Intracranial stereotactic navigation

COST ANALYSIS AND PATIENT OUTCOMES REVIEWED

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Introduction

Intracranial neoplasms or brain tumors comprise only a small percentage of the growths that are seen in patients. Surgery to diagnose and treat brain tumors can be quite involved for both the patient as well as the personnel involved in the operation itself. The traditional means of operating on intracranial neoplasms was that of a craniotomy, which involves removing and replacing a section of the skull. This surgery, although at most times routine, has become less and less frequent. In this day of micro technology and computers, surgeons are looking to "build a better mousetrap." Also, in an environment of increased health care costs, lowered reimbursement for the surgeons, and hospitals that are cracking down on lengthy surgical procedures, stereotactic navigational surgery has become an accepted modality in neurosurgical practice.

Minimally invasive surgery has become the standard of care for the surgical patient. Whether it is a gallbladder that is being removed or the resection of a colloid cyst of the third ventricle in the brain, the goals are the same: to provide the patient with a treatment of the disease or the slowing of its symptoms, minimize the surgical risk involved, preserve the normal anatomy, and most importantly, promote a rapid recovery so the patient can return to work and family. The use of stereotactic navigation in the realm of neurosurgery provides the patient and the surgeon a means of achieving these goals.

Several years ago, a patient being treated with craniotomy for a tumor was informed about the risks involved. These risks sometimes outweighed the benefit of having the surgery. With the recent advances in stereotactic navigation, the neurosurgeon is able to operate on the more refined areas of the brain with greater precision, while reducing morbidity.

Review of literature

Kelly stated that, "The stereotactic surgery of the future may employ all or a combination of the following technologies: frameless stereotactic surgery, robotic technology, microrobotic dexterity enhancement, and telepresence robotics."[7] This statement has never been more true. Although surgery is several years away from robots taking the place of skilled surgeons operating on fragile areas of the brain, there are other devices that are in the surgeon's arsenal to enhance the patient's outcome from a potentially life-threatening surgery.

Bhardwaj and Bernstein surveyed the practicality of performing a brain biopsy using a framed-based stereotaxis system from a financial and patient satisfaction standpoint.[1] For a period of five years, from August 1996 to August 2001, the study was conducted on a total of 76 patients. The group was broken down into gender, with 41 female and 35 male patients. The mean age of the group was 56.9 years of age, with ages ranging from 18 to 86 years.[1] A stereotactic ring was secured to the patient's head using local anesthetic. The patient underwent a non-ionic contrast, computerized tomographic scan of the head and frame. These images were then used to guide the biopsy needle into the area of concern. The biopsy procedure itself was carried out in the operating room using standard sterile technique. The skull was penetrated using a standard 7 mm burr hole. A biopsy needle was then introduced into the brain and a section of tissue was removed. One tissue sample was routinely obtained. At the completion of the procedure, the patients were transferred to the recovery room, where they were closely monitored by the nursing staff. After a total of four hours of observation, the surgeon assessed and approved the patient for discharge.[1]

The most commonly diagnosed lesions were that of glioblastoma multiforme (35 patients). Other forms of brain cancer and infections comprised the rest of the pathological findings (41 patients). Bhardwaj and Bernstein also reported the most common site of surgery was that of the frontal lobe.[1] The success rate of the study was 97.4%. Out of the 76 patients operated on, two patients were not discharged from the hospital because the biopsy procedure itself could not be performed, and the patients underwent extended observation and further investigation.[1]

The authors reported two complications among the study group. One patient with a deep-seated glioma had degeneration of neurological status. Another patient developed an intraventricular hemorrhage as a complication of the procedure. Both of these patients were still discharged on the day of surgery.[1]

The cost analysis was carried out using a software program. The original figures are in Canadian dollars, with US equivalents listed in parentheses.[10] At the institution where the surgeries were performed, the cost of a one-night stay in the intensive care unit is $2,400 CAD ($1,757 USD). The cost of a night's stay in a neurosurgical step-down unit is $1,800 CAD ($1,318 USD). Finally, the cost of a home-care nurse visit is roughly $60 CAD ($44 USD). The current trend for a brain biopsy is for a patient to spend one night in the neurosurgical intensive care unit or step-down bed before being discharged. There-

Definitions of terms

Brain shift. A slight shift in brain position caused by gravity acting on the brain after the skull is opened. The forces of gravity act upon the brain itself by pulling it toward the ground. This, combined with the aspiration of cerebrospinal fluid, allows the brain to relax.

Collimation: The radiological method shaping and confining the X-ray beam to a given area based on the patient's tumor.

Ferromagnetic: Relating to or demonstrating the magnetic attraction of iron containing materials.

Fiducials. Special stickers impregnated with barium sulfate that create a radiopaque markers on the patient's skull. These stickers take the place of a frame being bolted to the patient's head.

Glioblastoma multiforme: A type of brain tumor that forms from glial (supportive) tissue of the brain. It grows very quickly and has cells that look very different from normal cells.

Intracranial: Pertaining to inside the cranial vault.

Pallidotomy: A surgical procedure in which a part of the brain, called the globus pallidus, is lesioned in order to improve symptoms of tremor, rigidity, and bradykinesia. A pallidotomy is a surgical procedure where a needle is guided into the area of the brain that controls fine motor movement and a lesion is literally burned into the patient's brain, thus stopping the transmission of damaged signals to the extremities.

Radiosurgery: A technique for treating inoperable brain cancers; a CT scan is used to locate the tumor, which is then bombarded with precise, high doses of radiation.

Sella turcica: The bony structure that houses the pituitary gland.

Stereotactic: A radiation therapy technique involving a rigid head frame that is attached to the skull; high-dose radiation is administered through openings in the head frame to the tumor while decreasing the amount of radiation given to normal brain tissue.

Transsphenoidal: Through the sphenoid bone.

fore, the average savings of a strictly outpatient approach to stereotactic brain biopsies range from $1,740 CAD ($1,274 USD) to $2,340 CAD ($1,714 USD).[1]

Bohinski et al reported on the use of magnetic resonance imaging (MRI) to aid in the resection of glial cell brain tumors. The system utilized in the study was that of a Hitachi vertical field open MRI scanner. The scanner was located adjacent to the operating suite.[2] Although the cost of the scanner was not disclosed in the report, it can be said with confidence that a scanner of this capacity costs in the area of $1 to $1.5 million, with the building of a MRI-safe operating room and equipment adding $3 to $4 million to the price tag.

Bohinski's study stated that, after removal of all visible tumor by the neurosurgeon, the dura mater, skull, and scalp were loosely approximated and covered with a sterile drape. The patient was then transferred to the MRI scanner where the head was fixed in the scanner.[2] Contrast enhanced images were then obtained. Although total scan time of the patient varied, due to various imaging needs, the mean scanning time reported was that of 16 minutes.[2] If the area of resection was satisfactory to the neurosurgeon's expectations, the skull was closed primarily in a standard fashion in the MRI suite. However, if more resection was required, the patient could then be brought back into the operating room.[2]

The accuracy of the MRI scans was quite impressive. Out of a total of 40 patients, 15% of the scans obtained were indistinct and unusable.[2] Materials in the room and on the patients themselves had interfered with the quality of the magnetic images. These scan-altering objects were removed, and the patient was rescanned.

In the study group, 53% of the patients required additional resection of the mass, and 12.5% of the patients in the group had worsening of neurological symptoms, with one patient who expired due to an unrelated air embolus in the pulmonary artery.[2]

Even though the neurosurgical community has received great criticism for the use of the intraoperative MRI, Bohinski's group argues the importance of it. They state that, "one of the goals of our MROR (Magnetic Resonance Operating Room) design was to incorporate sufficient flexibility so that other practitioners (those referring patients for diagnostic imaging or those interested in developing peripheral interventions for other organ systems) could use the MRI center routinely."[2]

Although the primary use of the MRI was for neurosurgical applications, other specialties could subsequently utilize the scanner for their own purposes. They also state the implementation of guidelines for a less expensive route of treating certain types of brain tumors before proceeding to employ the use of the MRI.

Eskandar et al headed a long-term study of 1,761 patients diagnosed with Parkinson's disease that were treated stereotactically from 1996 to 2000. The surgical intervention for this study was performed at 71 different hospitals by 61 various neurosurgeons.[3] Functional neurosurgical treatment varied from patient to patient. Sixty percent of the group studied received a stereotactic pallidotomy. A similar procedure, a thalamotomy, was performed on 6% of the group.[3]

Deep brain stimulators, a pacemaker for the brain, were implanted in 33% of the study group. This newer, less invasive treatment has become the gold standard of care of patients with Parkinson's disease. A reference frame was bolted to the patient's skull, and the frame and the skull were then scanned together to aid the neurosurgeon in placement of the electrodes deep in the subcortical regions of the brain responsible for motor movement.[3]

The mean age of the patients surveyed was 64 years, with ages ranging from 57 to 72 years. The complication rate was reported at 1.8% with subdural hematomas comprising 0.5% of the reported complications. There were four deaths reported within the group comprising 0.7% of the complications.[3] Deaths only occurred in institutions where the procedure is rarely performed. This is due to superior intra- and postoperative care in institutions that are familiar with the procedure, compared to that of an institution which performs one to two of these surgeries a year.

Cost analysis of the various procedures has been reviewed. The average length of stay of the patients was reported at two days.[3] Cost comparison was executed between the three types of stereotactic surgery surveyed. Deep brain stimulation (DBS) showed an increased cost because the cost of the device that is implanted into the patient is quite expensive. The total cost for DBS was $35,700, compared to the lesion generating procedure at a mean cost of $14,300.[3]

Hadani et al report on a new, innovative intraoperative MRI scanner, built specifically for intracranial neuronavigation. This MRI scanner, which conveniently fits under the operating room table, thus eliminating the need for transport of the patient to an MRI suite for imaging, is controlled by a neurosurgeon present in the sterile field.[4]

Although the MRI unit can be utilized in any existing operating room, some modifications must be undertaken to ensure the safety and quality of the patient and images respectively. Nonferromagnetic equipment, such as anesthesia machines and microscopes, that must be present in the room, are moved far enough from the magnet as to not to be drawn toward it. Standard surgical instrumentation may be utilized. However, MRI safe instrumentation is preferred because of the time and the traffic involved with moving the instruments to a safe location within the room. Copper shielding was placed behind the walls and ceiling of the operating suite to eliminate any radio frequency interference from the rest of the surgical services department.[4]

The navigational portion of this scanner is rather simple. A sterile wand is supplied with the system to locate the position of the resec-

FIGURE 1

The StealthStation® guides the surgeon through the process of acquiring data for navigation.

Image provided by Medtronic, Inc

tion margins in relation to the images acquired throughout the surgical procedure in real time. These images are viewed on a liquid crystal display (LCD) monitor in three planes: axial, coronal, and sagittal.[4]

Of the 20 patients included in the Hadani group study, 14 of the surgeries were craniotomies for tumor removal and six were transsphenoidal approaches to the pituitary gland. For the tumor removal group, the intraoperative MRI scan demonstrated the remaining tumor within the brain. This enabled the surgeons to remove the entire residual tumor seen by the MRI scan. Concerning the pituitary surgery, Hadani utilized the MRI navigation to aid the placement of the surgical speculum and instrumentation through the sphenoid and within the sella turcica. In addition, overall removal of the tumor was confirmed with the aid of the intraoperative MRI unit.[4]

As with any new piece of equipment, there is a learning curve associated with its use. This is especially true with this intraoperative MRI scanner. As the surgical team becomes more comfortable with the use of the equipment, the preparation and operative time is decreased. Hadani's study reported the average scan time added to the operative time was from 3.5 to 7 minutes.[4] No complications were reported with the use of the system.

Jane, Thapar, Alden, and Laws describe the use of a frameless stereotactic system to aid the surgeon into the sella turcica for a transsphenoidal resection of a pituitary gland tumor. The system used, the StealthStation® navigational system with FluoroNav™ virtual fluoroscopy system software, is manufactured by Medtronic Sofamor Danek. The system utilizes fluoroscopic images taken in the operating room to aid in navigation around the bony structures it has scanned. A relatively inexpensive system in comparison to others on the market, the system is easy to set up. The computer guides the surgeon systematically through the process of acquiring and manipulating the images received to create data that is useful to navigation. Utilizing the fluoroscope, information is relayed to the computer via a cable system. These images are registered to the patient using a reference arc mounted close to the skull.

A study group was created from 20 patients treated using this navigational system on 10 procedures and using standard fluoroscopy on the remaining 10 patients.[5] The average age of the patients in the group was 37.7 years. The types of tumors that were removed were, most commonly, pituitary adenomas and craniopharyngiomas. The mean set-up time compared between the groups was not noteworthy. FluoroNav surgeries were reported to be seven minutes longer than the standard fluoroscopic procedure.[5] Interestingly, the image-guided surgery times were 18 minutes faster than the traditional navigation. The accuracy of the system was also reviewed. Not one single imaged guided surgery had to be converted to a standard surgery. No complications were reported.[5]

The charges for billing were not significant between the two groups studied. The imaging guided platform added a cost of $310 per patient in operative time.[5] Another cost comparison was performed between the FluoroNav and CT-guided frameless stereotaxy. The total cost of utilizing FluoroNav was reported at $324.10. The cost of using a frameless stereotactic system was determined to be $1,066.68.[5] This difference is due to the technical fee charged for using the computerized tomography scanner, the radiologist fee, and the increased set-up time in the operating room.

Kaakaji et al studied the potential consequences of stereotactic brain biopsy patients who were discharged early from the hospital. Utilizing the ViewPoint frameless navigational system, 139 patients were treated from January 1996 through July 1998. The mean age of the patients was 53 years. Each patient received a CT scan of the brain to assess any problems that may have arisen after biopsy. After the scan was cleared, the patients were then transferred to a nursing unit where they were observed for one day and then discharged.[6]

One of the goals of our MROR (Magnetic Resonance Operating Room) design was to incorporate sufficient flexibility so that other practitioners (those referring patients for diagnostic imaging or those interested in developing peripheral interventions for other organ systems) could use the MRI center routinely.

All the biopsy procedures were performed utilizing CT or MRI guidance with the application of an external stereotactic frame or the employment of a frameless system.[6] After administration of general anesthesia, a standard 7 mm burr hole was created in the patient's skull. Tissue specimens were obtained utilizing an average biopsy needle. Out of the group, 83% were diagnosed with a tumor. The remaining diagnoses included infection, stroke, and other neurological disease processes.[6]

Complications associated with this stereotactic brain biopsy were compared. Out of the study group, five patients developed a complication. The most common complication was a small hemorrhage formation at the site of biopsy. Only one of the patients suffered permanent neurological deficit. Deaths in three patients were reported, but they were not related to the biopsy procedure itself. Out of the 86 patients who received the stereotactic brain biopsy, 71 were well enough for same-day discharge.[6]

Economic analysis was directed toward hospital charges, net revenue, direct costs, and indirect costs.[6] Out of the patients surveyed, 96 records were available for review. Revenue decreased 14% in short stay patients and 45% in the extended observation patients.[6] A direct cost to the hospital was seen to increase 16% and 28% for each group studied. Profits were reported to be 6% higher in the extended outpatient group when compared to the short-stay group. Direct costs, however, were 35% higher.[6]

An abstract from Paleologos, Wadley, Kitchen, and Thomas on the use of image guidance during craniotomies for meningiomas reviewed 100 patients who had received surgery stereotactically and 170 patients who had received a traditional craniotomy. Although the operative times associated with the two groups were not significant, the image guided surgery group was shorter. Intensive care unit stay was also compared. Image guided patients were in the intensive care unit for an average of one day, while the traditional craniotomy patient's mean length of stay was 1.7 days. Mean total hospital stay was reported at 13.5 days for the traditional groups and 8.5 days for the image guided group.[8]

Complications were lower in the image-guided group when compared to the traditional surgery group, 6% to 14% respectively. The most common problem reported was that of hematoma formation. The average cost increase of surgery per patient was 20% higher for the traditional surgery group than the image guided surgery group.[8]

Cost analysis of stereotactic radiosurgery for metastatic brain lesions versus an open approach was surveyed by Rutigliano et al. The authors reported that radiosurgery for metastatic brain tumors showed a savings of $7,378 when compared to that of an open resection of the mass. A lower complication cost per case was also appreciated. This was studied by cost comparisons from five sites that were used for radiosurgery.[9]

Discussion

All the stereotactic systems reviewed have one similarity: They all provide for a safer, less morbid outcome than that of a standard "un-navigated" intracranial surgery at a lower cost to the patient and facility.

Although the concepts are the same when choosing a stereotactic navigational system, the purchase can be quite pricey. The least expensive system is a framed system. This design consists of a cylindrical ring that surrounds the patient's head and is held in place by literally screwing bolts that are that attached to the frame into the patient's skull. The frame is marked with specific coordinates measured in millimeters. These coordinates are used to help navigate the biopsy needle or probe into the depths of the brain. The frame and the patient are then scanned together in a computerized tomographic scanner. The images of the frame and patient are then used to give a trajectory to follow to allow the passage of instrumentation to its desired target.

The concept of this type of navigation is not new. The idea itself has been around since the late 1800s when a framed stereotactic ring was used to study the brain in animal models. It was not until the early 1900s that the idea had been brought up to use this new contraption in neurosurgery on human patients.

Framed surgery is still utilized quite frequently today in this age of super computers and silicon technology. Surgery for Parkinson's disease and other movement disorders are being treated successfully using framed surgery. An increasing number of institutions are recognizing the importance of combining minimal access surgery with stereotactic navigation. The fact that a patient can have outpatient brain surgery is no longer uncommon. It provides a means of increasing the patient satisfaction, while enhancing the standard of care and lowering the costs in this period of reduced reimbursements. Several patients have received this form of treatment, and it has proven itself nearly flawless. This type of biopsy system has given way to the next generation of stereotactic navigation.

A frameless navigational system incorporates the same principles, but involves a few other components. The initial purchase of the system consists of a computer platform, an infrared camera or magnetic field generator, and a referencing instrument. The computer is usually a high-speed platform that is capable of reproducing highly detailed images. The infrared camera basically is the eye of the system. In some systems, a magnetic field generator is used in place of the infrared camera. Both variations encompass the same goal, which is to provide a probe recognized by the computer.

In frameless navigation, the brain of the patient is scanned in a computerized tomographic scanner. Instead of a frame being bolted to the patient's head, special stickers, called "fiducials" are placed on the patient's skin. These fiducials are impregnated with barium sulfate to make them radiopaque. The fiducials are arranged in such a way that they surround the area to be operated. Surgeons place 7-12 fiducials on the patient to increase the accuracy of the system. Once the patient has been scanned, he or she is taken to the operating room to be prepped for surgery. The images obtained from the CT scan are then loaded into the computer, and a program is used to register or compare the fiducial makers on the screen with the ones that are on the patient. After the images and the patient are registered with the computer, the surgeon can proceed with the operation. Usually, a sterile probe is used to identify the surgeon's position in relation to the images acquired earlier that day. Some of the systems on the market provide instrumentation, such as suction tips and a clamp-on sensor, which allows the surgeon to use any instrument to aid in the navigation. The accuracy of this system is high; room for error is between 1-2 mm.

Frameless stereotactic navigation has become the gold standard in the surgical treatment of brain tumors. There are several factors to take in account when an institution decides to undertake a purchase of a navigational system. Obviously, the price is a major consideration. In the middle price range, a frameless system offers the surgeon an increased amount of flexibility when it comes to the surgical options. The system can be utilized for a biopsy, navigation, or even precise work, such as deep brain stimulator implantation for movement disorders, such as Parkinson's disease and spastic rigidity. Most systems on the market range from $150,000 to $200,000. This makes them affordable for the smaller, non-teaching institutions.

Some systems may be used with other surgical disciplines in mind. Otorhinolaryngological surgeons are using the stereotactic navigation technology to guide them into the intricate cavities of the paranasal sinus. Some of the systems on the market can be combined with other diagnostic modalities such as fluoroscopy.

Pituitary surgery, by tradition, has involved the employment of ionizing radiation images to guide the surgeon through the nose, sinuses, and eventually to the base of the brain where the pituitary gland resides. This technique carried an extra risk for the personnel in the room. Now, the surgeon can take just a few snap-shots with the fluoroscopic unit, load them into the stereotactic system, and use those images to guide the instruments into the brain, while eliminating the excessive exposure of X-rays to the personnel and patients. All of this is possible without a substantial increase in cost to the patient or the hospital.

The latest and most expensive of all stereotactic navigational systems is the intraoperative MRI. How can the expense of intraoperative MRI for navigation within the brain be justified? Even though the two previously described systems are very useful in brain biopsy and functional neurosurgery, neither account for brain shift. After the skull is opened and brain shift occurs, the images displayed on the computer screen from a scan earlier in the day are no longer accurate. The brain can shift, on average, 1-3 mm. The shift may not seem large, but when a neurosurgeon is operating on areas of the brain that control motor movement and speech, every micron counts.

Neurosurgeons often prefer MRI navigation to the other types when operating on brain tumors. Certain types of brain tumors, such as glioblastoma multiforme, are only visible on an MRI scan and not to the naked eye. The finger-like projections of this very aggressive and fatal type of primary brain cancer can only be detected by MRI.

Brain shift, tumor visualization, and the protection of vital areas of the brain show the importance of an intraoperative MRI, but these added benefits do not come without a profound cost. The average price of the MRI unit itself can range from $1-3 million, and does not include the cost of standard operating room equipment that is MRI compatible. This is not a purchase that most institutions encounter without some heavy funding and several years of planning.

Various additional expenses and considerations add to the larger picture. One consideration involves how the unit will be housed. Some institutions use the MRI in a standard operating room that has been converted for MRI use. Other hospitals use another dedicated room, outside the main operating room, to acquire the data. The latter makes the MRI accessible for diagnostic and other therapeutic procedures when neurosurgery is not being performed. On the other hand, the risks of contaminating the wound and sterile field increase when the patient must be transported with a loosely closed skull and scalp and placed into the scanner.

One manufacturer produces an MRI scanner that fits neatly under the operating room table and is raised and lowered as needed. This is especially beneficial since minimal alteration to the existing surgical suite is needed. During a scan, instrumentation and other ferromagnetic equipment must be moved out of the magnetic field, a few feet from the scanner. This advance in technology has proven to be an effective adjunct to the treatment of intracranial lesions.

The final type of stereotactic system is a radiosurgery system, or "knifeless" surgery system. This system utilizes radiation that has been specifically shaped or collimated to the shape of the patient's own tumor to destroy the tumor itself while preserving normal brain tissue. The most popular type of system utilizes a robotic arm that moves about the patient's head to approach the tumor from all angles. Although still in its infancy, radiosurgery has proven itself as the best choice of treatment for patients both with intracranial lesions that are easily operable and those that are inoperable. It has also proven to be a cost savings device when compared to the surgical systems surveyed.

In recent years, stereotactic intracranial navigation has become an accepted addition to the neurosurgeon's armamentarium. This has not come about without great controversy. Again, the price appears to be the primary factor. More institutions are being equipped with a guidance platform, because the accuracy of the system, a substantially lower complication rate, and the potential for a genuine outpatient surgery are realized when in comparison to a surgery without navigation.

Several companies manufacture stereotactic navigation systems on the market today. Each system possesses unique features. Some are adaptable for spinal applications. Others can be used with or without a frame. The main goal of all stereotactic navigation within the brain is to provide the surgical patient with a faster, more accurate, safer surgery, without morbidity or mortality, while decreasing the overall cost to the patient and the hospital. In the age of decreased reimbursement and managed care, this has never been more needed.

Conclusion

Every patient has the right to quality care when it comes to a surgical procedure. This includes the training of the surgeon, nurses, and other personnel directly involved with his or her treatment. Most patients overlook the type of equipment the surgeon will use to perform the procedure. Hospital administrators also tend to miss this detail. The employment of a stereotactic navigational system for intracranial surgery is a piece of equipment that has become invaluable in the operating room.

Traditionally, most neurosurgeons worked off the CT scans obtained preoperatively and the anatomy of the brain he or she sees on the operating room table. Although still very reliable, performing surgery this way carries an increased expense to the patient and the hospital, both economically and postoperatively. Stereotactic navigation provides the patient and the surgeon a means of receiving and performing a minimally invasive surgery while enhancing the accuracy and ultimately the outcome of the surgery itself. Surgeries on once unreachable areas of the brain are now possible by the use of a stereotactic system. Whichever system a hospital chooses, it is not a purchase that should go without careful research of the surgeons' needs. Also, it must be understood that the purchase of the system is not inexpensive, but the money saved in postoperative care and increased standard of patient care far outweigh the expense.

THE MAIN GOAL OF ALL STEREOTACTIC NAVIGATION WITHIN THE BRAIN IS TO PROVIDE THE SURGICAL PATIENT WITH A FASTER, MORE ACCURATE, SAFER SURGERY, WITHOUT MORBIDITY OR MORTALITY, WHILE DECREASING THE OVERALL COST TO THE PATIENT AND THE HOSPITAL.

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