go hand in hand for the present and future.

Transferring from conventional thoracotomy to uniportal VATS depends on new technology helped in safe , shorter hospital stay. Robotic surgery is the future.

Finally our respondents recommended some new processes and actions for the integration of Virtual Reality, Simulations etc. in Surgery?
I think the minor surgeries would be a start when implicating the virtual reality and would give the practitioner a good experience when exposed to the same setting intra operatively.

Roboting surgery

Same answer in previous question.

One of my recommendations that if the health committees that approve the residency programs, can involve these technologies in the training programs “specially in early years of surgical specialties and their residency programs” that might solve the deficiencies in the residents contributions in OR and will make it more safe for the surgical patients as only experienced surgeons “at least senior residents” can contribute in working in the real operation.

None

Navigation Scans

Before each Complicated surgery to make surgeon more confident.

All residents should have the opportunity and should be included in the residency program.

VR may have a role in the future but needs more adoption and practice.

In the next section we synthesize the key findings of our research.

4. DISCUSSION

The term “simulation” is well known to the medical community. For many years, medical students, residents, and practicing physicians have had the opportunity to practice their skills using medical simulations (Ziv et al., 2003). Simulation training in medical education is defined as “a technique to replace or amplify real patient experiences with guided experiences, artificially contrived, and that evokes or replicates substantial aspects of the real world in a fully interactive manner” (Rehder et al., 2016).

In simulators, the power of automation is seen. A cause and effect relationship with computer integration allow for instant input and output of score reports. Many metrics, such as precision and precision scales, are described by predetermined values that reflect the ideal dexterous technique. Simulations help learners to build on other attributes that form capable neurosurgeons, in addition to concentrating on technical skills and cognitive analysis. Variations in these values generate reports of feedback. It is possible to calculate the time to completion, the number of errors carried out, and the need for assistance. These include contact with patients, teamwork, decision, and leadership (Konakondla et al., 2017).

Ergonomic analyses are widely applied today in industry, military, and sports training to help professionals to achieve optimal efficiency with a low probability of error and injury (Berguer, 1999). During surgery, ergonomic stress is of considerable importance. Surgeons prefer to lean forward into, or even over, the surgical area to see and manipulate tissues because of the location of the patient; this results in increased muscle movement to stabilize the upper body. Moreover, awkward postures kept for long periods of time result in musculoskeletal fatigue and physical complaints (Albayrak et al., 2007). In addition, due to the complexity involved and risk to the patient (when fine errors occur), some specialties require more practice than others.

Preoperative preparation may have a significant effect on the whole procedure, as neurosurgeons will decide about their full surgical strategy during the simulation, including how to position the patient, how to conduct the craniotomy, and how to reach the tumor. In several interventions, surgical preparation as an important step for these reasons (Kumar et al., 2017).

For neurosurgical procedures, the general goal of patient positioning is to provide optimum surgical visibility while ensuring patient safety. One of the most important factors when preparing patients for neurosurgical procedures is positioning the head and neck, and proper positioning facilitates optimum surgical approach and visibility. In the immediate postoperative period, complications associated with head and neck positioning may exist (Vaisbuc et al., 2017).
The majority of surgeons blamed posture for their symptoms. In several situations, surgeons found themselves having to work at heights that can bring pressure on their elbows or backs due to incorrect operating tables heights or even because of poorly designed tables. This is despite the lack of awareness regarding the ergonomics guidelines to ensure an ideal posture (Atesok et al., 2017). Currently, two-thirds of surgeons have none or only a slight awareness of the ergonomic factors contributing to their symptoms (Mussi et al., 2020).

Kant et al. researched the posture of doctors and nurses during surgery and found that because of their frequent and longer static head-bent and back-bent postures, surgeons and scrub nurses experience considerable stress on the musculoskeletal system (Kant et al., 1992). Radermacher et al. have reported that over 70 percent of intraoperative work postures are significantly static during laparoscopic and orthopedic surgery (Radermacher et al., 1996). Mirbod et al., lately surveyed musculoskeletal complaints among orthopedic and general surgeons, and found a considerable occurrence among orthopedic surgeons of complaints of pain in the shoulders (32%) and neck (39%). In the same study, similar symptoms have reported by general surgeons with a prevalence of 18% and 21%, compared to 15% and 18%, respectively, for pharmacists (Mirbod et al., 1995).

During and after spine surgery, many spine surgeons reported neck and back pain. The spine angle of the surgeon was ergonomically examined in a study by Park et al. (2010) during the surgery, and the kinematics of the spine of the surgeon were correlated with musculoskeletal exhaustion and pain. Spine angles varied according to the height of the operation table and method of visualization. Park et al. (2014) noted that when laparoscopic surgeons adjust posture, fatigue reduction has been ergonomically demonstrated as feasible. Therefore, from the viewpoint of ergonomic and human factors, all measures must be extended to improve the surgeon, computer, and patient interface.

5. CONCLUSION

There are training and rehearsal gaps that, in the past, were never addressed by simulation technologies, such as operating room ergonomics skills, patient positioning, and choosing incisions. This study affirms the need for training in surgical ergonomics skills to improve outcomes. Teaching principles of ergonomics using simulators have been proven to improve end-user skills in numerous fields and are now considered standard in training. The gathered data will facilitate the creation of a simulation technology prototype. In the operating room, ergonomic risk factors should be explicitly defined, potential strategies to be introduced should be explored, and implications should be measured.

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CONFLICTS OF INTEREST

Declare conflicts of interest or state “The authors declare no conflict of interest.”
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