WHITE PAPER

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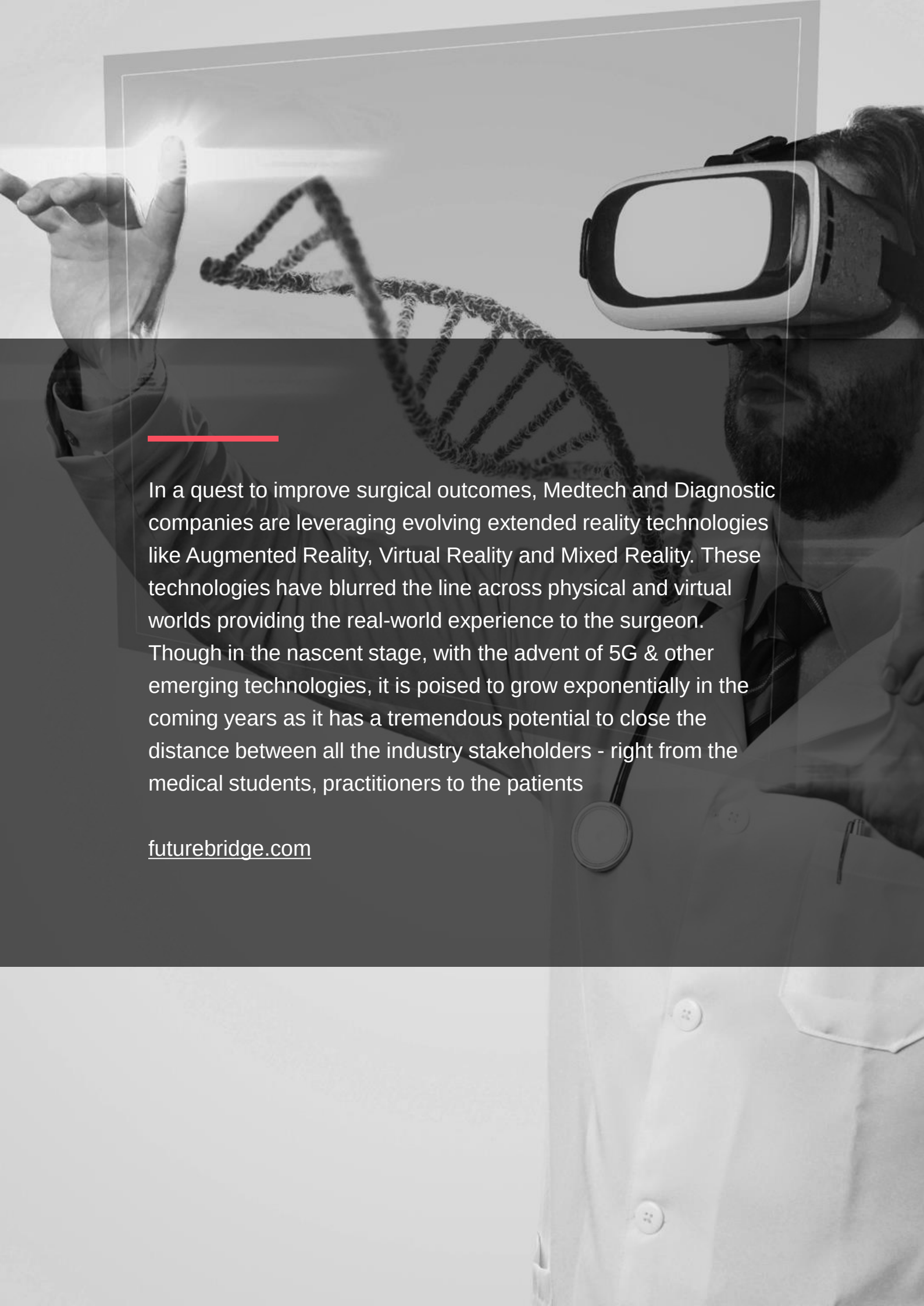
Extended reality: Future of digital surgery

FutureBridge



In a quest to improve surgical outcomes, Medtech and Diagnostic companies are leveraging evolving extended reality technologies like Augmented Reality, Virtual Reality and Mixed Reality. These technologies have blurred the line across physical and virtual worlds providing the real-world experience to the surgeon. Though in the nascent stage, with the advent of 5G & other emerging technologies, it is poised to grow exponentially in the coming years as it has a tremendous potential to close the distance between all the industry stakeholders - right from the medical students, practitioners to the patients

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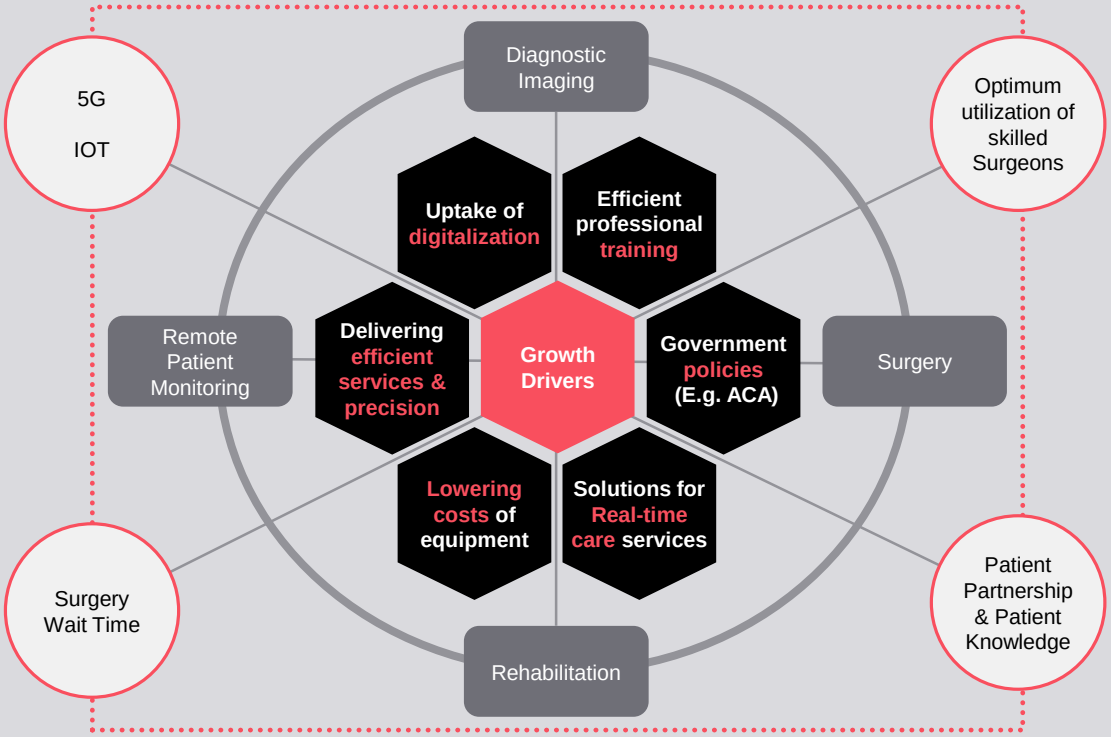
Introduction

The ability of Extended Reality (XR) to allow physicians or surgeons to be virtually present at remote locations and provide interactive & realistic virtual 3D anatomical models is transforming the healthcare industry.

XR healthcare market is poised to witness exponential growth due to the growing adoption of Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) by the healthcare industry, and rising investments by the provider institutions in the emerging technologies. Globally, the XR healthcare market is estimated to reach $5.1 billion by 2025.

The major applications that are driving the growth of the XR market are surgical simulation/training, diagnostic imaging, remote patient monitoring, and rehabilitation. Refer to *Exhibit 1* for growth drivers and applications of XR. AR & VR helps academia to enhance the future surgeons' understanding of human anatomy and physiology, and also assist the practicing surgeons to carry out complicated surgeries with utmost precision and accuracy.

EXHIBIT 1: Growth drivers and applications of Extended Reality (XR)



Source: FutureBridge analysis

Researchers are exploring other ways in which these immersive technologies can be used to enhance the healthcare experience & improve outcomes. One such example is using VR as exposure therapy to alleviate the patient's fears & phobias.

The XR healthcare market is also supported by patient demands and government policies like the Affordable Care Act, which emphasizes the patient's overall experience along with improved outcomes, and improves patient knowledge by visual representation of procedures and interventions. Moreover, even the provider institutions are using it to streamline their medical operations. For example, surgeons are leveraging XR to develop an individualized approach for each patient and plan for each step of complex surgeries like tumor removal or separation of conjoined twins.

The growing number of healthcare startups leveraging AR & VR technology has garnered the interest of private investors which is further propelling the market. For instance, in February 2019, US-based startup Vicarious Surgical, which enables surgeons to perform minimally invasive surgery through single micro-incision by combining virtual reality with its proprietary human-like surgical robots, secured a $10 million investment from Bill Gates' Gates Frontier.

Multiple projects are running in well-known universities like the University of Mississippi focusing on prevention, diagnosis and treatment for neurological disorders.

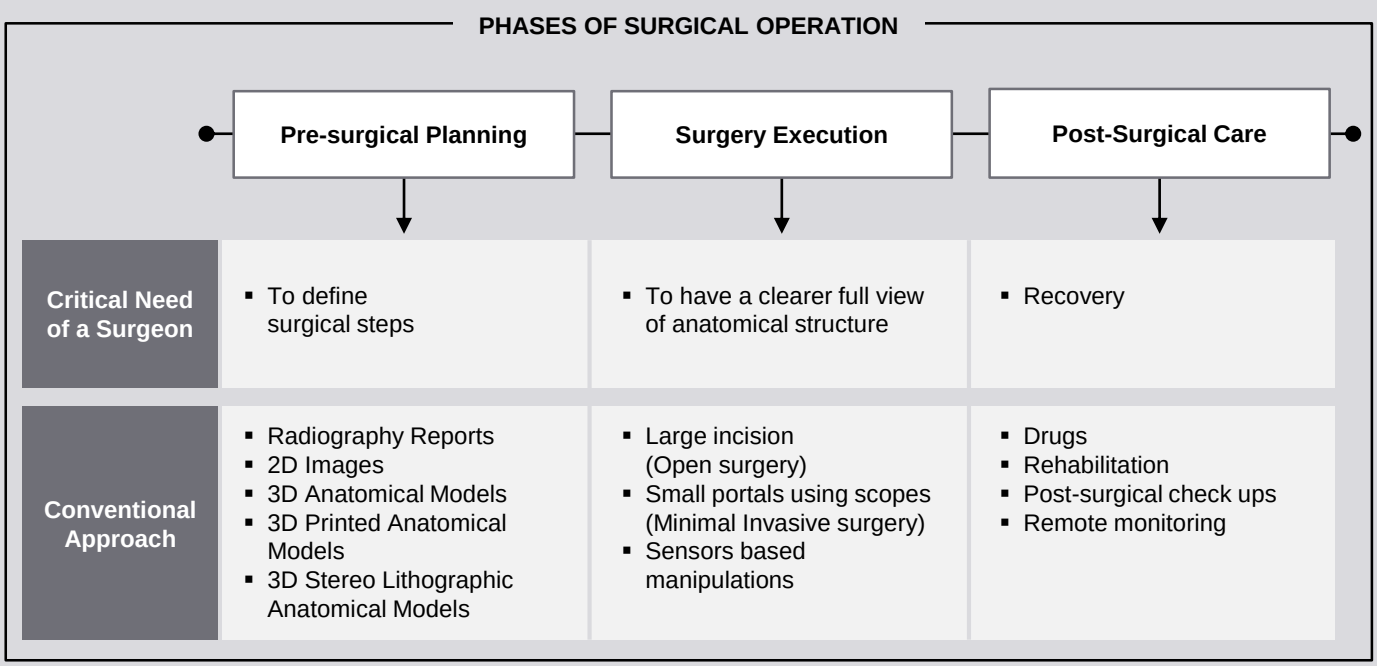
Though in the nascent stage, few organizations have already started reaping the benefits of these immersive technologies and with the recent technological advances, XR is likely to open up new frontiers in the healthcare industry.

Conventional approach – the need for advancement

The three major phases of any surgery are pre-surgical planning, execution & post-surgical care *(refer to Exhibit 2).* For pre-surgical planning, over the years surgeons have been referring to various image scans and patients' medical profile data to understand a surgical problem. Nowadays, surgeons use various types of 3D anatomical models printed or manufactured based on radiography reports to replicate patient-specific anatomical structures for a better understanding of the surgical problem. Once the plan is developed, the surgeon proceeds to perform the surgical procedure. The surgeon either makes a large incision to have a clear full view of the anatomical structure or inserts video scopes through multiple small

incisions that capture video data which is then transmitted and displayed on a monitor located in the operating theatre. Upon completion of the surgery, the surgeons prescribe drugs or rehabilitation therapy and monitor the patient's recovery by arranging check-ups on a timely basis either face to face or via remote monitoring technology.

EXHIBIT 2: Conventional approach to the critical needs of a surgeon at each phase of the surgical operation



Source: FutureBridge analysis

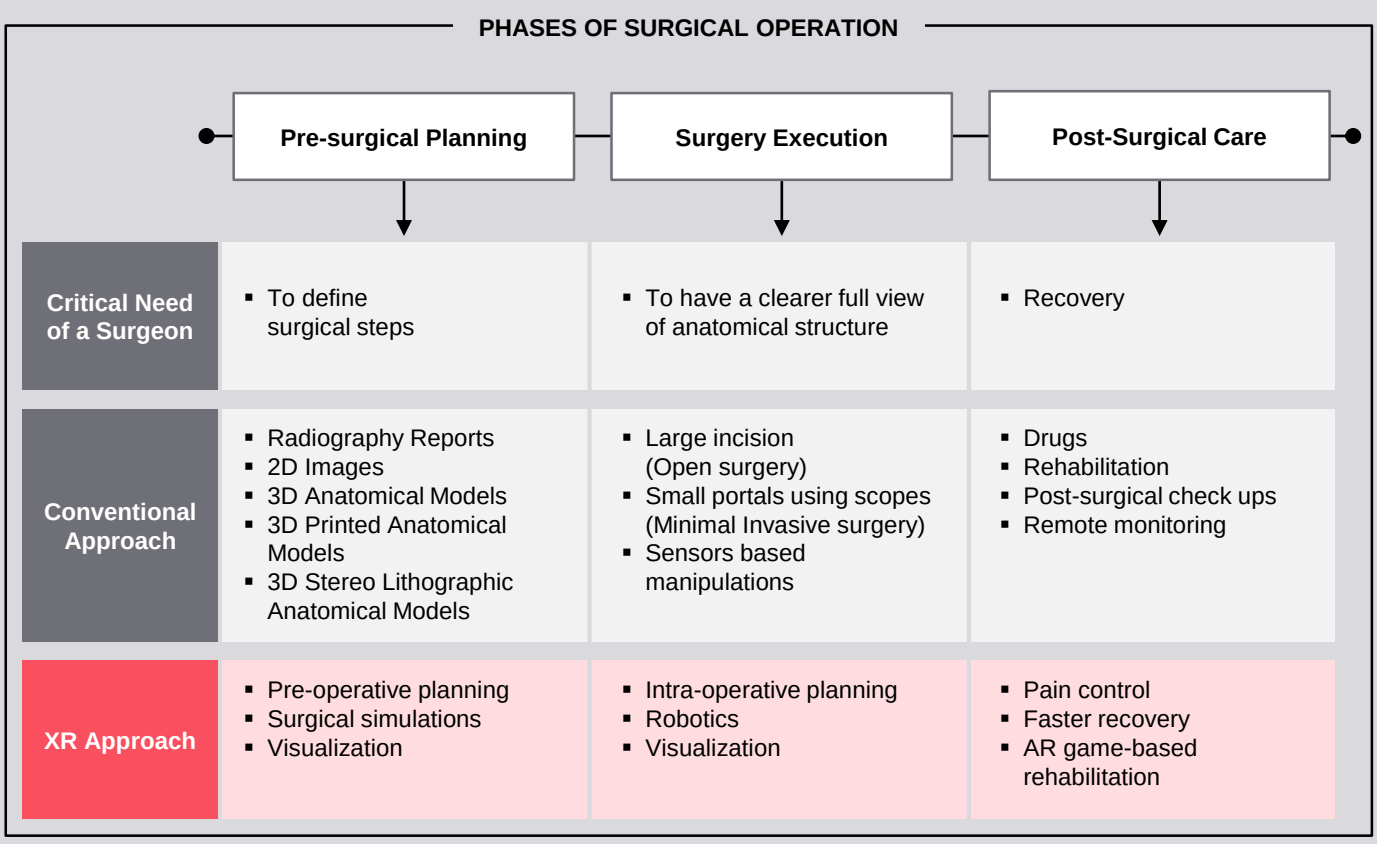
However, there are several drawbacks in using the current technologies which fail to provide better surgical outcomes. For example, current 3D anatomical models do not provide minute and exact details of the location of nerve tissues or blood capillaries in or around the anatomical structure. In such cases, the surgeon has to consciously visualize those nerve tissues or blood capillaries situated around the anatomical structure and accordingly plan the surgical steps. There are high chances that the surgeons may forget to include those minute details and as a result, they often fail to establish a proper and effective surgical plan.

Even while executing the surgery, continuous blood oozing from the surgical site due to the incision obstructs the views of the anatomical structure. Further, the surgeon repeatedly needs to watch the monitor while using the video scopes to locate the surgical device at the surgical site while performing the surgery simultaneously. This is physically tiring for the surgeon and increases the period of the surgical procedure.

Furthermore, the current remote monitoring technologies are facing several network issues such as low bandwidth, sudden loss of communication signal due to rains, or power disruption, which results in ineffective monitoring of the patient's recovery during post-surgical care.

Therefore, there is a need for such a technology that can replace the existing technologies with features that can overcome the above-mentioned drawbacks and provide better surgical outcomes to the patients. Refer to *Exhibit 3* to understand how XR is changing the conventional approach.

EXHIBIT 3: XR approach to address the critical needs of a surgeon at each phase of the surgical operation

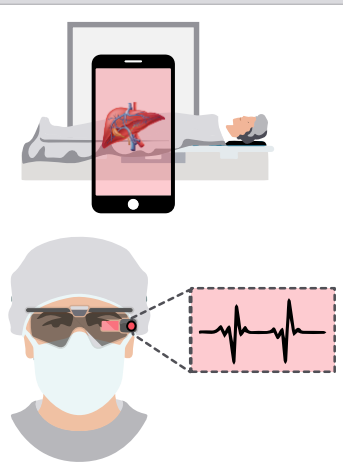
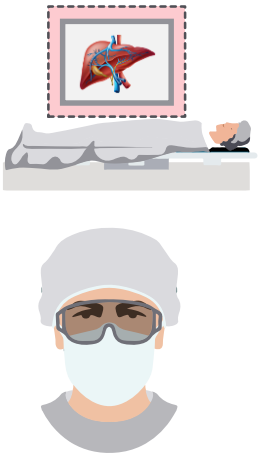
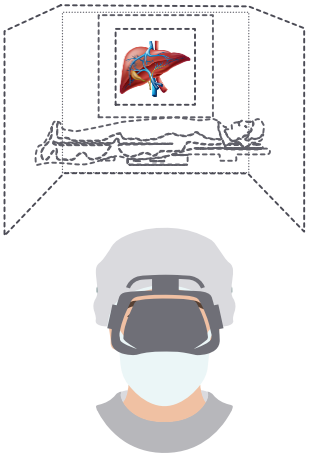


Source: FutureBridge analysis

Extended reality – *beyond physicality*

Extended reality is a technological revolution in immersive computing, it is considered as an umbrella term for augmented, virtual, and mixed reality *(refer to Exhibit 4)* . The 'X' in XR is considered as a variable and can stand for any letter.

EXHIBIT 4: Understanding AR, VR & MR

Augmented Reality	Virtual Reality	Mixed Reality
This technology overlays the digital environment in the real world by using computer-generated images and other sensory inputs	It refers to technology that uses reality headsets to generate sounds, images, and other sensations which can replicate a real environment or create an imaginary world.	It is a combination of both virtual and augmented reality, hence it is known as hybrid technology. MR creates environments and visualizations where physical and digital objects co-exist and interact in real-time.
Digital **separated** from Physical	Digital **integrates** with Physical	Digital **replaces** Physical
		

Source: FutureBridge analysis

In the extended reality system, computer-processed imaging data is provided to the surgeon in real-time via dedicated hardware and software. The augmented image is then projected using various displays, projectors, cameras, trackers, or other specialized equipment. The most basic method is to superimpose a computer-generated (CG) image on real-world imagery captured by a camera and display the combination of these on a computer, tablet PC, or a video projector. The main advantage of AR is that the surgeon is not required to look away from the surgical site as opposed to conventional visualization techniques.

Another possibility is to use a special head-mounted display (also known as “smart glasses”) which are similar to eyeglasses. They use special projectors, head tracking, and depth cameras to display CG images on the glass, effectively creating the illusion of augmented reality. Several XR systems with an HMD have already been developed with success. Using an HMD is beneficial as there is almost no obstruction in the surgeon’s view compared to a traditional display.

The Utah-based startup Novarad, introduced its product OpenSight as the first FDA 510(k) cleared AR medical solution for the HoloLens in pre-operative surgical planning. It enables the surgeon to create 2D, 3D, and 4D images of patient anatomy and also allows them to accurately overlay those images onto the patient's body for surgical planning. OpenSight can handle multiple users at once in clinical or training applications.

Even VR has a role to play in surgical planning. Immersive Touch Inc.'s ImmersiveView VR is one such technology that transforms patient's computed tomography (CT) and magnetic resonance (MR) images into accurate and high-resolution virtual reality models. The physicians can manipulate and explore these virtual reality models from any angle. ImmersiveView can optimize outcomes and decrease time in the operating room resulting in overall improvement of pre-operative planning and patient satisfaction with reduction in costs.

When it comes to the execution phase, companies like Scopis are leveraging mixed reality technology to make surgeries safe, accurate, and effective. Its Holographic Navigation Platform offers improved precision and pace to surgeons. The Holographic Navigation Platform can be used with Microsoft's HoloLens headset to see the planned positioning of pedicle screws which are overlaid onto the patient, building the mixed reality experience. The system allows the surgeon to locate the screws' planned position in less time with the holographic visualization.

One of the most important elements of post-surgical operation is rehabilitation to facilitate faster recovery. Many companies have started leveraging XR for this phase of surgery as well. For example, NeuroR4, which is a post-stroke rehabilitation system based on AR technology. The system provides motor imagery which can be defined as the mental execution of a movement without any overt movement or without any peripheral activation using a virtual 3D arm that replaces the paralyzed arm in a virtual avatar of the patient. It can be used either in rehabilitation centers as well as at home. The system includes exercises to achieve a range of motion (ROM) of flexion and abduction of the shoulder.

Extended reality finds its applications in various fields and its usefulness becomes more predominant in training, preoperative evaluation, and preparation of surgeons. Research on the applicability of these technologies in other healthcare domains is taking place at a breath-taking speed and surely newer applications will spur out of it very shortly. However, scaling up these technologies is a hard row to hoe.

Barriers to implementation – *factors preventing extended reality to become a reality*

Despite the effective outcomes in the surgery, the adoption of XR is challenging due to various aspects. These challenges need to be countered to promote the growth of the XR in the healthcare domain.

Technical Barrier/Infrastructure

The application of XR in surgery needs immense computing and advanced algorithms to overlay the reconstructed images in the virtual environment. At the moment, the hospitals lack such resources and infrastructure to adopt XR in surgery. A significant amount of investment is required to overcome this challenge. With the advancements in the technology and entry of several companies, the cost seems to be lower down.

The dearth of appealing design

Lack of good user experience due to bulky visualization devices and cumbersome installation has proven to be a major barrier to the wide adoption of XR. Hence the visualization devices need to be light in weight, handy, and smaller.

Latency

Latency is the short delay experienced between a command and execution. Ensuring that the digital information generated by software within the headset is displayed in real-time with 100 percent accuracy through the lens and the projected image is of utmost importance. However, this barrier would be overcome with the help of 5G technology, which can transmit the information with minimal or almost zero latency.

Cost

Apart from technological barriers, financial challenges due to expensive XR gear have delayed the growth of XR in the healthcare industry. The first-generation VR headsets like Oculus Rift (Facebook Inc.) and HTC Vive (HTC Corporation) are quite expensive, restraining the healthcare professionals to invest in them. Many companies are working on developing low-cost VR devices to attract consumers.

Lack of knowledge/Expertise

The lack of knowledge and expertise to use XR in healthcare professionals may risk the life of the patient. Before the implementation of XR in the operation theatre,

rigorous training of surgeons on XR technology is needed for a better understanding of device usage, guidelines, and protocols. Dissemination of this knowledge is an important unmet need.

Possible solutions – *industry best practices & use cases*

The anticipated benefits of XR will only be beneficial by overcoming the above-mentioned barriers. Many companies have come up with their products utilizing XR technology, compatible with the needs of surgeons and nurses. Companies need to demonstrate the value that XR devices can bring to the table. This can be achieved through a healthcare venture with established academia or medical professionals. This would also encourage healthcare professionals to adopt XR devices in surgeries.

- **Augmedics:** An Israeli start-up waiting for FDA approval for **AR headsets** to be used by surgeons for **spinal surgery**. The company has developed lightweight eyewear, Vizor to project the 3D model of the patient's CT scan.
- **Alphabet:** Google has introduced a low-cost 3D VR device, Cardboard which looks like a set of big square goggles and costs around $20. Doctors at Nicklaus Children's Hospital in Miami used the device to perform critical heart surgery by **visualizing scanned images in 3D virtual reality.**
- **Oculus & VRHealth:** Collaboration between the two companies has brought respite to the patients undergoing chemotherapy experience. **VR distraction therapies** are helping patients to manage their pain and alleviate their anxiety.
- **Johnson & Johnson:** The Company has established **24 VR training centers for surgeons** and nurses to train them on orthopedic surgery – total knee replacement with direct anterior approach and hip fracture treatment with a proximal femoral nail.

Conclusion

The wave of digitalization has struck the medical industry in various forms and one of them is the application of XR. Being in the nascent stage, XR has already proven its ability in the healthcare industry and other industries such as gaming, automotive, manufacturing, and the list goes on. The benefits of XR start from pre-surgical planning to a virtual assistant during surgeries and extend to post-surgical rehabilitation. The medical students are reaping the benefits of XR's interactive learning capability which eventually enhances their knowledge & learning experience. Although the applications of XR are expansive, the adoption by medical practitioners is quite sluggish. There are several reasons: cost of implementation, the need for proper training and expertise, etc. However, many companies have started leveraging the niche status of XR in the medical industry and commercializing their products. Several big medical devices companies such as Medtronic are researching the various usage possibilities of the XR technologies in many of their business divisions.

Many start-ups across the globe are experimenting to combine XR with robotics, artificial intelligence, and other advanced technologies for providing sophisticated training environments and enhanced assistance to surgeons. With the introduction of 5G, the popularity of XR is expected to increase exponentially as XR devices need constant connectivity for fast response times. As the technology evolves, the penetration of XR is predicted to be deeper in the healthcare industry. The healthcare companies may look up the applications of XR in parallel industries and adapt the offered solutions in surgery ensuring they are in line with regulatory requirements.

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