A Modern Neurosurgical Operating Theater at «Evangelismos» Hospital

George Stranjalis[12], Lampis Stavrinou[1], Athanassios Hatzis[2], Damianos Sakas[12]

[1] Dept. of Neurosurgery, University of Athens, «Evangelismos» Hospital, Athens, Greece
[2] Hellenic Neurosurgical Research Centre, «Prof. Petros S. Kokkalis», Athens, Greece

Abstract. Our newly built modern operating theater is a vital addition to the refinement of neurosurgical techniques and essential to the development of minimally invasive surgery in the Neurosurgery Clinic at «Evangelismos» General Hospital. There is a constant demand for changes as we strive to improve our practices and the environment for the benefit of our patients. These changes are heralded by our new operating theater. The modern operating room requires an increasing number of new surgical instruments, monitoring and imaging devices, information systems, and communication networks. We paid attention to the integration of all these resources in order to improve the quality and efficiency of our surgical and training procedures.

Keywords: operating room - theater, neurosurgery, surgical informatics

1 Introduction

The diagnosis and management of neurological diseases have been improved, in large part due to technological advances. Similarly, the neurosurgical operating room has increased in complexity and specificity with multiple forms of equipment now considered necessary as technical adjuncts. Six working groups of the “OR2020: The Operating Room of the Future Workshop” reviewed key areas of research and development : (1) Operational Efficiency and Workflow, (2) Systems Integration and Technical Standards, (3) Telecollaboration, (4) Surgical Robotics, (5) Intraoperative Diagnosis and Imaging, and (6) Surgical Informatics [2].

The «Evangelismos» General Hospital Neurosurgical Operating Theater (**ENOT**) opens a window to the future for the construction and operation of modern operating rooms because it is based on the above key areas. More specifically, the exigent nature of various neurosurgical diseases, along with the fast-paced technological refinement and the continuous expansion of neurosurgical indications, especially in the field of neuromodulation, has spawned a great challenge for state of the art equipment in a modern neurosurgical operating room. This challenge is further aggravated by the need for continuous neurosurgical training of experienced and younger doctors.

The fundamental characteristic of a modern neurosurgical operating suite is dedication; this inherently implies a self-contained, autonomous operating environment. This requirement for a committed neurosurgical suite is produced not only from the need for a highly sterilized environment, but also from the diversity of the neurosurgical procedures which are quite dissimilar to the majority of other surgical procedures. **ENOT**, which was constructed in 2006, consists of the main suite, two auxiliary rooms and an observation room. All are outfitted with laminar flow ventilation.

2 The Main Neurosurgical Operating Suite

Execution of conventional freehand surgical procedures is dependent, to greater or lesser degree, on hand-eye coordination. Most important, the invasiveness of a surgical procedure is determined primarily by the accessibility of the target structure.
Limited visualization, difficult localization and lack of control beyond the smaller-sized operational volumes remain the fundamental problems with minimally invasive surgery [1]. An integrated countermeasure system comprised of pre-operative imaging devices, computer-guided surgical intervention, intra-operative visualization, anesthesia machines, specialized lighting, sophisticated surgical instrumentation and other equipment, provides a framework for the newer surgical strategies in the **ENOT**.

2.1 The Surgical Microscope

The centerpiece of the main operating suite is the Zeiss NC-4 OmniNeuro surgical microscope. It is a high-tech machine which not only magnifies and illuminates the surgical field, but it is also capable of integrating the image with CT and MRI data. As a result, the neurosurgeon can not only see the delicate structures within the brain and spinal cord as he operates but he can also find the abnormalities shown on the CT or MRI by allowing the microscope to be navigated by the stereotactic computer. The microscope allows miniaturization of operating corridors, reduction of operative trauma and increased effectiveness at the target site. It is an indispensable tool for complex tumor cases and vascular procedures and is considered pivotal in applying the “keyhole” concept of brain and spine surgery.

2.2 Image-guided Computerized Stereotactic Surgical Intervention

Our department has a long-standing commitment in performing state-of-the-art neuromodulation procedures. Some of these - such as deep brain stimulation (DBS) for movement disorders (Parkinson’s disease, spasticity), pain and epilepsy - require the precise placement of electrodes deep within the basal ganglia, in predetermined anatomical loci. Such complex procedures call for a vast array of equipment which, among others, includes accurate target localizers. Target localization for DBS is performed on both a structural and electrophysiological level. The anatomical target localization is accomplished through the placement of a stereotactic frame and CT image acquisition which is later fused to preoperative MR images.

The Stereotactic Frame. DBS presupposes the use of a stereotactic frame, a three-pin head fixation system and image fusion software. We utilize both the Radionics CRW and the Leksell stereotactic frames. The frame is mounted on the three-pin system (Integra, Mayfield). Understandably, the surgical table is capable of supporting the Mayfield unit for stereotactic procedures. Image fusion and electrode placement planning is attained at a dedicated workstation. This workstation is located in an autonomous auxiliary room and consists of a powerful PC equipped with the Radionics StereoCalc and ImageFusion systems. Electrophysiological localization for refining the electrode placement is achieved through a separate workstation (Leadpoint, Radionics) which allows real-time microelectrode recordings (MERs) from the stimulated target and the adjacent structures.

Neuronavigation (Frameless Stereotaxy). The two-dimensional (2D) static images typically used today, although obligatory, are not considered sufficient. In that direction, our new **ENOT** suite is equipped with highly sophisticated image processing and visualization tools that provide three-dimensional real-time visualization, allowing the surgeons to localize critical anatomy. We utilize the Radionics OmniSight Excel, a neuronavigation system which integrates the CT or MRI images with real-time anatomical data in a 3D image, hence enabling neurosurgeons to accurately localize the smallest of lesions. It allows precise pre- and intra-surgical trajectory planning and target localization. The neuronavigator, which applies the same principles as the common GPS-systems, further supports the application of the concept of minimally invasive neurosurgery.

2.3 Other Equipment

The Neuromonitoring System. The neuromonitoring system (Medtronic) obtains and co-interprets triggered and spontaneous electrophysiological signals from the patient as the surgery proceeds. These signals are used as preemptive alarms when the surgeon is in proximity to critical nervous structures and in risk of compromising their anatomical integrity. It is a system aiming for increased surgical safety.

The Ultrasonic Aspirator. The Ultrasonic aspirator (Cusa), utilizes ultrasonic waves to comminute tumors or remove useless bone growth in degenerative spinal disease with great respect to normal tissue.

The C-arm Fluoroscopy System. The C-arm fluoroscopy system uses a different visualization technique for intraoperative image acquisition.

The Ceiling-Mounted Columns. ENOT is equipped with two ceiling-mounted independently maneuverable columns with a 360-degree rotation capability that ensures greater versatility of ergonomics and an increased effortlessness of work-flow. These house standard surgical equipment for both the anesthesia and surgery team. A positive air-pressure system is integrated in one of those columns, which powers the high-speed drill. Another separate free-rotating, ceiling-mounted arm supports a 17-inch screen, which is located opposite to the surgeon. This screen can display images from various sources such as the microscope or the neuronavigator. It ensures that the surgeon has all the necessary data displayed within his visual field, thus minimizing surgery team distraction and fatigue. It also allows for both the anesthesiologist and potential observers to have direct visual contact to critical surgery data or imaging.

3 The Impact of the Observation Room

The microsurgical techniques often applied in neurosurgery and the small surgical field in most procedures makes training a challenge. The surgical field through the microscope is usually only visible to the surgeon and his assistant. Furthermore, the surgeon's need for mental concentration calls for an environment free of distractions. In our new operating theatre, therefore, all training is conducted in a separate training room, the Observation Room. This is attached to the main neurosurgical operating suite, but can be easily isolated through lead-coated sound-proof doors.

Observation Room serves multiple purposes; it is used to host the neuronavigation computer system, the DBS computer system, digital capturing and transmission system, and the electronic medical record (EMR)- media library system. Computer-based informatics programs provide compehensive and decision-making support to the surgical care team and lead to an effective telecollaboration with other staff members and visitors.

3.1 Equipment Description and Space Allocation

The Observation Room is divided into two parts: The front part accommodates 8 seats for the spectators and the computer-based multimedia system comprised by a 40 inches TV, two PCs, a colored laser printer, a DVD-recorder and an audio console. The other half of the room is used for the neuronavigation and DBS workstations, a rack mounted infrastructure for the audio-visual and computer network equipment, and two cupboards for the storage of materials and personal belongings of the staff.

The Video I/O System. A video matrix switch in the observation room routes video from at least three cameras located in the main neurosurgical operating suite. A roof camera shoots a general view of the operating room. This way medical staff can watch from their office the pre-operative stage preparation. This camera may also be used for security purposes. Secondly, a digital camera suspended to a free-rotating roof arm takes a view of the surgical field. Alternatively, a head-mounted camera can be used for the same shooting plan. Finally a video signal taken from the microscope displays the microsurgical field. If needed, a fourth video signal may be taken from a video camera in a separate conference room or from any of the digital workstations (Omnisight, Leadpoint, ImageFusion etc). All video input sources can be transmitted with high quality either over cable or streamed over the local computer network and distributed simultaneously to various output devices (computer monitors, TV, video projector, DVR), in essence creating a "matrix" pattern of interconnection possibilities for operative, educational, and archiving purposes.

The Audio I/O System. In a similar fashion the audio mixer console controls audio signals generated from standalone microphones and computers' sound cards in the observation room, the main operating suite, medical staff offices, conference room and lecture amphitheatre. This two-way communication system between the sender and receiver can be used for remote consultation, evaluation, mentoring/proctoring, and monitoring purposes [2].

3.2 Telecollaboration – Teleconferencing

Our audiovisual systems were successfully tested in two demanding occasions: In 2008, our department organized and hosted an advanced course on computer-guided neurosurgical navigation and another on stereotactic techniques and deep brain stimulation. As the number of participants in both courses greatly exceeded the persons' capacity of the observation room, the lectures took place at the hospital's auditorium. In these occasions, live video feed from the operating room and the ongoing surgical procedure was transmitted directly to the auditorium. As the procedure progressed, general images from the OR alternated with images from the workstations and the surgical field in a flawless and speedy fashion. A two way audio/visual communication was established effectively between conference participants and surgical staff.

3.3 Surgical Informatics

Photos taken during the operation, video capturing and processing into video clips, images, assessment-evaluation documents, tissue/pathologic recognition and other sources of multimodal/sensory inputted data generated for the patient are all linked to his/her EMR record. In addition to this homegrown clinical information systems for specific neurological disorders such as Epilepsy, Spasticity, Parkinson, and Dystonia are also available. Both the EMR and these neurological databases include separate sections for the description and the main characteristics of surgical operation. These information systems and others used for neuronavigation and DBS are not fully linked or integrated but in some cases data exchange is possible through common computer network resources. Nevertheless there is a lack on informatics standards, annotation, and indexing methods.

4 Future Plans

The OR2020 Workshop identified five broad areas of technology requirements : *"standards for devices and their use in the operating room; interoperability of devices for a plug-and-play medical network; improvements in surgical robotics, surgery-specific image acquisition, processing, and display; and improvements in* *communications"* [3]. Our homegrown and commercial medical information systems must adhere to these requirements. It follows that effective surgical informatics systems should be developed to reduce the high cost and increase the safety of neurosurgical operations.

With the respect to the imaging-visualisation systems, intraoperative MR or CT-guided neurosurgery represents a natural progression from framed and frameless stereotactic techniques. These technologies have the advantage over frameless neuronavigational systems of being able to perform near real-time imaging, which allows the surgeon to compensate for intraoperative brain shift. Intraoperative functional techniques such as MR spectroscopy, functional MRI, MR angiography and venography, and diffusion-weighted imaging, which have become routine at some high-field MR units, can significantly influence surgical decision making. Although intraoperative real-time imaging is still in its infancy and its indications and full potential have yet to be determined, we feel that an intraoperative CT scanner would be a valuable adjunct in the **ENOT.** Space restrictions would limit our choices to a portable intraoperative CT scanner or even a compact low-field (0.12-0.15T) MRI scanner with little compromise in image quality acquisition and clinical decision-making [4].

In regard to teaching and training capabilities, we feel that the greatest setback comes from the lack of protected time for real-time surgery observation by members of the staff who are either not actively present in the operating room or occupied with other activities in the department. A better scheduling of the surgery of interesting or rare cases and possibly the application of a rotation system in training of resident doctors may successfully address this problem.

5 Conclusion

ENOT is a state-of-the-art operating theatre; it is dedicated, autonomous and interdisciplinary. It allows for a wide spectrum of neurosurgical procedures by applying: current developments in areas of imaging, sensors, and visualization; new devices for localization and navigation; new capabilities for minimally invasive or reduced-access surgery and innovative concepts related to advanced operative venues. It also provides the best possible training setting through the application of surgical informatics and telecollaboration.

We anticipate in the near future to achieve a near-real-time operational control of complex devices while still allowing the neurosurgeon to perform surgical procedures in an interactive way. This need can only be satisfied with the development of robotic instruments, appropriate user interfaces and the application of postmodern human-computer interaction techniques. Real-time computer-assisted safety, control of high-tech surgical tools and robotic surgical intervention through a virtual reality environment, is still a vision to capture.

Acknowledgments. Construction of **ENOT** was funded by the Hellenic Neurosurgical Research Centre «Prof. Petros S. Kokkalis» and other private donations.

References

1. Jolesz, F.A., Kikinis, R., Shtern, F.: The Vision of Image-Guided Computerized Surgery: The High-Tech Operating Room. In: Taylor, R.H., Lavallee, S., Burdea, G.C., Mosges, R. (eds.), Computer-Integrated Surgery : Technology and Clinical Applications. pp. 717-721. MIT Press, London (1996)
2. OR2020: The Operating Room of the Future. http://www.or2020.org/OR2020_REPORT/Report_Files/index.html (accessed 27-3-2009)
3. Cleary, K., Kinsella, A.: OR2020: the operating room of the future. J Laproendosc Adv Surg Tech A 15(5):497-573 (2005)
4. Hirschl, R.A., Wilson, J., Miller, B., Bergese, S., Chiocca, E.A.: The predictive value of low-field strength magnetic resonance imaging for intraoperative residual tumor detection. J Neurosurg (2009)