ENTERTECH
İSTANBUL TEKNOKENT

FUTURE OF SURGERY
PATENT REPORT

INTRODUCTION

In the evolving landscape of surgical innovation, understanding the trajectory of technological advancements is crucial. This patent landscape report aims to provide insights into the future of surgery, as inferred from recent patent filings. Our focus is not on definitive predictions, but on discerning emerging trends and potential advancements that could shape surgical practices.

Surgery has undergone significant transformations, evolving through various phases of technological and methodological enhancements. In this report, we concentrate on a few key areas that are indicative of future trends: minimally invasive surgery, robot-assisted procedures, advanced data analytics, artificial intelligence (AI), and the integration of augmented (AR) and virtual reality (VR) in surgical settings.

These areas are chosen for their potential to minimize patient discomfort, enhance precision, and improve outcomes. Minimally invasive and robot-assisted techniques are particularly notable for their role in reducing recovery times and increasing surgical accuracy. Meanwhile, the integration of AI and data analytics promises to refine diagnostic and operative procedures, potentially leading to more personalized and effective treatments.

Additionally, augmented and virtual reality technologies are emerging as valuable tools for surgical training and real-time assistance during operations. While examining patents in these domains, we seek to provide a glimpse into the innovative approaches that may become more prevalent in future surgical procedures.

This report, through its exploration of patent data, aims to offer a nuanced perspective on the possible directions of surgical advancements, highlighting areas of innovation that could be pivotal in the coming years.

REPORT SEARCH METHOD

The methodology adopted for this patent landscape report on the future of surgery involved a structured and comprehensive approach to patent searching, focusing on revealing trends and advancements in surgical technology between 2014 and 2024. Our search strategy was twofold, beginning with a broad query followed by a more focused search incorporating specific keywords and classes relevant to our target areas.

Initial Broad Search

Our initial query was designed to capture a wide array of patents in the field of surgery. The search parameters were:

Keywords: "Surgery," "Invasive," "Surgical," "Operation"
International Patent Classification (IPC): A61B Class, "Diagnosis; Surgery; Identification"
Date Range: 2014 to 2024

This query returned a substantial number of results, totalling 192.685 documents.

The IPC A61B, which encompasses "Diagnosis; Surgery; Identification" served as a foundational category for our search, ensuring that the results were relevant to the medical and surgical domain.

Refinement with Specific Keywords and Classes

To home in on the specific areas of interest for this report, we refined our search by incorporating additional keywords and relevant IPC subclasses. These keywords and classes were chosen to align with the emerging trends in surgery: minimally invasive surgery, robot-assisted procedures, advanced data analytics, artificial intelligence (AI), and the integration of augmented and virtual reality (AR/VR) in surgical settings.

The refinement involved searching within the results of our initial broad query using the following criteria:

   • **Minimally Invasive Surgery:** Keywords such as "minimally invasive" "laparoscopic" "endoscopic"
   • **Robot-Assisted Procedures:** Keywords including "robot-assisted" "surgical robot" "robotic surgery".
   • **Advanced Data Analytics & Artificial Intelligence:** Keywords such as "data analytics" "machine learning" "AI" "predictive modelling"
   • **Augmented & Virtual Reality:** Keywords like "augmented reality" "virtual reality" "AR/VR".

This refined search was crucial in filtering the vast array of patents to those most relevant to our areas of interest. It enabled us to delve deeper into the nuances of each field, ensuring that our analysis was both comprehensive and focused.

RESULTS (Initial Broad Search)

Publication Date Trends: Our initial broad search in the patent landscape of surgery over the last decade-plus reveals a significant growth in patent filings, underlining the rapid advancement in surgical technologies and innovations. The distribution of patent documents by publication year is as follows:
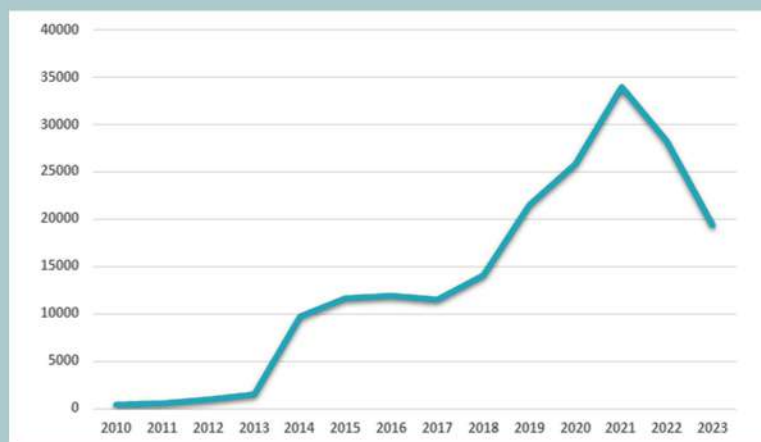
A notable surge (significant and consistent increase) in patent filings is observed from 2014, reaching a peak in 2021. This trend (upward trajectory) underscores an escalating interest and investment in developing new surgical technologies and procedures.

The observed decrease in the number of documents in 2023 may be attributed to the typical 18-month publication delay for patents from the time of application, indicating that more filings are still in the pipeline.

Geographic Distribution of Patent Applicants: The geographic distribution of patent documents offers a global perspective on the origins of innovation in surgical technology:

TOP 10 - Applicants (country)	Number of documents
USA	63327
South Korea	9706
Japan	8485
Switzerland	7095
China	4730
Russia	4368
Germany	4101
Puerto Rico	2445
Great Britain	2219
Canada	1993

The United States leads substantially in the number of documents, followed by South Korea, Japan and Switzerland indicating a strong focus on surgical innovation in these countries.

Top 20 Patent Applicants: A look at the top patent applicants provides insight into the key entities driving surgical innovation.

TOP 20 - Applicants	Number of documents
COVIDIEN LP	2701
ETHICON LLC	1863
ETHICON ENDO SURGERY	1377
OLYMPUS CORP	1318
CILAG GMBH INT	1222
FUJIFILM CORP	704
INTUITIVE SURGICAL OPERATIONS	557
HOSPITAL ZHENGZHOU UNIV	488
WEST CHINA HOSPITAL SICHUAN UNIV	464
UNIV ZHEJIANG	457
KONINKLIJKE PHILIPS NV	447
TYCO HEALTHCARE	441
UNIV JILIN	430
UNION HOSPITAL TONGJI MEDICAL COLLEGE HUAZHONG UNIV	429
SHANGHAI 9TH PEOPLES HOSPITAL SHANGHAI JIAOTONG UNIV	412
CANON KK	392
HOSPITAL QINGDAO UNIV	351
XIANGYA HOSPITAL CENTRAL SOUTH UNIV	348
CHINESE PLA GENERAL HOSPITAL	336
HOSPITAL MEDICAL COLLEGE XIAN JIAOTONG UNIV	332

These top applicants range from specialized medical companies to educational institutions and hospitals, illustrating a diverse landscape of entities engaged in surgical innovation.

A remarkable observation from the data is the significant number of patent filings from **Puerto Rico***, which is primarily influenced by the activity of Ethicon. Specifically, some patents filed by Ethicon LLC and Ethicon Endo Surgery are attributed to their Puerto Rico-based company,* **Ethicon Endo Surgery LLC.** *Founded in 2005 and located in Guaynabo, Puerto Rico, this entity specializes in the design, development, and distribution of surgical equipment such as endoscopic cutters, clip appliers, endoscopic access device systems, breast biopsy devices, and sedation delivery systems. This substantial contribution highlights the importance of Ethicon's innovations in the global surgical patent landscape and explains Puerto Rico's notable presence in the data.*

RESULTS (Minimally Invasive Surgery)

In our continued effort to delve deeper into the innovations within Minimally Invasive Surgery, we have expanded our patent search with additional keywords.

The query was structured to capture a broad spectrum of MIS-related innovations, using a combination of keywords and IPC classifications. The enhanced query includes:

Extended Keywords: "Minimally," "Laparoscopic," "Laparoscopy," "Endoscopic," "Endoscopy," "Keyhole," "Laparoendoscopic," "Arthroscopic."

IPC Classification: A61B, which pertains to diagnosis, surgery, and identification.

Date Range: 2014 to 2024.

This search strategy was designed to provide a comprehensive overview of the patents in the realm of minimally invasive surgical techniques, instruments, and methodologies.

Publication Date Trends: The data from the focused search on Minimally Invasive Surgery (MIS) demonstrates a clear trend in patent activity over the past decade-plus:
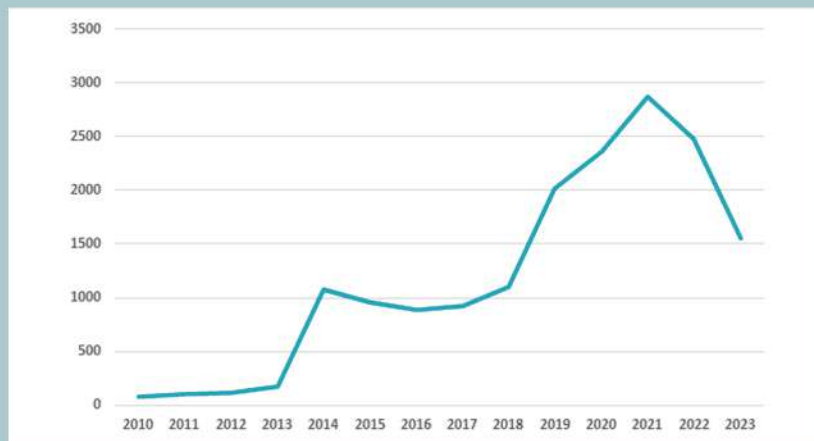
This timeline indicates a substantial increase in patent filings related to Minimally Invasive Surgery (MIS) starting from 2014, with a peak in 2021. The drop in 2023 aligns with the typical patent publication delay and does not necessarily reflect a decrease in innovation or filings.

Geographic Distribution of Patent Applicants: The global landscape of Minimally Invasive Surgery (MIS) innovation is diverse, with the United States leading in the number of patent filings:

Top 10 - Applicants (country)	Number of documents
USA	7241
South Korea	896
Russia	655
Japan	609
China	576
Germany	356
Switzerland	330
Israel	284
Netherlands	186
Canada	159

This distribution underscores the United States' dominant role in surgical innovation, with significant contributions from South Korea, Russia, Japan, and China.

Top 10 Patent Applicants: Examining the top entities in Minimally Invasive Surgery (MIS) patent filings reveals both industry leaders and innovative institutions:

Top 10 – Applicants (company)	Number of documents
COVIDIEN LP	260
INTUITIVE SURGICAL OPERATIONS	117
OLYMPUS CORP	101
CHENGDU BORNS MEDICAL ROBOTICS INC	93
FUJIFILM CORP	84
UNIV ZHEJIANG	79
BOSTON SCIENT SCIMED INC	61
SHANDONG WEIGAO SURGICAL ROBOT CO LTD	59
UNIV JILIN	53
UNIV TIANJIN	52

These top applicants include a mix of medical device companies, universities, and institutions, highlighting a dynamic field with contributions from various sectors.

PATENT ANALYSIS (Minimally Invasive Surgery)

US11844497B2 - Systems and Methods for Object Measurement in Minimally Invasive Robotic Surgery

Overview: The patent **US11844497B2**, filed by **COVIDIEN LP**, focuses on a computer-implemented method for enhancing object measurement in minimally invasive robotic surgery. It details a system that captures images of objects at a surgical site and accurately determines and displays their sizes.

Key Features

   • **Advanced Imaging Technique:** This system uses an imaging device to capture and display images of an object within a surgical site.

   • **Size Determination Method:** The size of the object is calculated based on the geometry of a surgical instrument in the image, the depth of pixels, and the relative positions of the instrument in different frames.

   • **Enhanced Visualization:** The system displays the captured image along with a graphical representation of the object's determined size, aiding surgeons in making precise assessments during surgery.

Significance

This patent is significant for its contribution to minimally invasive surgery, where accurate measurement of objects within the surgical site is crucial. The method improves upon traditional techniques by providing enhanced visualization and measurement directly within the surgical view, potentially increasing the precision and safety of surgical procedures. The use of advanced image processing techniques, such as neural networks, for size determination, demonstrates an innovative blend of technology and medical expertise, pushing the boundaries of what's possible in robotic-assisted surgeries.

US10646293B2 - Laparoscopic Ultrasound Robotic Surgical System

Overview: The **US10646293B2** patent, filed by **INTUITIVE SURGICAL OPERATIONS and UNIV JOHNS HOPKINS,** introduces a Laparoscopic Ultrasound (LUS) robotic surgical system that enhances minimally invasive surgical procedures. This system allows a surgeon to train it to automatically control the movement of an LUS probe, eliminating the need for manual adjustments during surgery. It captures a sequence of 2D ultrasound image slices, processes them into a 3D computer model of an anatomic structure, and displays it as an overlay to assist the surgeon. Virtual fixtures can also be defined to guide surgical tools accurately based on the ultrasound image.
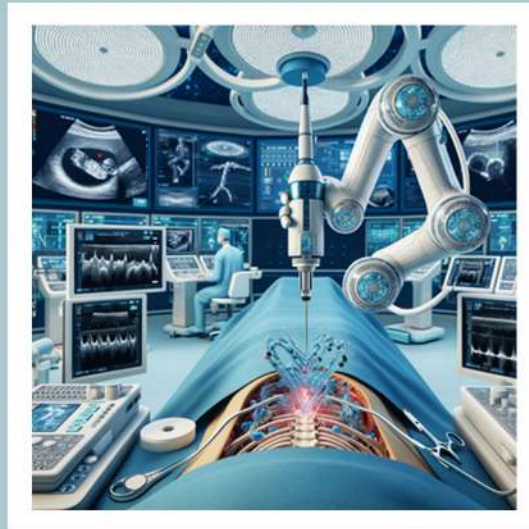
Key Features

- **Robotic Assistance:** The system incorporates a robotic arm to control the movement of the ultrasound probe, reducing the surgeon's manual workload.
- **Image Processing:** It captures and processes 2D ultrasound image slices into a 3D model of the anatomic structure.
- **Enhanced Visualization:** The 3D model can be displayed as an overlay on a camera view or Picture-in-Picture (PIP) mode, aiding the surgeon in inspecting anatomic structures for abnormalities.
- **Ultrasound Probe Flexibility:** The ultrasound probe is designed with an ultrasound sensor, an elongated shaft, and a wrist mechanism allowing pitch and yaw movements for optimal imaging.

Significance

This patent represents a significant advancement in the field of minimally invasive surgery. By automating the movement of the LUS probe and providing a 3D overlay of anatomic structures, it enhances the precision and safety of surgical procedures. The ability to define virtual fixtures and control the probe's orientation adds a new level of versatility to robotic-assisted surgery. This innovation is poised to make minimally invasive surgery even more accessible and effective.

US10213223B2 - Arthroscopic Surgery Method for Ankle Ligament Reconstruction

Overview: This patent, filed by **OLYMPUS CORP**, describes an arthroscopic surgery method for ankle ligament reconstruction using an ultrasonic treatment tool. The method involves removing a synovial membrane, securing a view for a remnant ligament, and then creating bone holes in the fibula, talus, and calcaneus. The ultrasonic treatment tool with specific projections is utilized to achieve these surgical steps.
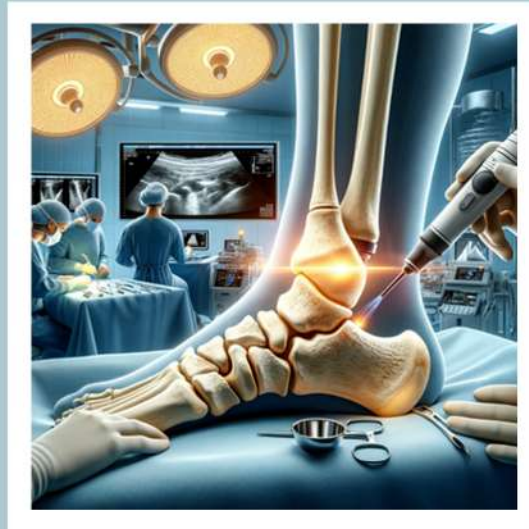
Key Features

- **Ultrasonic Treatment Tool:** The method employs an ultrasonic treatment tool with a probe that transmits ultrasonic vibration and a treating portion on its distal end. This treating portion includes various projections for specific purposes.
- **Guide Hole Formation:** The method involves forming guide holes in the fibula, talus, and calcaneus.
- **Projection Insertion:** The first projection of the ultrasonic treatment tool is inserted into the formed guide hole.
- **Bone Hole Creation:** The first projection, along with a plurality of second projections that output ultrasonic vibrations, is moved along the guide hole. This process creates bone holes in the fibula, talus, and calcaneus.
- **Tendon Fixation:** After forming the bone holes, the method includes fixing a tendon to these holes, facilitating ankle ligament reconstruction.

Significance

This patent introduces a method for ankle ligament reconstruction that utilizes ultrasonic technology to create bone holes with precision. The ability to remove a synovial membrane, secure the view for the remnant ligament, and then form bone holes in the fibula, talus, and calcaneus offers potential benefits in ankle surgery. The use of ultrasonic treatment tools enhances surgical accuracy and reduces the manual effort required for these procedures.

RESULTS (Robot-Assisted Procedures)

The following results provide an overview of patent activity related to Robot-Assisted Procedures in the field of surgery and medical technology.

Publication Date Trends: The data demonstrates a significant trend in patent activity in the field of Robot-Assisted Procedures over the past decade-plus. The number of patent documents published each year is as follows:
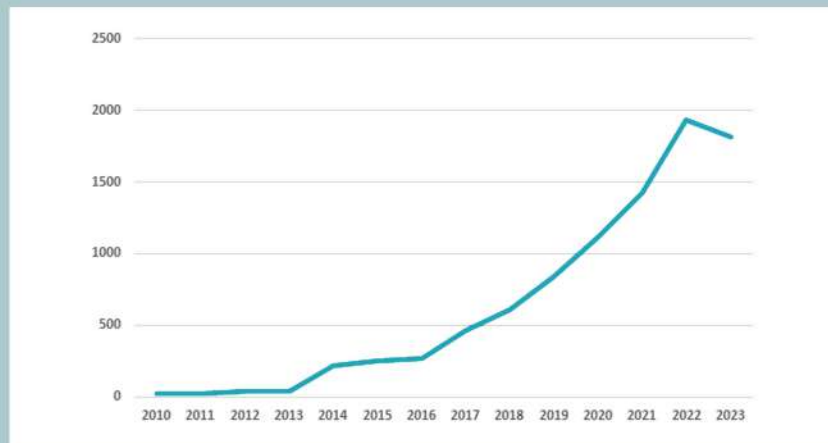
This timeline reflects a substantial increase in patent filings related to Robot-Assisted Procedures, with a peak in 2022. The decrease in 2023 is likely due to the typical patent publication delay rather than a decline in innovation or filings.

Geographic Distribution of Patent Applicants: The global landscape of Robot-Assisted Procedure innovation is diverse, with several countries actively participating in patent filings. The top countries involved in these patent filings are as follows:

Top 10 - Applicants (Country)	Number of documents
USA	5839
China	787
South Korea	567
Great Britain	556
Switzerland	498
Japan	399
Canada	276
Germany	258
Israel	224
France	180

These statistics highlight the United States as a dominant force in surgical innovation, with significant contributions from countries like China, South Korea, Great Britain, and others.

Top 10 Patent Applicants: The top entities leading in Robot-Assisted Procedure patent filings include a mix of medical device companies, research institutions, and innovative organizations. The leading companies or entities, along with the number of documents filed, are as follows:

Top 10 – Applicants (Company)	Number of documents
COVIDIEN LP	304
ETHICON LLC	168
CILAG GMBH INT	139
SHANGHAI MICROPORT MEDICAL ROBOT GROUP CO	139
CMR SURGICAL LTD	130
VERB SURGICAL INC	130
GLOBUS MEDICAL INC	126
INTUITIVE SURGICAL OPERATIONS	126
SHENZHEN JINGFENG MEDICAL TECH CO LTD	126
CHENGDU BORNS MEDICAL ROBOTICS INC	122

These leading entities represent a dynamic landscape of innovation in Robot-Assisted Procedures, contributing to advancements in the field of surgery and medical robotics.

This part provides valuable insights into the patent activity surrounding Robot-Assisted Procedures, highlighting the growth, geographic distribution, and key players in this innovative field.

PATENT ANALYSIS (Robot-Assisted Procedures)

US11607278B2 - Cooperative Robotic Surgical Systems

Overview: The patent, filed by **ETHICON LLC** and **CILAG GMBH INT**, describes a cooperative robotic surgical system consisting of two automated surgical systems that can work together. The first system includes a user control console, a robotic actuator, and a surgical system controller with a processor and memory. The second system mirrors the first and is connected through a communication interface. The second system can be controlled through the user control console of the first system.

Key Features

   • **Dual Robotic Systems:** The patent presents a system with two automated surgical systems, each with its user control console, robotic actuator, and controller.

   • **Communication Interface:** Both systems are connected through a communication interface, enabling them to share information and work collaboratively.

   • **Wireless/Wired Communication:** The communication interfaces can be either wireless or wired, providing flexibility in communication methods.

   • **Data Transfer:** The patent describes the transfer of data from one system to the other, allowing for control and coordination of functions.

   • **Sensor Integration:** The first system incorporates sensors in data communication with its processor, enhancing its capabilities.

Significance

The cooperative robotic surgical system outlined in this patent offers the potential for enhanced surgical procedures. With two robotic systems working together and sharing information, complex surgeries can be conducted with greater precision and control. The integration of sensors further improves the system's ability to adapt to different surgical scenarios.

US11819300B2 - Robotic Surgical System and Method

Overview: This patent, filed by **GLOBUS MEDICAL INC**, presents a robotic surgical system and method for performing robotically assisted surgery that involves the precise removal of hard or non-fibrous tissues during a surgical procedure while preserving soft tissues. The system employs a multi-axis robot with a reciprocating tool that can be controlled via a computer or telemanipulator. Radiopaque fiducial points are used for alignment, and real-time imaging is employed to guide the surgical process.
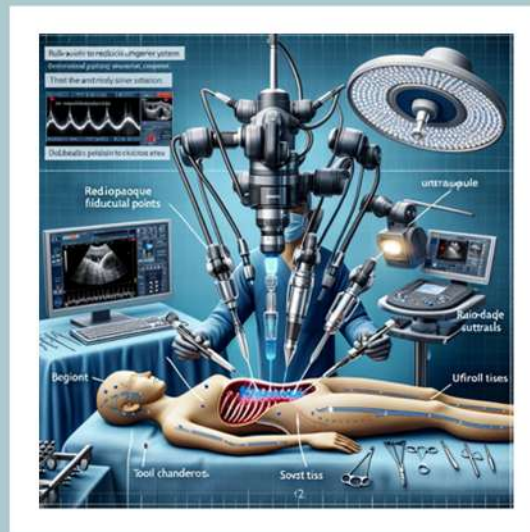
Key Features

- **Multi-Axis Robot:** The patent introduces a multi-axis robot with interconnected arms, including a distal arm equipped with a tool holder capable of retaining surgical tools and an ultrasound probe.
- **Radiopaque Fiducial Points:** The method involves securing radiopaque fiducial point devices to the patient to aid in alignment and positioning during surgery.
- **Real-Time Imaging:** Real-time ultrasound imaging is utilized to provide continuous visual feedback during surgery.
- **Tool Changer:** A tool changer allows for the securement of various surgical tools to the robot's tool holder, enhancing versatility during procedures.
- **Alignment and Overlays:** The patent describes the alignment of images and overlays of various images, including real-time images, for surgical guidance.

Significance

This patent introduces an advanced robotic surgical system and method that combines real-time imaging with a multi-axis robot to perform precise surgeries involving the removal of hard tissues while sparing soft tissues. The ability to change surgical tools during the procedure enhances adaptability. This technology has the potential to improve surgical outcomes and expand the reach of skilled surgeons, allowing them to operate remotely if needed.

RESULTS (Augmented & Virtual Reality)

In this section, we explore the intersection of cutting-edge technologies, including Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), and the domain of Surgery and Invasive Medical Procedures. Our focus is on uncovering how these immersive technologies have been harnessed in the field of surgery and invasive medical procedures.

Publication Date Trends: The timeline below illustrates the number of patent documents related to the intersection of Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), and Surgery and Invasive Medical Procedures published each year from 2010 to 2023. Notably, there has been a steady increase in patent activity in recent years, reflecting the growing utilization of immersive technologies in the medical field.
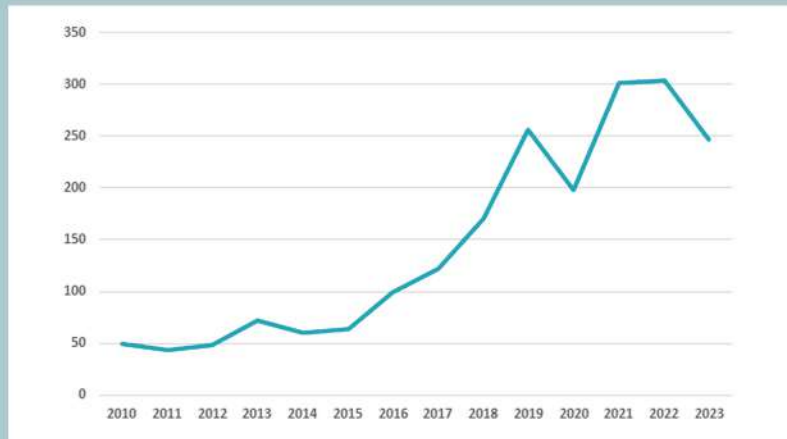
Geographic Distribution of Patent Applicants: The global landscape of patent applicants in the domain of Augmented and Virtual Reality in Surgery and Invasive Medical Procedures is diverse, with several countries actively participating in patent filings. The top countries involved in these patent filings are as follows:

Top 10 - Applicants (Country)	Number of documents
USA	1769
South Korea	381
Canada	137
Switzerland	127
Japan	124
Germany	96
China	88
Israel	69
Netherlands	68
Taiwan	66

These statistics highlight the United States as a prominent leader in innovating the intersection of AR, VR, and XR with Surgery and Invasive Medical Procedures, with significant contributions from countries such as South Korea, Canada, Switzerland, and others.

Top 10 Patent Applicants: The leading entities driving innovation in the field of Augmented and Virtual Reality for Surgery and Invasive Medical Procedures include a mix of medical device companies, research institutions, and innovative organizations. The top companies or entities, along with the number of documents filed, are as follows:

Top 10 – Applicants (Company)	Number of documents
MAKO SURGICAL CORP	34
COVIDIEN LP	32
INTUITIVE SURGICAL OPERATIONS	21
HUTOM CO LTD	20
KONINKLIJKE PHILIPS NV	20
GLOBUS MEDICAL INC	16
CILAG GMBH INT	15
FUJIFILM CORP	15
VERB SURGICAL INC	14
STRYKER CORP	12

These leading entities represent a dynamic landscape of innovation, leveraging AR, VR, and XR technologies to advance the field of Surgery and Invasive Medical Procedures. Their contributions contribute to the ongoing transformation of medical practices.

This part offers valuable insights into the evolving landscape of Augmented and Virtual Reality within the domain of Surgery and Invasive Medical Procedures. It reflects the increasing integration of immersive technologies, the global distribution of innovation, and the key players driving progress in this innovative field.

PATENT ANALYSIS (Augmented & Virtual Reality)

US2021093400A1 - Surgical Guidance System with Virtual Models

Overview: This patent, filed by **MAKO SURGICAL CORP**, presents a surgical guidance system with virtual models designed to assist in surgical procedures. The system involves several key components and operations, including generating anatomical models from patient anatomy, proposing virtual surgical components, tracking surgical instruments and anatomical features, and displaying relevant information on a screen. The system aims to improve surgical precision and planning.
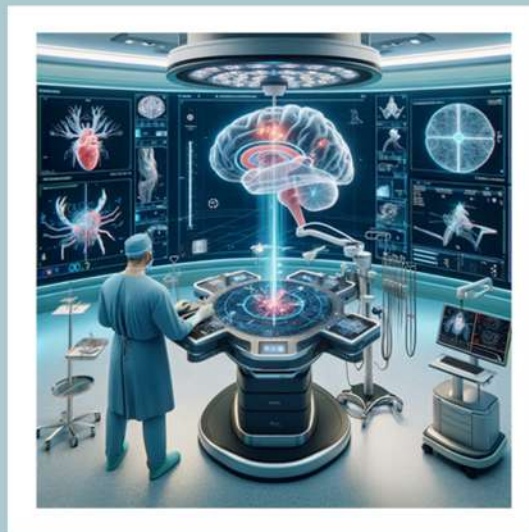
Key Features

- **Anatomical Model Generation:** The patent describes a method for generating anatomical models based on a patient's anatomy.
- **Virtual Surgical Components:** The system allows for the selection and placement of virtual surgical components on the anatomical model.
- **Surgical Instrument Tracking:** The patent includes the tracking of both surgical instruments and anatomical features.
- **Real-Time Display:** A significant aspect of this system is the real-time display of relevant information. It simultaneously displays the planned resection geometry, the anatomical model, and a graphic corresponding to the surgical instrument.

Significance

The patent introduces a surgical guidance system that leverages virtual models and real-time tracking to enhance surgical procedures. By generating anatomical models and allowing the placement of virtual surgical components, surgeons can plan and visualize surgeries with greater precision. Real-time tracking and display of instruments and anatomical features provide critical feedback during the surgery, potentially leading to improved outcomes.

US11413099B2 - System, Controller, and Method Using Virtual Reality Device for Robotic Surgery

Overview: This patent, filed by **KONINKLIJKE PHILIPS NV**, presents a control unit for a surgical robot system that leverages virtual reality (VR) technology to enhance robotic surgery. The system includes a robot, a VR device (such as a head-mounted display), and a control unit. It enables real-time transmission of patient images to the VR device, tracks user input and head/eye movements, and assists in guiding a surgical instrument to a target within the patient's body.
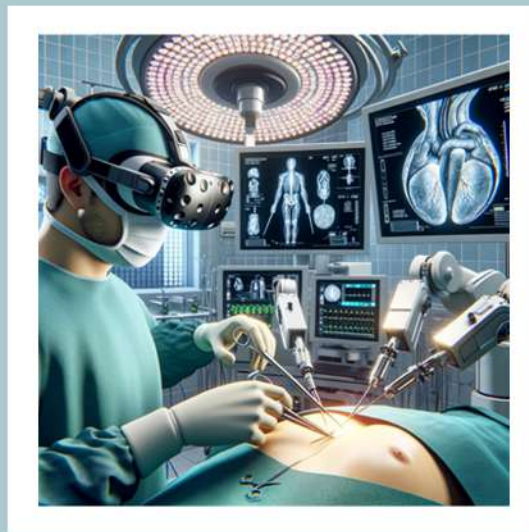
Key Features

- **Anatomical Image Transmission:** The patent describes a method for transmitting acquired live images of a patient to a VR device for display on a viewer.
- **VR User Input:** It allows for receiving input data from the VR device, including tracking data based on a user's response to the displayed patient images.
- **Path Determination:** The system processes input data and acquired images to determine or select a path for the surgical instrument operated by the robot.
- **Robot Control:** It transmits control signals to guide the robot's surgical instrument to the target based on the determined path.

Significance

This patent introduces a novel approach to robotic surgery by integrating VR technology. By providing surgeons with live patient images in a VR environment and tracking their movements, it enhances precision and allows for real-time adjustments during surgery. Surgeons can visualize and plan surgical procedures with greater accuracy, potentially leading to improved outcomes.

US11607277B2 - Registration of Surgical Tool with Reference Array Tracked by Cameras of an Extended Reality Headset for Assisted Navigation During Surgery

Overview: This patent, filed by **GLOBUS MEDICAL INC,** introduces a camera tracking system designed for computer-assisted navigation during surgery. The system utilizes an extended reality (XR) headset with tracking cameras to identify a reference array attached to surgical tools. It determines if the reference array is registered with characteristics of a surgical tool in a database. If unregistered, the user can select the tool and register it through hand gestures. The system then provides a representation of the tool's characteristics on the XR headset's display.

Key Features

- **Automatic Registration:** The system initiates a registration process when a reference array enters the field of view of tracking cameras on an XR headset.
- **Identification and Pairing:** It identifies the reference array and checks if it's paired with a surgical tool's characteristics in the database.
- **User Selection:** If unregistered, it presents a list of surgical tools for the user to select from using hand gestures.
- **Representation Display:** After registration, it displays a representation of the selected tool's characteristics on the XR headset's display.

Significance

This patent offers a novel approach to enhance surgical navigation using XR technology. Surgeons can easily register and visualize surgical tools in real-time through an XR headset, improving precision and efficiency during surgery. The use of hand gestures for tool selection adds a user-friendly aspect to the system's interface, potentially contributing to better surgical outcomes.

CONCLUSION

The comprehensive analysis of the patent landscape in the realm of surgical innovation, particularly from 2014 to 2024, reveals a clear and dynamic trajectory of technological advancements. This report has delved into various emerging trends and potential advancements in key areas like minimally invasive surgery, robot-assisted procedures, advanced data analytics, artificial intelligence (AI), and the integration of augmented (AR) and virtual reality (VR) in surgical settings. The findings highlight a significant shift towards technologies that aim to minimize patient discomfort, enhance surgical precision, and improve overall outcomes.

One of the most striking trends is the marked growth in patent filings, with a peak observed in 2021, indicating a robust and continuous investment in developing new surgical technologies. Geographically, the United States has emerged as a leader in surgical innovation, with substantial contributions from other countries like South Korea, Japan, and Switzerland. This global spread of innovation underscores the worldwide focus on enhancing surgical practices.

Moreover, the involvement of various entities, ranging from medical companies to educational institutions, reflects a multi-dimensional approach towards surgical innovation. This collaborative effort between different sectors is driving forward the boundaries of what is possible in surgical procedures.

KEY FINDINGS

- **Minimally Invasive Surgery (MIS):** There has been a substantial increase in patent filings related to MIS, suggesting a strong shift towards less invasive surgical approaches. The technologies focused on enhancing imaging techniques, precision in size determination, and incorporating advanced tools like ultrasonic devices for specific surgical applications such as ankle ligament reconstruction.

- **Robot-Assisted Procedures:** A significant rise in patents related to robot-assisted surgeries indicates the growing importance of robotics in the surgical field. Innovations like cooperative robotic systems and advanced robotic surgical methods underscore the potential for these technologies to revolutionize surgery by enhancing precision, control, and safety.

- **Augmented & Virtual Reality:** The integration of AR and VR in surgical settings is a burgeoning field, as evidenced by the steady increase in patent activity. These technologies are being leveraged to improve surgical planning, guidance, and training. The use of VR for robotic surgery control and XR technology for enhanced surgical tool navigation marks a significant leap in surgical methodology.

- **Geographical and Entity-Specific Contributions:** The US leads in innovation, but significant contributions are also observed from countries like South Korea, Japan, and Switzerland. Top entities such as COVIDIEN LP, ETHICON LLC, and INTUITIVE SURGICAL OPERATIONS play pivotal roles in driving surgical advancements.

- **Technological Convergence:** There is a notable trend towards the convergence of various technologies, such as AI, data analytics, and imaging techniques, within surgical innovations. This convergence is setting the stage for more integrated, efficient, and patient-centric surgical procedures in the future.

In conclusion, the future of surgery is poised to be significantly influenced by these technological advancements. The trends identified in this report not only offer insights into the current state of surgical innovation but also provide a window into the future, where surgeries are more precise, less invasive, and increasingly augmented by advanced technologies. This evolution in surgical practices promises to enhance patient outcomes and redefine the standards of medical care.