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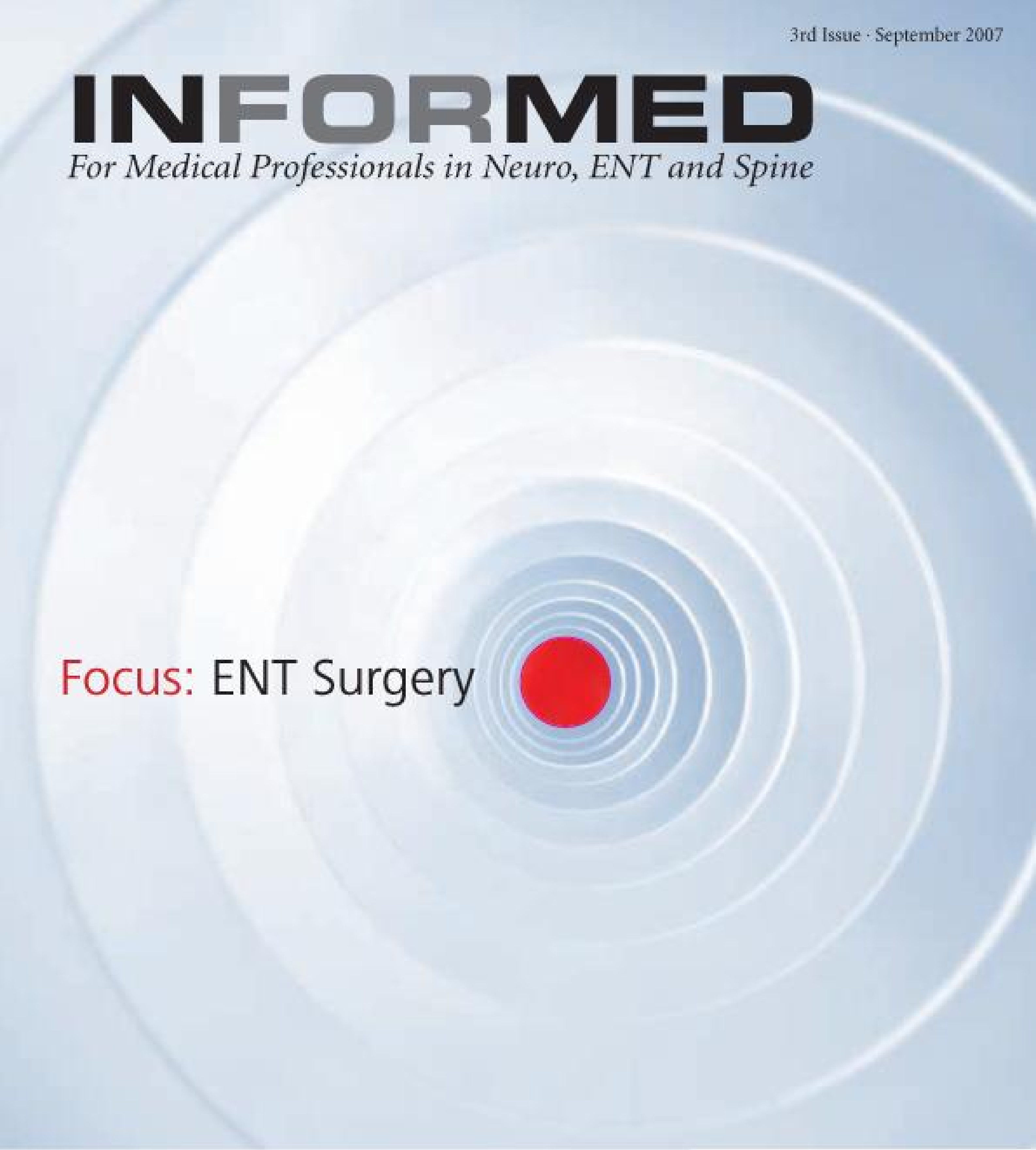
INFORMED

For Medical Professionals in Neuro, ENT and Spine



Focus: ENT Surgery

Dr. Hans-Joachim Miesner

Dear Readers,

In the past few years, we often saw that innovations were developed in the medical environment through the use of already established technologies in new fields of application. These include, for example, cardiac pacemakers, brain stimulation, cochlear implants or retina implants, which are all based on similar technologies and principles. Fluorescence techniques, about which we have already reported in this magazine, have been used for procedures in ophthalmic surgery for many years, and have recently started to arouse a high level of interest in neurosurgery. Be it for the development or use of such applications, knowledge must be created and shared in order to achieve the greatest possible synergy effects.

In light of this, Carl Zeiss Surgical and Carl Zeiss Meditec merged under the Carl Zeiss Meditec AG banner last year. Carl Zeiss Meditec now covers the full portfolio of medical solutions of Carl Zeiss and is dedicated to providing innovative technologies across a broad spectrum of applications in ophthalmology, neurosurgery and ENT surgery. We will utilize the synergies created by the merger to continuously develop innovative visualization solutions in the future. The third issue of INFORMED therefore focuses on trendsetting ideas and technological developments. We will shed some light on their application, particularly in ENT surgery, with articles on skull base surgery, navigational systems and intraoperative imaging. We hope that you will continue to find INFORMED interesting and helpful. For this reason, we would be extremely grateful for your opinions and ideas regarding future issues and invite you to send us your comments using the postcard at the back of this issue. Happy reading!

Yours,

Hans. J. Miesner

Hans-Joachim Miesner

Director Neuro/ENT & Spine


FOCUS
350mm
ZOOM
1.7x
LIGHT
ON
MENU
PHOTO
FREEZE
DRAPE
AUTO-BAL
DICTATION
FULL SCREEN
Livevideo
FOCUS SPEED
ZOOM SPEED
LIGHT INTENSITY

OR of the Future – A Vision?!

Thomas Lenarz, M.D., Ph.D.

Modern-day operating rooms are crammed full of high-tech devices, but none can yet overcome their primary weakness – their logistical connective inadequacies. It is time to redesign the OR based on a meticulous analysis of processes and material flows, with new data and user interface standards.

Today's operating room is a work environment with deep-rooted historical origins. Current device-related components have improved significantly, particularly during the last few years; new medical devices have been added (especially intraoperative support systems for imaging, monitoring, navigation and robotics). The OR's general concept, however, has changed very little – logistically, today's operating room is an island: currently, the on-call resources are more or less limited to elementary supplies such as water, electricity, medical gases and air conditioning (we will discuss PACS later). All other factors (support systems, sterile equipment, patient-related data) contributing to the success of any type of head and neck surgery have to be manually supplied and configured for each operation. Ensuring the availability of these systems requires keeping a costly inventory of equipment, with individual provisions tying up highly qualified personnel and bringing about costly delays.

Strong market growth vs. a poor ergonomic posture

Medical technology continues to grow at a rapid pace worldwide: According to a survey conducted in Germany by the Federal Ministry of Education and Research 5,700 million euros are invested in medical technology products every year. Another 6,800 million euros are spent on devices from foreign manufacturers. Worldwide, the German medical technology industry ranks second between the USA and Japan. However, a survey conducted by U. Matern, M.D., University Hospital Tuebingen in Germany, among 3,600 surgeons also showed that:

- In the opinion of approximately 40% of those surveyed, a surgeon's incorrect working posture can endanger both the patient and the OR team
- 70% do not consider the current surgical devices' functionality to be intuitive; switches are too small, the systems' navigation menus are not clear
- 70% of the ORs are not part of a hospital's network

- Only 13 of the 3,600 surgeons surveyed actually use alternative input assistance such as voice control
- Only 7% of the users read the instructions (most of which are simply too long)

Studies on ergonomics have shown that the optimum line of sight to the monitors (one, not several!) is straight ahead and slightly below the horizontal viewing plane: only 50% of the users operate their screens properly; half of the other 50% know they are doing it incorrectly, but have not changed their habits. The others are not aware of this fact at all. As a consequence, most surgeons prefer floaters to operate their medical devices.

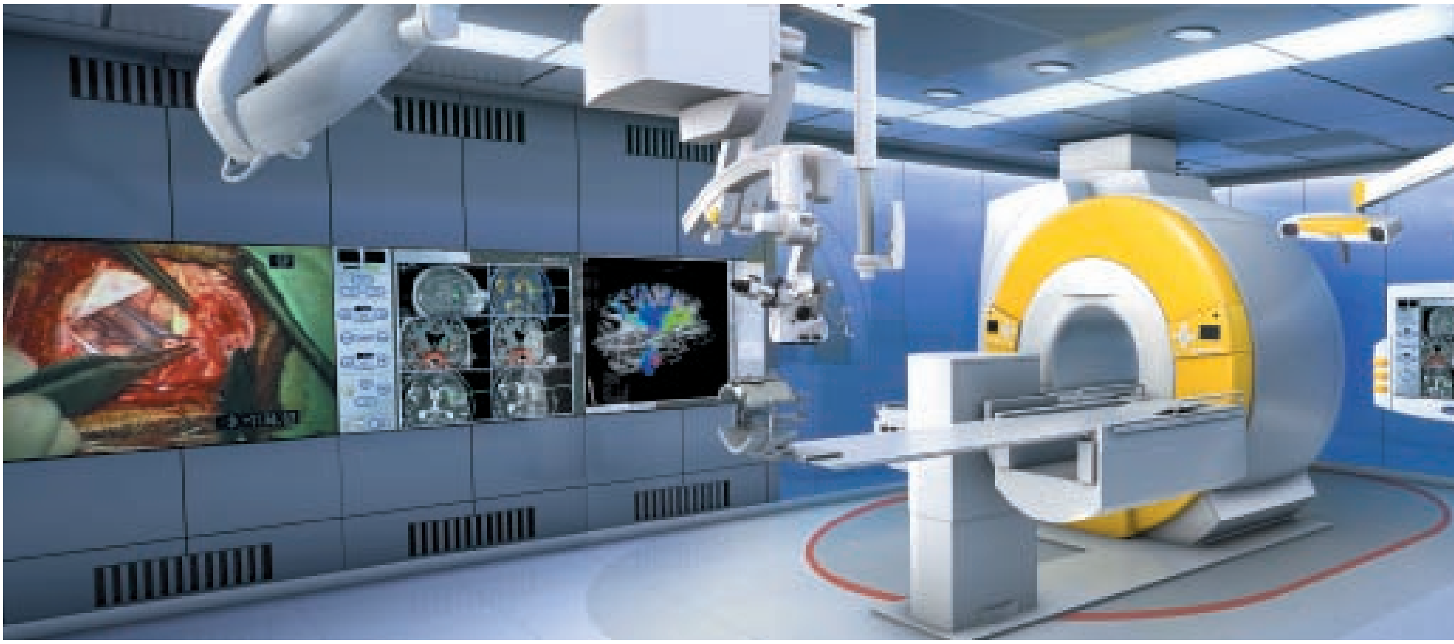
In most complex work systems, 70 to 80% of all mistakes can be traced to human error. Various studies have come to the conclusion that 50 to 80% of human errors can be linked to inadequately designed technology or its flawed implementation.

Redesigning the workflow

To implement the OR of the future, it will not suffice to install a 3 Tesla MRI in a sufficiently large room. The essential work lies in a comprehensive OR space redesign based on a meticulous analysis of processes and material flows:

- How does the patient get to the OR?
- Which technology and information must be available? When and where?
- Which staff is required? When and where?
- How is the required sterile equipment provided on time?
- How can the safety for patient and staff be increased?
- How are complications recognized, controlled and recorded? How can everybody learn from such events?

Modern research on the extensive topic of ergonomics provides suitable measures to carry out such analyses. However, creating real-life solutions from such results can only succeed in close cooperation with the medical technology industry. And herein lies the essential problem: a manufacturer must individualize his brand and distinguish his products from those of the competition. Thus, every manufacturer defines proprietary data standards, tries to establish his understanding of intuitive functionality with the user, and "protects" his systems through missing or incompatible user interfaces. Therefore, product concept diversity becomes the obstacle in advancing



BrainSUITE iMRI is a fully integrated image-guided neurosurgical OR suite from BrainLAB AG the user interface and system functionality.

The handling of radiological image data shows that processes can work: the DICOM standards for the patient-specific coding of image data has existed for many years. Also, hospitals are increasingly implementing PACS (Picture Archiving and Communication System) configurations, allowing constant availability of this information even in the operating room. However, progress in linking such data with CIS/HIS frameworks has not yet reached this level.

One screen, one mouse, one manager

Most intraoperative support systems provide visual output, usually on a screen; input generally occurs over a keyboard, mouse or touch screen. These common characteristics offer vast possibilities to improve system functionality: as not all information is required at the same time – or could even be digested by the surgeon, if provided – only one touch screen with one sterile mouse (or similar pointing instrument) would, in most cases, suffice in the surgery's proximity. The requested information for each case (image data, device settings, patient's vital signs, etc.) is displayed on demand. In fact, a handful of innovative research projects are elaborating these important questions.

In the operating room of the future, a data manager will handle the flow of information. This person should be very familiar with the surgical and anesthesiological subsystems in the operating room. Before surgery, he can process image data, for example, the merging of CT and MRI volumetric images, and segment structures, if required, and define approach routes in collaboration with the surgeon. He should also be capable of judging intraoperative measuring data, recognize pathological changes during surgery and communicate these to the surgeon. These activities entail considerable responsibility: the data manager can, of course, be supported in his tasks with knowledge-based software algorithms; the final responsibility, however, rests with the personal judgment of the operating surgeon. The invaluable advantage for the surgeon would be focusing on only a few, but highly significant interfaces.

Every second the surgeon does:
- not have to ask for the floaters
- not have to operate a device
- not have to wait for material supplies and patient information and does
- not have to flip through an instruction manual

is valuable time he can dedicate to treating his patients.

Image courtesy:
BrainLAB AG, Feldkirchen, Germany

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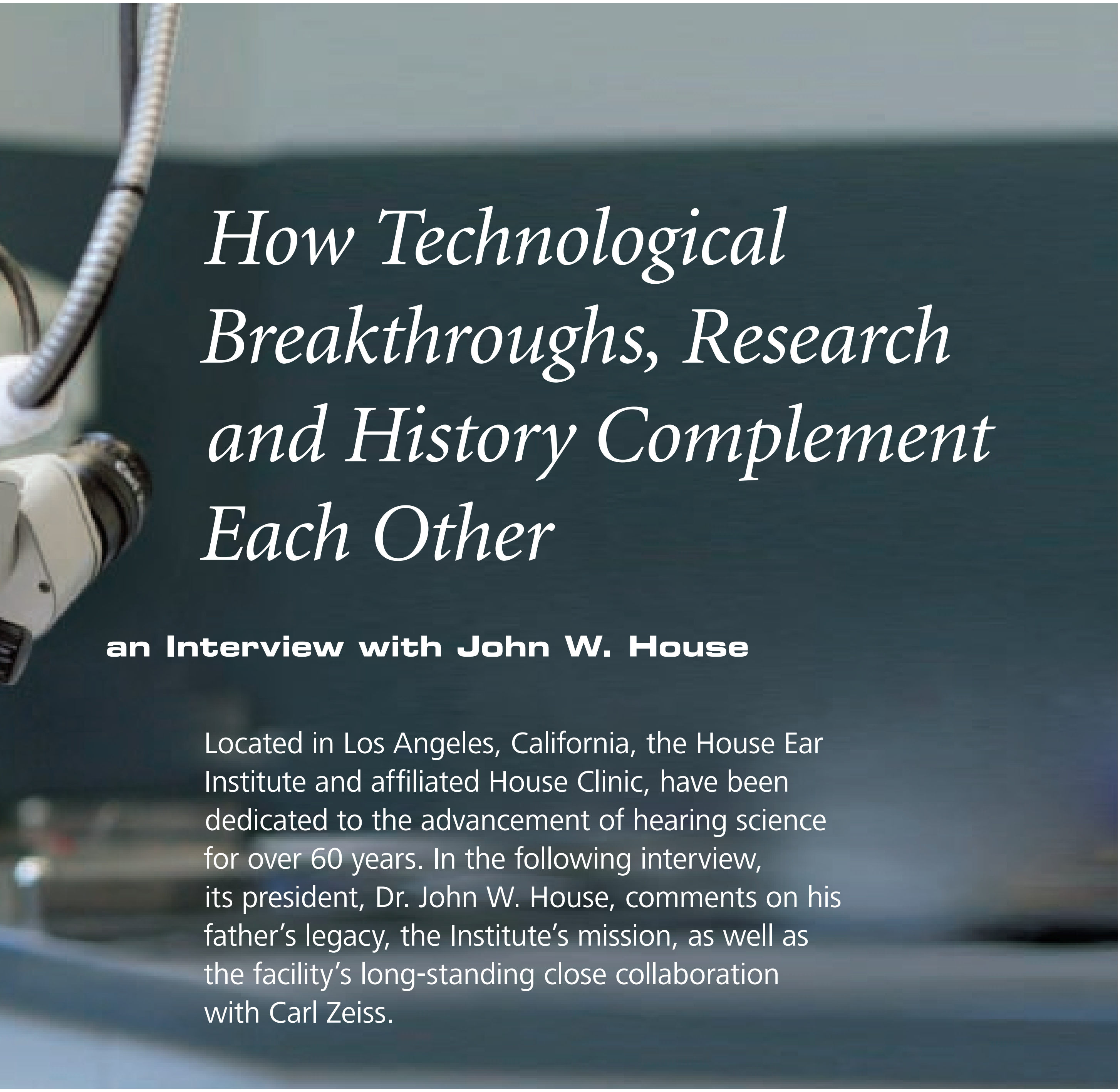
The House Ear Institute's research and education facility today



How Technological Breakthroughs, Research and History Complement Each Other

an Interview with John W. House

Located in Los Angeles, California, the House Ear Institute and affiliated House Clinic, have been dedicated to the advancement of hearing science for over 60 years. In the following interview, its president, Dr. John W. House, comments on his father's legacy, the Institute's mission, as well as the facility's long-standing close collaboration with Carl Zeiss.

Established in 1946 by Howard Payne House, M.D., as the Los Angeles Foundation of Otology, and later renamed for its founder, the House Ear Institute has been engaged in the scientific exploration of the auditory system from the ear canal to the cortex of the brain for over 60 years. The House Ear Institute is a non-profit organization dedicated to advancing hearing science through research and education to improve quality of life. Under the leadership of Howard P. House, the Institute became internationally recognized as a center of excellence where researchers and physicians work together under one roof, investigating novel treatments for those with hearing loss and related disorders. Today, the House Ear Institute's five-story facility accommodates more than 160 staff members within 22 departments. It is a leader within a vast global network of organizations dedicated to the field of hearing health.

Research is at the core of the House Ear Institute's mission. The international medical science community looks to the House Ear Institute as a leader in the quest to understand the nature of the human auditory system as well as hearing loss and related diseases. The Institute is renowned for developments in sensory aid technologies for hearing loss, for understanding the basis of hearing and hearing-related disorders at the cell and molecular level, for the complex neurological interactions between the auditory system and the brain, and for diagnosis and treatment advancements to improve the quality of life for people with disorders affecting the auditory system and related functions.

The Institute's discoveries have helped millions of people receive successful treatments. Moreover, founder Howard P. House believed that knowledge is only meaningful when it is shared. The Institute continues that philosophy in its work today, and shares its knowledge with the scientific and medical communities as well as the general public through its education and outreach programs. Since 1946, the House Ear Institute's professional education programs have been attended by more than 22,000 doctors and research fellows. The House Ear Institute and the House Clinic, originally established as a private practice in 1939, are both located in Los Angeles and work closely together to enhance the quality of life for people with hearing loss and related disorders. The House Clinic is internationally recognized as one of the world's foremost neurotology medical practices. Patients

In 1974, the Los Angeles Foundation of Otology was renamed the Ear Research Institute which was later renamed the House Ear Institute in 1981.

Howard P. House in surgery, 1960's

> **"My father was one of only a few people in the country performing an operation called fenestration to restore hearing in patients with otosclerosis."**

worldwide visit the House Clinic, seeking leading-edge quality care for hearing loss, ear diseases, and related medical concerns.

INFORMED met with Dr. House, President of the House Ear Institute and clinician and surgeon at the House Clinic.

INFORMED: Please describe the history and development of the House Ear Institute and the House Clinic.

House: The House Ear Institute was founded in 1946 by my father, Howard P. House, in Los Angeles. Upon finishing his residency in 1938, he traveled around the world and studied with leaders to learn the latest techniques in ear surgery at the time. When he returned to Los Angeles to set up his private practice, he was one of only a few people in the country performing an operation called fenestration to restore hearing in patients with otosclerosis. In 1946, he operated on two individuals who were so grateful for the restoration of their hearing, they presented him with a donation to begin an institute dedicated to the research and education of hearing loss and related ear disorders. Since its inception, the non-profit institute has grown from a one-person office to a five-story building with a $20 million budget and 160 employees. The House Clinic, which was also established by my father, originally started out as his private practice in 1939. The clinic today consists of nine physicians, including one neurosurgeon and the rest otologists and neurotologists. At the clinic, we see 6,000 new patients annually and 25,000 returning patients. We perform over 300 acoustic neuroma surgeries per year in addition to countless other otologic procedures.

INFORMED: What is unique about the House Ear Institute, and what are some of its accomplishments over the past 60 years?

House: Since 1946, the House Ear Institute has led the way in defining the causes of hearing loss and balance disorders, improving medical treatments, surgical procedures and prosthetic devices. The Institute's scientific discoveries and breakthroughs have helped millions of people receive successful treatment. In addition to our research programs, the Institute has been dedicated to education, and thousands of physicians from around the world have visited the House Ear Institute to observe surgery, visit the clinic, take courses and perform research.

> **"Because of William House's use of the ZEISS microscope for removing acoustic neuromas, it is now the gold standard for almost all neurosurgical procedures."**

There have been many accomplishments we are proud of over the past 60 years, but I will only highlight a few that have both historical merit as well as a significant impact on the practice of medicine today. In 1956, my father traveled to Germany to visit the ZEISS factory in Oberkochen and met with Dr. Littmann. He was introduced to the OPMI® 1 surgical microscope and was instantly impressed. He brought back the operating microscope which he used in his private practice for years. Additionally, because of his interest in education, he worked with an engineer named Jack Urban to develop a side arm for student doctors to view the surgeries from around the world. It was called the House Urban Viewing Tube. Mr. Urban also developed an adapter for a 16 mm camera and a camera to take the first motion pictures through the ZEISS microscope, and later closed circuit TV for teaching physicians how to perform specific surgeries.

In 1958, my uncle William House introduced the use of the ZEISS microscope for removing an acoustic neuroma which, at that time, was a condition that had a 40 percent mortality rate. Because of William House's use of the ZEISS microscope for removing acoustic neuromas, it is now the gold standard for almost all neurosurgical procedures.

INFORMED: How has the House Ear Institute influenced Carl Zeiss Meditec in the development of surgical microscopes?

House: Our history with ZEISS goes back to 1956. ZEISS is truly the pioneer in the entire area of otologic surgery, and much of what we do today wouldn't be possible without the use of its operating microscope. As far as what the House Ear Institute has contributed to ZEISS, I would say it really has been a life-long supportive relationship where the Institute has made improvements in medical treatment as a direct result of ZEISS technology and, at the same time, the Institute has contributed to the development of new technologies. For the past three years, I worked closely with the engineering team on the OPMI Pentero microscope. The team would bring a prototype microscope to the clinic for feedback, and I would use it for ear surgery as well as skull base surgery. Prior to the microscope, I worked with the engineering team on the YAG laser in the

Howard P. House (on the right) is showing two visiting doctors the original ZEISS surgical microscope undraped and with a camera attached.

same capacity. My relationship with ZEISS goes back 10 years, and prior to that, my father and uncle both worked with engineering teams on product development.

INFORMED: What impact has Carl Zeiss Meditec had on the House Ear Institute and the House Clinic?

House: A tremendous impact. ZEISS is the gold standard in the industry, and they have made excellent lenses for a very long time. Their product history is solid, and because of their revolutionary contributions in technology, we are able to use micro dissection techniques to safely remove tumors, preserving adjacent structures. The ZEISS technology has significantly reduced mortality rates.

INFORMED: It was a pleasure to meet you. Thank you very much for this interesting interview.

Image courtesy:
House Ear Institute, Los Angeles, CA, USA

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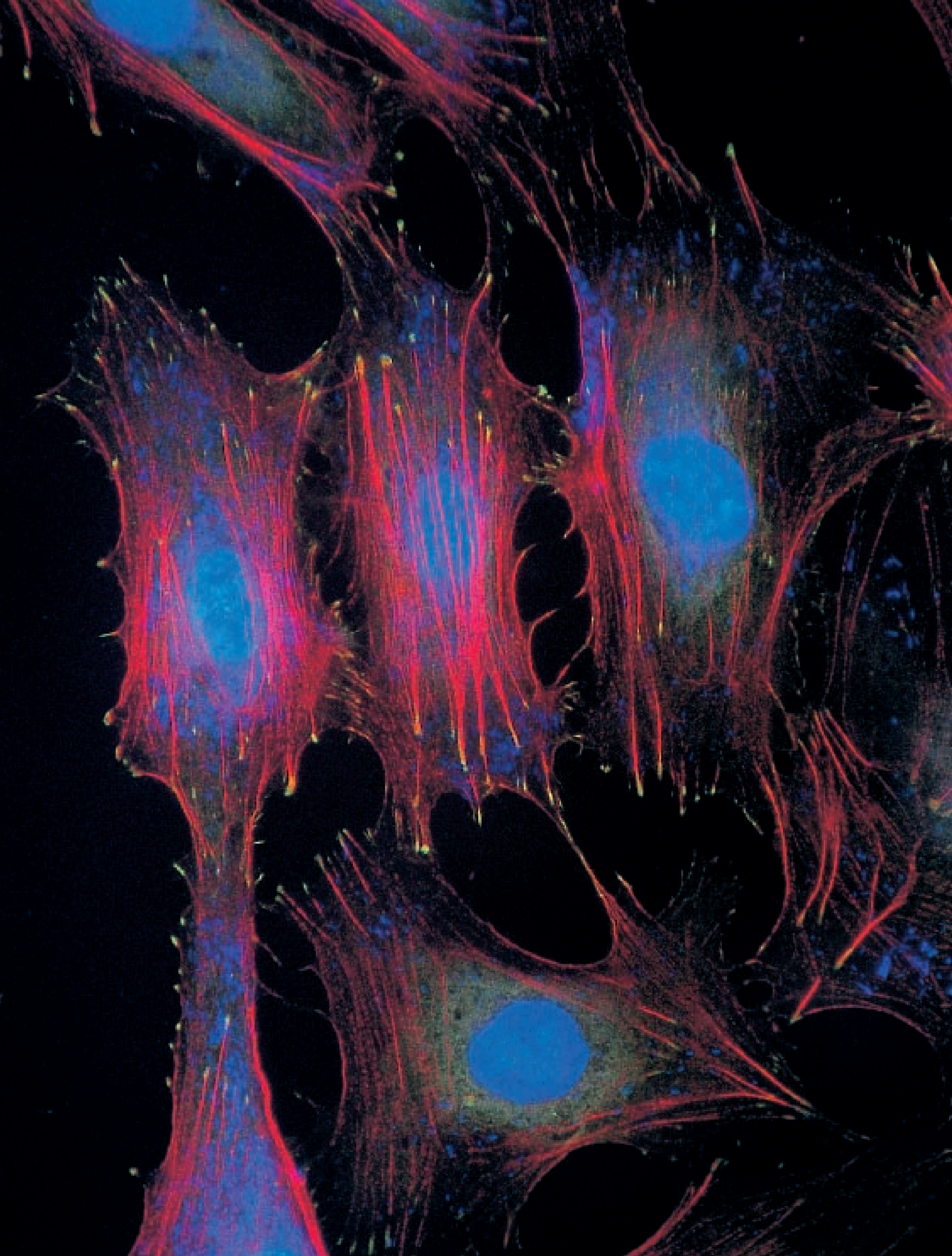

Intraoperative Imaging of the Microanatomy and Integration into the Clinical Workflow

Martin Leinung, M.D.

With current and future trends in surgery focusing more and more on minimally invasive procedures, intraoperative imaging technologies and approaches play an increasingly important role. At the moment, the research focus on the myriad of techniques outlined in the following article particularly centers around the improvement of intraoperative imaging as a diagnostic support tool for successful minimally invasive therapeutic measures.

One important convergence trend in minimally invasive surgery is the integration of diagnostic measures with therapeutic procedures. For example, the integration of patient examination and treatment has merged into modern practice within interventional radiology and intraoperative imaging. Intraoperative imaging has progressed tremendously in the area of technique development. Conventional imaging modules can be built into specially equipped operative theaters, and streamlined imaging systems can be applied for mobile intraoperative use to integrate imaging into a conventional OR.

Current medical research focuses on imaging of tissue clusters (microanatomy) and on visualization at the subcellular level (in vivo histology). One very important point to consider is the intraoperative differentiation of malignant or benign pathologies. Various research groups are working on the implementation of imaging modalities which allow an "optical biopsy" with sufficient sensitivity and specificity. The long-term goal is to shrink, diagnose and treat melanomas in a single surgical procedure.

High-resolution ultrasonography (HR-US) and endosonography are well-established imaging

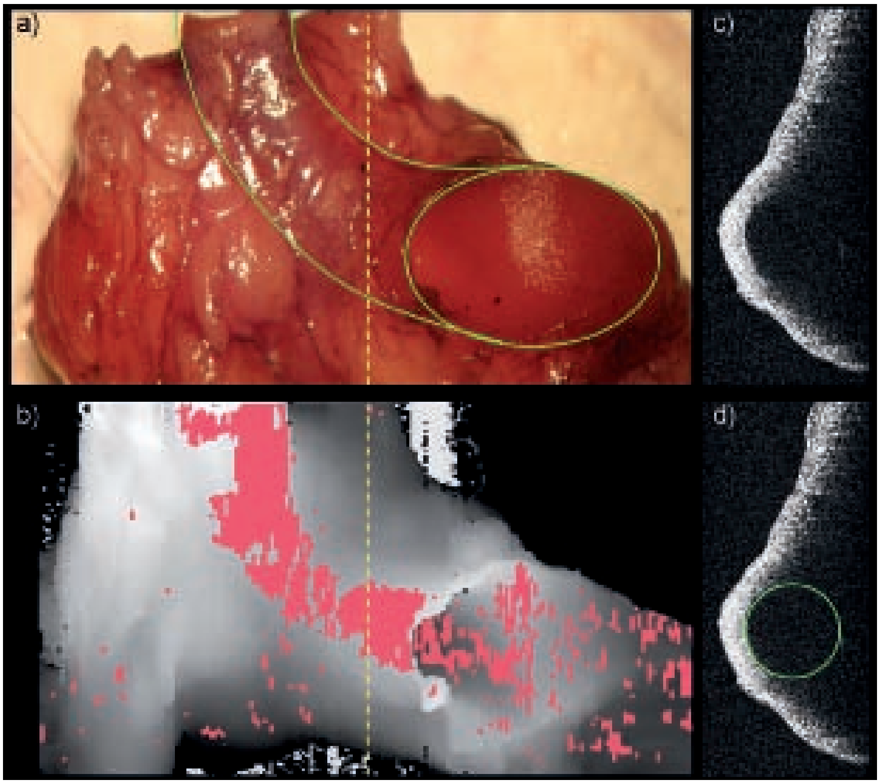

Fig. 1: Specimen with a vein embedded into fatty and connective tissue (a). The green lines indicate the course of the vessel. Picture b) shows a grey-scaled height map of the specimen extracted from a set of 184 consecutive 2D OCT images. The reddened areas have been generated by an automatic algorithm for detection of vessels within the 2D OCT images. Pictures c) and d) show the original OCT image corresponding to the position which is marked with the dashed yellow line in pictures a) and b). In picture d) the vessel is marked in green color.

techniques that can fulfill the demands for low-cost, non-ionizing and ease of use. HR-US is often referred to as ultrasound biomicroscopy (UBM), which has found clinical use primarily in ophthalmology for a number of procedures, including the diagnosis of squamous cell carcinomas.

Contact endoscopy (CE) is a further development of conventional rigid endoscopes, routinely used in otolaryngology. At magnifications up to factor 150, the most superficial cell layers of mucosal processes can be examined. While CE does not allow for cross-sectional imaging, it does provide visualization of the mucosal vessel structures (e.g. teleangiectasias) in unstained mucosa. Cell membranes and nuclei can be visualized after being stained with non-toxic agents such as methylene blue.

Optical coherence tomography (OCT) is a cross-sectional imaging method based on back-scattering of photons emitted by a broadband light source (e.g. superluminescence diodes). This imaging method is essentially comparable to the principle of sonography. The level of depth is displayed when the signal beam is replaced with a set split reference beam. One- or two-dimensional scans of the probe beam provide 2D or 3D visualizations of the specimen at a resolution of approximately 10 μm. Ex vivo experimental devices achieve up to 3 microns of axial resolution. The depth of penetration is approximately 0.5 to 2 mm, depending on tissue type.

OCT is now established in ophthalmology as a diagnostic tool for the ocular fundus. Research groups are currently exploring the potential of this technique for in vivo examination of cutaneous or mucosal processes. Intraoperative OCT allows the identification of tissue borders. This could be an enormous future advantage for radical tumor resection combined with maximum preservation of function, or for identification of submucosal tumor growth, as it is sometimes seen in adenoidcystic carcinomas. Among others, new light sources such as femtosecond-lasers are investigated as a basis of an integrated device for optical biopsy and therapeutic laser therapy. These approaches also require a (semi-)automatic interpretation of the OCT imaging data (Fig. 1).

Laser scanning confocal microscopy (LSM) is known as fluorescence imaging in experimental settings. Some manufacturers provide endoscopic LSMs for examination of colorectal neoplasms or pathologies predominantly of the urinary bladder. A refinement of LSM is Multiphoton Microscopy (MM) with even better axial resolution, allowing imaging of subcellular structures as nuclei and filaments. Increase of laser fluence enables the investigator to selectively cut or excise parts of these structures. An adaptation of these systems to in vivo conditions and the evaluation of a potential medical benefit have to be resolved in the future (Fig. 2).

In contrast to the techniques explained above, autofluorescence and induced fluorescence do not represent the histologic structure of tissues or cells, but rather depend on alterations of the cell metabolism. Autofluorescence (AF) is mainly used in bronchoscopies for detection of altered mucosa. Its principle is based on the ability of flavin mononucleotide (FMN) in normal cells, to emit green fluorescence when they are exposed to blue light. Due to a lack of FMN in malignant cells they do not emit green fluorescence, and one obtains a negative image of the tumors. AF has also been validated by some authors for inspection of the upper airways, especially the larynx. In contrast, induced fluorescence (IF) is based on selective accumulation of protoporphyrine IX (PP IX) in neoplastic tissue that can be detected as a violet fluorescence. Induction of tumor tissue to fluorescence is achieved via administration of 5-aminolevulinic acid (5-ALA, a precursor of PP IX) that can be applied via inhalation, i.v. injection and peri- or intra-tumoral infiltration. It accumulates more or less selectively in tissues with a high regeneration rate. Especially in the mouth cavity and the oropharynx, it is well known that even normal cells contain physiologically relevant quantums of PP IX, so that false-positive results have to be expected in these areas.

Integration of the diverse imaging methods into the clinical environment is a demanding issue due to several reasons:

- High-resolution implies large datasets. Pre-interpretation of raw data could be an adequate solution, but who will be responsible for any iatrogenic impairment caused by misleading filtering and presentation of imaging data?
- Subcellular imaging provides information on single cells, but the surgeon has to treat the entire tumor. Surgery by hand is accurate to a tenth of a millimeter maximally, visual control via surgical microscopes and micromanipulators for laser surgery are mandatory. But there is not only the problem of alignment of different scales, one also has to relocalize the additional imaging information within the patient's anatomy. Intraoperative edematous swelling or tissue shift due to partial tumor removal can alter the spatial configuration completely.
- Apart from costs and spatial restriction, communication problems do often hinder the parallel use of intraoperative assistance devices. Most manufacturers protect their hardware interfaces, conceal software communication protocols and open them only for research purposes. Truly integrated surgery

Fig. 2: Femtosecondlaser cut of a single actin fiber in a living endothelial cell. The fiber retracts after cutting due to tension. Specimen: bovine capillary endothelial cells, fixed, stained with green fluorescence protein.

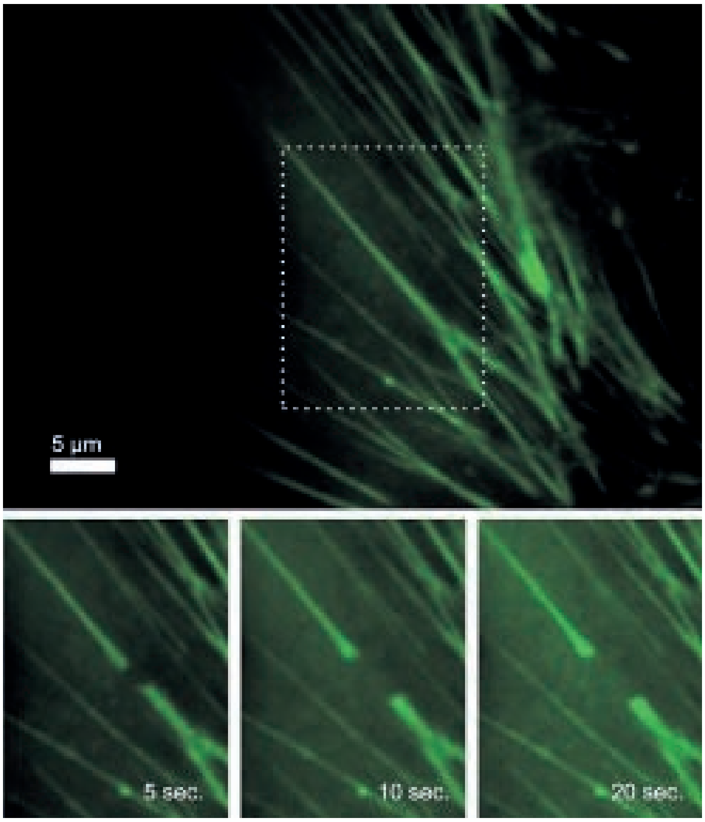

Fig. 3: MultiVision enables the surgeon to superimpose color contours and data into both eyepieces of the surgical microscope. Moreover, video data, pre-operative data, endoscope images as well as the entire touchscreen interface can be injected into the MultiVision display.

environments can only be implemented by (cooperation of) market leaders of diverse areas of medical engineering. Good examples for all-embracing multimodal surgical equipment are the OR1 from Storz or the BrainSuite of BrainLAB with an integrated ZEISS surgical microscope. The ZEISS surgical microscopes offer an intuitive open interface for almost any kind of visual additional information via MultiVision™ technology (Fig. 3). Furthermore, Carl Zeiss provides hardware and software interfaces for navigation systems; OPMI® Pentero® is even equipped with features for video documentation and networking capabilities via DICOM.

Highly-specific solutions and custom-made designs without open-source base will not promote any true integration. Only a fruitful collaboration of research, clinic and industry will compass further amelioration of high-standard medicine which meets ergonomic aspects, soaring financial limitations and the expectations of today's patients.

Image courtesy:

Fig. 1: Martin Leinung, M.D., Department of Otolaryn–gology, Medical University of Hanover, Germany

Fig. 2: Alexander Heisterkamp, Ph.D., Department Biophotonics/Lasermedicine, Laser Zentrum Hannover e.V., Germany

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Beaming Your Attention towards Lasers in ENT

OPMI® Application Tip #3

Every surgeon experiences situations in which he wishes to restore the natural function of an organ without contacting and injuring the surrounding tissue. This is one of the main reasons for the use of lasers as a surgical instrument in many different specialties of medicine.

Fig. 1: A laser micromanipulator integrated into the surgical microscope.

At low pulse energies, the laser allows surgery on very fine tissue structures. It is precisely for this reason that laser systems have been used in medicine for some time now. By integrating the surgical microscope into the laser platform, surgeons are able to effectively perform microsurgery on minute anatomical structures. The surgical microscope with a magnification of up to 20x allows laser surgery on fine, mobile structures such as the tympanic membrane or the ossicle, without injury to adjacent, healthy tissue.

About spot size

The active and aiming beams are delivered to the surgical field via a micromanipulator (Fig. 1). Today's state-of-the-art micromanipulators have minimum spot sizes of approximately 0.1 to 0.2 mm. To use the exact spot diameter for the respective application, there are some points to consider:

In laser treatment, the most important beam parameter is the power density at the treatment area (e.g., the applied laser energy divided by the area of the laser spot). This definition implies that when the spot diameter is reduced at the place of treatment, the laser pulse energy regime has to be reduced accordingly if a constant physiological effect is to be achieved.

The minimization of the pulse energy to an appropriate setting for the respective application is essential for the safety of the device. (CO_2 lasers may be equipped with a computer-assisted optical scanning system that helps to reduce tissue carbonization and thermal necrosis, since the laser beam is swept over the tissue area and dwells for a minimum duration on each tissue point.)

The microscope's focus has to correspond to the focus setting on the micromanipulator to obtain a laser spot aimed precisely on the working plane. This way, a maximum effect at the intended treatment area is obtained.

Mechanical attachment of the micromanipulator

The different micromanipulator models available today require specific attachment procedures to the microscope's body. The following recommendations are intended to facilitate an optimized solution in your individual case:

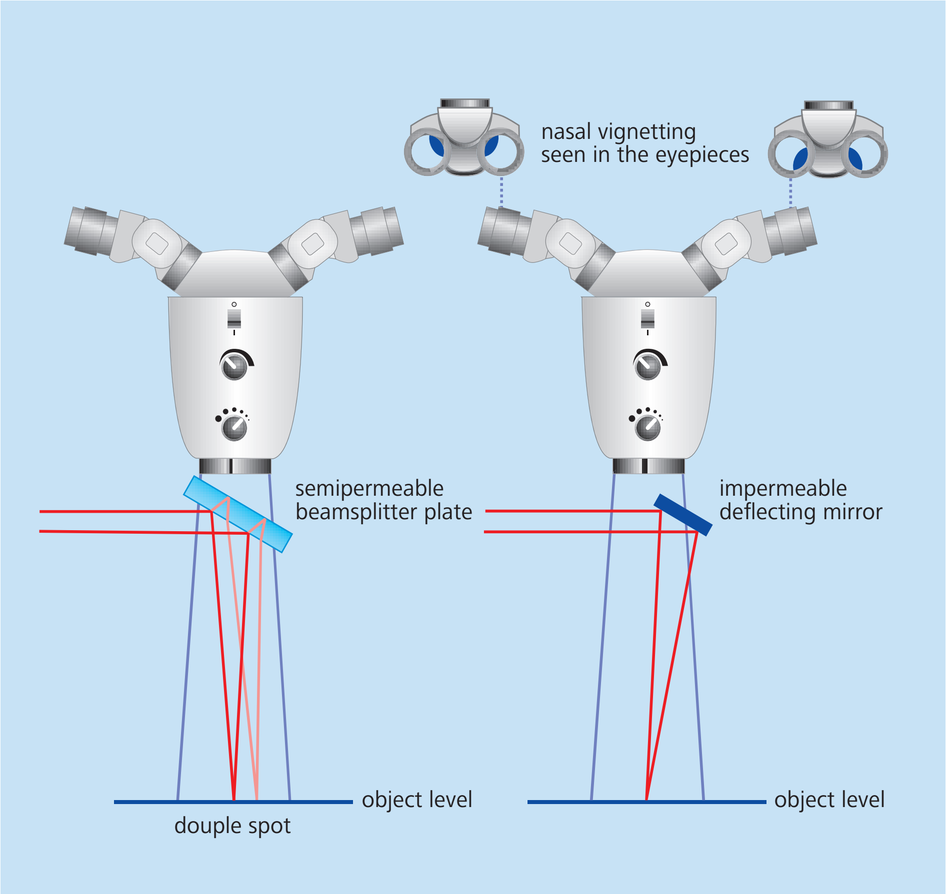

Fig. 2: Optical resctrictions when using the surgical microscope in combination with a laser micromanipulator. A double spot may be produced by the aiming beam when using a semipermeable beamsplitter plate (left). Nasal vignetting appears in the eyepieces when using an impermeable deflecting mirror (right).

- If the surgical microscope is equipped with a varioscope system, choose a micromanipulator that enables an adjustable working distance to avoid a deviation in the focal planes for both the laser and the microscope.
- If an adapter plate is required for mounting the micromanipulator to the microscope's body, please note that the plate's size might cause dimming of parts of the laser beam and the microscope's illumination path.
- Micromanipulators designed specifically for small objective lenses should not be used with surgical microscopes equipped with objective lenses of larger diameters (e.g., varioscope optics), since mechanical collision and optical dimming would otherwise occur.

Optical adjustment and restrictions

Before using a surgical microscope for laser applications, a check should be made to ensure that the working distance of the microscope corresponds to the working distance for the laser micromanipulator:

1. Before every surgical procedure, please check the correspondence of the two working distances for both the microscope and the laser micromanipulator by directing a trial laser shot at a wooden spatula located in the focal plane.
2. If the alignment is correct, the laser is focused precisely on the working plane with the active beam set at its maximum effect. The wooden spatula must be sharply focused in this position. If this

is not the case, the working distance has to be corrected by focus adjustment.

3. After correctly matching the two focal planes, the focal distance of the surgical microscope should not be changed to avoid an unfocused laser beam.

4. Since varioscope optics allows the surgeon to move the focal plane up and down, these changes have to be synchronized with the focal plane of the laser beam. However, if the micromanipulator is not able to adjust its focal length automatically to the focal length of the microscope, the varioscope mechanism needs to be deactivated. In this case, an external module (mounted between the microscope's housing and the suspension system) can be used for fine focusing by simultaneously moving the surgical microscope and the micromanipulator. This synchronized adjustment ensures that the microscope and micromanipulator remain focused on the same focal plane.

The focused laser spot is generated by firstly enlarging the beam through a system of lenses and consequently beaming it towards the target area through a deflecting mirror. This mirror can be finely adjusted using a joystick to allow the exact positioning and movement of the laser spot. Since the deflecting mirror is attached directly beneath the objective lens of the surgical microscope, some restrictions may occur (Fig. 2): If the deflecting mirror is designed as a semi-permeable beam splitter plate, a double spot of the aiming beam may appear at the target (due to a second reflection of the beam inside the plate adjacent to the intended reflection on its surface). In contrast, if the deflecting mirror is designed as an impermeable mirror, dimming is seen in a part of the eyepieces (known as nasal vignetting) and also on the video image, if attached, since a part of the mirror is located inside the visual beam path. In addition, it can lead to a visible reflection of the illumination light. However, the dimming disappears with higher magnification. Reducing the diameter of the spot illumination helps to minimize reflections.

Safety requirements

When working with a laser system in combination with the surgical microscope, it is important to remember a number of safety requirements:

1. The treating physician must wear appropriate laser safety eyewear (when working with a CO_2 laser system, the treating physician is protected by the lens system of the microscope, which completely absorbs any deflecting laser radiation).

2. The OR team has to wear appropriate laser safety eyewear during the entire procedure.

3. The patient's eyes must also be properly protected during the entire procedure.

4. All objects within the area in which there is a possibility of exceeding the allowed limits of laser irradiation (known as laser hazard area), including the floor, must have diffusely reflecting surfaces or be covered with diffusely reflecting material. For example, endotracheal tubes must be able to resist the laser radiation.

5. Explosive or easily inflammable materials, liquids or gases can ignite fires. Materials which might explode should not be kept in the laser hazard area. Inflammable drapes, surgical gowns, gauze or other flammable materials must be kept out of the beam path.

Despite these required laser safety principles, laser technology opens up new clinical application possibilities in ENT surgery, specifically in larynx surgery. The microscope integrated laser facilitates many procedures, or indeed makes them possible in the first place. In the field of ENT, among others, lasers are already used for endolaryngeal laser surgery or for laser surgical treatments within the ear such as stapedotomy or cochlear implantations. In particular, transoral laser surgery for laryngeal malignancies represents an important approach for the organ and function-preserving treatment of head and neck cancer. Beside these applications, others will continue to emerge in the future as laser technology and its integration into the surgical microscope are further refined.

Minimally Invasive Navigated Procedures on the Skull Base

Omid Majdani, M.D.

Over the past 20 years, image-guided technologies and approaches have significantly helped to enhance minimally invasive surgical procedures. Today, navigation technologies are well established in many intraoperative fields, particularly in the area of skull base surgery.

Navigation technology has played a dominant role in computer-assisted surgery (CAS) and has established itself in many fields as an intraoperative diagnostic instrument, in particular, in head and neck surgery. The introduction of patient images enabled by the navigation system into the surgical microscope facilitates instantaneous visualization of the surgical site and the spatial location of surgical instrumentation. The depth of the surgical approach can also be visualized with the navigation system by determining the focusing distance of the microscope. This is especially helpful in demonstrating the position of adjacent anatomical structures by use of the navigation system. Using navigational technology, a prospective planned approach to critical structures is possible, minimizing procedural complication rates typically experienced in the absence of this technology.

Today's navigation systems can detect objects in space via a non-contact technique. Optoelectronic systems locate points in space by firm placement of two or more cameras and space determination by triangulation. Points are marked by reference objects which contain infrared diodes (active optoelectronic systems) or reflector elements (passive systems).[1] The basic principle of electromagnetic navigation systems is the temporally and locally changing of magnetic fields. An electromagnetic transponder is fixed to the patient's head by adapting it to a headset, and a magnetic field sensor is attached to the distal part of the instruments.

The development of intraoperative navigation systems in the last 20 years has not solely concentrated on incremental technological achievements, but also on the increasing realization of ergonomic design, user operability, surgical efficiency, microscope system integration and its financial feasibility.

Anterior skull base procedures

The main application area for navigation systems is the surgery of the frontal skull base such as sinus surgery procedures. Critical structures such as the carotid arteries, the optical nerves and the orbits,

Fig. 1: The integration of navigational systems into the surgical workflow is a precondition for the routinely use of the systems.

the skull base and the hypophysis can be segmented preoperatively. During surgery, the position of the instrument and its distance to the highlighted critical structures can be demonstrated on the navigation screen. Similarly, in hypophysis surgery, the navigation systems represent a genuine alternative to the intraoperative fluoroscopy to ensure proper identification of this critical anatomical structure.

The injection of microscope videos into the navigation screen enables the illustration of the definite position of the instrument (microscope video) and the virtual position of the instrument calculated by the navigation system on the same screen. This kind of representation can be very useful for intraoperative documentation.

Surgery on midface fractures can also be optimized using intraoperative navigation systems. These cases present tripoid or orbital fractures, which are mostly unilateral in nature. Navigation assistance can be very helpful in the process of reconstructing the facial symmetry and ensuring the desired patient outcome. This procedure first involves a relatively complex preoperative segmentation of the non-fractured side. The anatomy of the unaffected side can then be mirrored to the contralateral fractured side. The symmetry planes can be computed on the basis of classical anatomical landmarks (sella turcica, supraorbital notch, porion, nasion and the anterior nasal spine).[2] During the surgery, the desired position of the fractured elements can be controlled by navigating their endpoint position and compared to the preoperatively calculated position.

Lateral skull base procedures

Procedures of the lateral skull base region such as acoustic neurinoma or infratemporal approaches to the skull base place make special demands on navigation systems and surgeons. Before the completion of preoperative images, special fiducial markers for registration need to be affixed to the patient. These markers are identified as artificial landmarks for the registration procedure at the beginning of the

Fig. 2: Navigational systems may be very useful teaching instruments, since the learners have biomedical information about the actual position of the instrument during the surgery.

surgery. By fixing a reference adapter to the skull, maximum navigation accuracy can be achieved. For tumor removal surgery, the overlay of CT scans and MRI images is reasonable in order to get both an optimal representation of the expansion of soft tissue, for example, tumor borders and sufficient imaging of bony erosions. Graphic data fusion can be accomplished, however, with arbitrary imaging modalities (CT scan and ultrasound, MRI and PET, etc.). If the tumor is very deep with difficult accessibility (e.g., biopsies at the skull base), it can be helpful to plan the trajectory preoperatively. The navigation system indicates during the surgery the planned direction, any deviations from the intended course, and the distance to the goal.

Soft tissue navigation

Due to the instability of soft tissue and its unpredictable position after the initial surgical approach, intraoperative navigation is not possible at this phase of the procedure. Baseline images for navigation must be updated intraoperatively to enable the surgeon to successfully complete the procedure. In order to capture the actual position of the soft tissue after trepanation of the intraoperative CT scan, a MRI or ultrasonics can be helpful. In future operating theaters, intraoperative imaging will be integrated more and more into all surgical systems. Since the complexity of the whole system continues to grow, ergonomic aspects in the workflow are becoming more and more important. The control of the different intraoperative diagnostic and therapeutic tools should be centralized to a common console which is easily attainable by the surgeon. As in head and neck surgery, most cases are done with a microscope, using it as a control panel for the operating room, and instruments seem to be a meaningful and feasible idea.

Robotic applications

New CT scan technologies based on flat panel detector volume computer tomography (fpVCT) could enhance the detail resolution capability of the image. It could be shown that by using fpVCT data for navigation, the localization accuracy of navigation systems can be improved.[3] This allows performing highly precise navigated procedures at the skull base. One possible procedure is the minimally invasive freehand or robot assisted cochlear implant surgery. A pilot

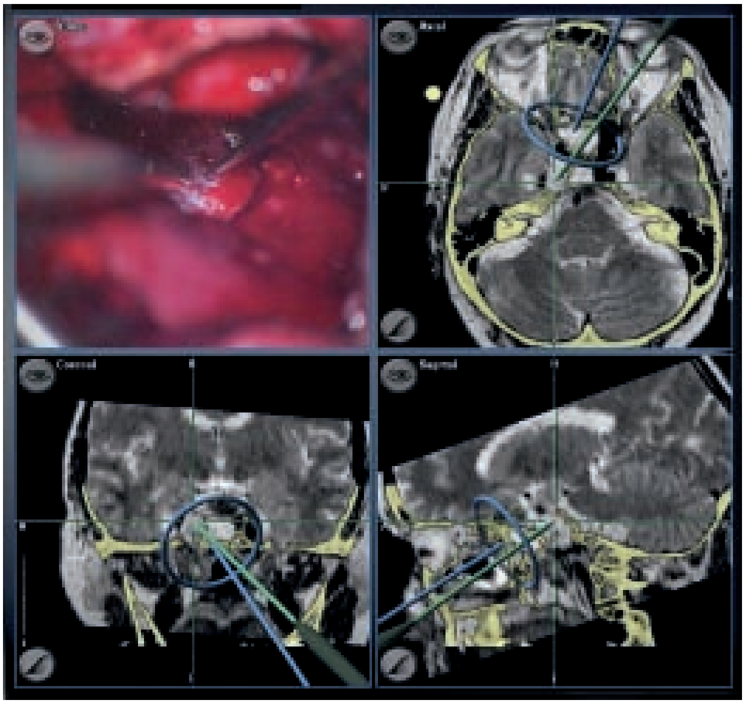

Fig. 3: The virtual position of the instruments calculated by the navigational system and the distance to the critical structures are demonstrated on the navigational screen. The injection of microscope videos into the same screen enables the illustration of the definite position of the instruments.

study was done on human cadaver temporal bones. The fpVCT image acquisition was done after 5 miniosteosynthesis screws were placed for registration procedure. The scan data was transferred to the planning computer. An approach trajectory was planed from the mastoid surface to the round window membrane niche without touching the critical anatomical structures (facial nerve, chorda tympani, sigmoid sinus, semicircular ducts and the cochlea). The data was transferred to the control unit of the robotic device. A medical drill was attached to the end effector. The robot was activated to move along the planed trajectory. For evaluating the result of the drill work, we performed postoperative CT scans, followed by a conventional surgical mastoidectomy on the temporal bones. With both methods, we were able to see that the critical structures were not damaged and the cochlea was opened at the planed target point.

The evolution of navigation technology has not slowed down despite the introduction of highly developed durable and multifunctional systems. Within this framework, a renaissance of robotics in medicine, this time based on small robots, seems to be becoming a reality.

Image courtesy:
Fig. 1 and Fig. 3: Omid Majdani, M.D., Department of Otolaryngology, Medical University of Hanover, Germany

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Skull Base Surgery – A Look at Current Trends and Benefits of New Developments

an Interview with Bruce J. Gantz, M.D.

The Department of Otolaryngology at the University of Iowa, founded in 1922, is among the oldest in the United States, and is recognized as one of the most comprehensive in the world. US News and World Report magazine has ranked this department among the top otolaryngology programs in the U.S. for the past 10 years.

INFORMED met with Bruce Gantz, M.D., Professor and Head, The Brian F. McCabe Distinguished Chair in Otolaryngology – Head and Neck Surgery at the University of Iowa College of Medicine and the University of Iowa Hospital and Clinics.

Dr. Gantz specializes in the management of neurosensory or inner ear hearing loss, chronic ear disease, conductive hearing loss, balance disorders, facial nerve disorders and tumors of the cranial nerves. He has taken major leadership roles in the establishment of the National

Institute for Deafness and other communications disorders. Dr. Gantz's current research interests include: cochlear implant clinical research, management of facial paralysis, hearing preservation in acoustic tumor surgery and management of chronic otitis media with cholesteatoma. In addition, Dr. Gantz has made major clinical contributions in skull base surgery. His publications include over 170 papers, and he has contributed to 50 books and chapters.

INFORMED: What are some of the new developments you are seeing in ENT surgery?

Gantz: There is a trend to advance endoscopic approaches to the skull base, yet it is not known if reducing access will provide improved outcomes. The microscopic approach to tumor removal in the skull base is the gold standard today, and growth and development of multidisciplinary teams to manage tumors of the skull base will continue.

INFORMED: Would you please describe the advantages of skull base surgery?

Gantz: Microscopic access to benign tumors that are intimately associated with vital neural and vascular structures reduces morbidity and mortality for the patient. The main indication for skull base surgery is the removal of various benign skull base and brain tumors. The occurrence of tumors varies with the age of the patient, his or her medical history and family history. Advances in microsurgical techniques, an increased understanding of both the skull base anatomy and behavior of disease processes, as well as improvements in neuroimaging have allowed tumors to be successfully treated.

> **"Skull base or cranial base surgery is one of the most complex areas of anatomy, it requires the closest cooperation between different services to ensure a positive outcome for the patient."**

INFORMED: What is the connection between neurosurgery and ENT surgery?

Gantz: An interactive team of surgeons with different training and expertise has expanded the surgical approaches to remove tumors of the skull base that were thought to be inoperable 25 years ago. Because skull base or cranial base surgery is one of the most complex areas of anatomy, it requires the closest cooperation between different services to ensure a positive outcome for the patient.

A skull base team consisting of neurotologists, neurosurgeons, head and neck surgeons, neuro-ophthamologists, neuroradiologists and interventional radiologists manage large skull base disorders. The skull base approaches developed by neurotology and head and neck surgeons have assisted neurosurgery in reducing morbidity and mortality for tumors of the anterior skull base, orbits, clivus, petrous ridge, petrous apex, jugular foramen and cranial nerves. Our team of neurotologists, head and neck surgeons and neurosurgeons perform more than 75 skull base cases per year.

INFORMED: What impact has Carl Zeiss Meditec had on ENT surgery?

Gantz: The ZEISS microscope has been instrumental in providing us access to the ear and skull base for more than 50 years now. Recent advances in otology and neurotology have been possible because of the microscopic precision afforded by ever-improving optics and illumination. In skull base surgery, the mobility of the microscope is essential, as well as critical, and changes in position, magnification and focus are occurring every few minutes as the surgeon works around multiple areas, including vital neural and vascular structures. As a result, it is extremely easy to make numerous adjustments hundreds of times during each procedure. The use of the microscope is essential to what we do, and its impact on mortality rates is significant. Very rarely do we have a problem with patient survival.

INFORMED: How has OPMI Pentero improved surgical procedures, and what are its benefits to you and your department?

Gantz: We find the OPMI Pentero microscope to be more surgeon-friendly and mobile than previous microscopes. The expanded imaging and video capabilities have added to our educational mission as well as helped to improve documentation. The new video touch screen is intuitive for all users, and it eliminates the need for an additional video monitor. Additionally, the digital patient files allow for instant access to all patient files during surgery.

INFORMED: Please describe the role of the surgical microscope during skull base surgery.

Gantz: The ZEISS microscope is critical to providing access to previously unresectable tumors. We could not provide the level of patient care and outcomes if the microscope was not available. It truly is the gold standard in imaging, and much of what we do today wouldn’t be possible without it. For example, we are able to use micro dissection techniques to safely remove tumors, while preserving adjacent structures such as facial nerves and auditory nerves. Additionally, the microscope has enabled us to significantly reduce mortality and improve the success rate of skull base surgery outcomes. Survival rate for benign tumors is extremely high, and reduction of the morbidity associated with the damage of neural and vascular structures also continues to improve.

> **“Recent advances in otology and neurotology have been possible because of the microscopic precision afforded by ever-improving optics and illumination.”**

INFORMED: It was a pleasure to meet you. Thank you very much for this informative interview.

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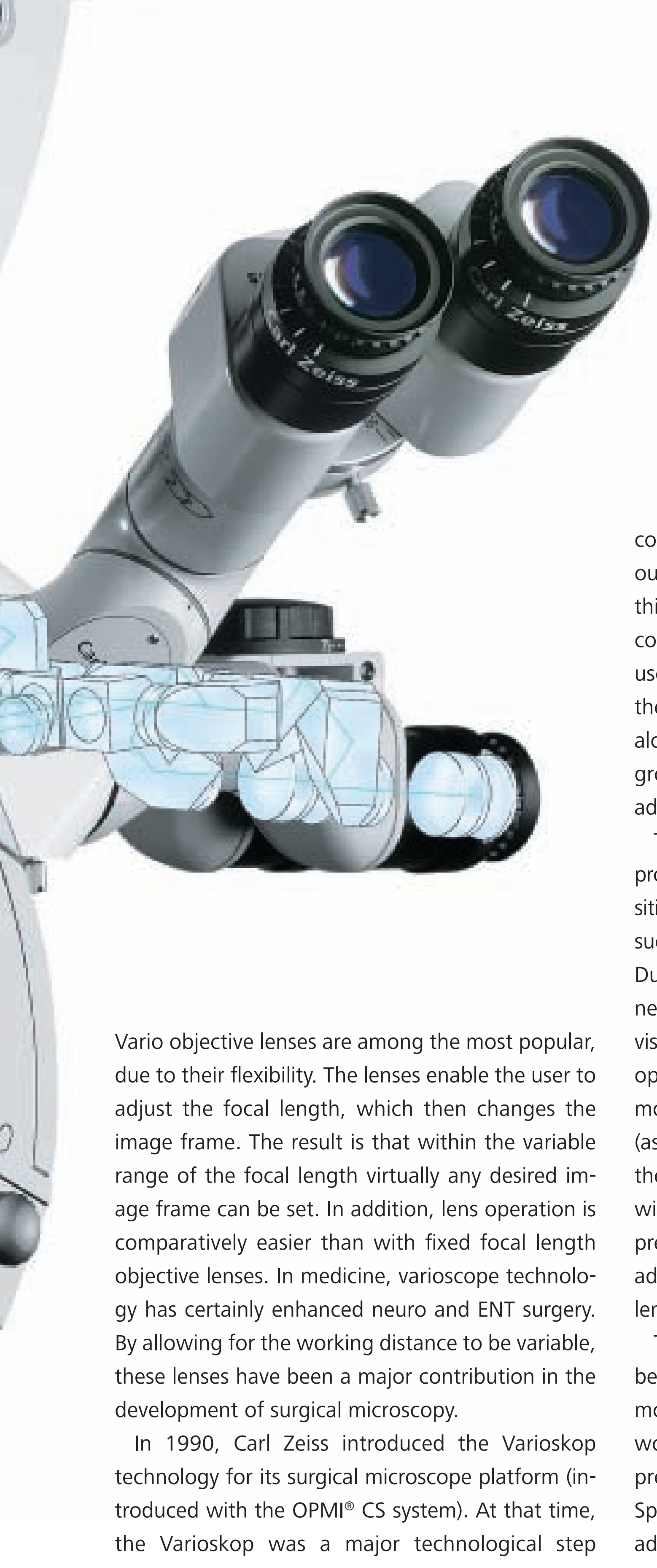
Vary Your Scope

How varioscope technology maximizes system ergonomics during treatment

Working with even the most convenient and ergonomic surgical microscope over a lengthier period of time frequently results in physical discomfort and related complications. With the introduction of the Varioskop$^{\text{TM}}$ technology, Carl Zeiss significantly improved operator comfort during surgical procedures.

When using a surgical microscope, comfort during treatment starts with the first look through the eyepieces. The region of interest should always be in focus without compromising a convenient and ergonomically correct working posture – particularly during long procedures. To optimize system design and improve procedural efficiency, manufacturers of surgical microscopes integrated variable focusing systems into the microscope optics which allow a quick set-up of the working distance. These vario objective lenses allow the surgeon to move the focal plane up and down without the need to change the objective lens – thus saving both time and effort. The term "vario objective" (or varioscope) is taken from the field of photography and technical optics, associated with still and film cameras.



Vario objective lenses are among the most popular, due to their flexibility. The lenses enable the user to adjust the focal length, which then changes the image frame. The result is that within the variable range of the focal length virtually any desired image frame can be set. In addition, lens operation is comparatively easier than with fixed focal length objective lenses. In medicine, varioscope technology has certainly enhanced neuro and ENT surgery. By allowing for the working distance to be variable, these lenses have been a major contribution in the development of surgical microscopy.

In 1990, Carl Zeiss introduced the Varioskop technology for its surgical microscope platform (introduced with the OPMI® CS system). At that time, the Varioskop was a major technological step forward and improved the use of microscopes in surgical procedures, allowing, for the first time, a continuous extension of the working distance without the need to change the objective lens. How was this possible? The Varioskop objective lens system consists of two lens groups with five lenses that are used to change the working distance. By displacing the upper lens group (comprising of three lenses) along the optical axis relative to the lower lying lens group, the actual working distance can be easily adjusted (see Fig. 1).

The basic rationale behind the Varioskop optics is to provide the surgeon with a comfortable working position, even for surgeries that may last several hours such as paranasal sinus or skull base procedures. During the surgical procedures the working distance needs to be adjusted frequently in order to clearly visualize the more distal areas of the anatomy as the operation progresses. Rather than permanently moving the whole microscope body for refocusing (as was standard procedure with a fixed focus lens), the surgeon can now adjust the working distance with two fingers using the Varioskop optics. High precision focusing and ease of use are the decisive advantages of Varioskop optics over single focus lenses.

The setting of the desired working distance can be adjusted manually or, in most ZEISS systems, via motorized integrated systems. In special cases, the working distance can also be set using a highly precise auto-focus mechanism such as the ZEISS SpeedFokus system. Today, the seamless, motorized adjustment of the focal plane in the working distance (range: 200 to 400+ mm) is now the standard in neuro and ENT surgical microscopes (e.g.,

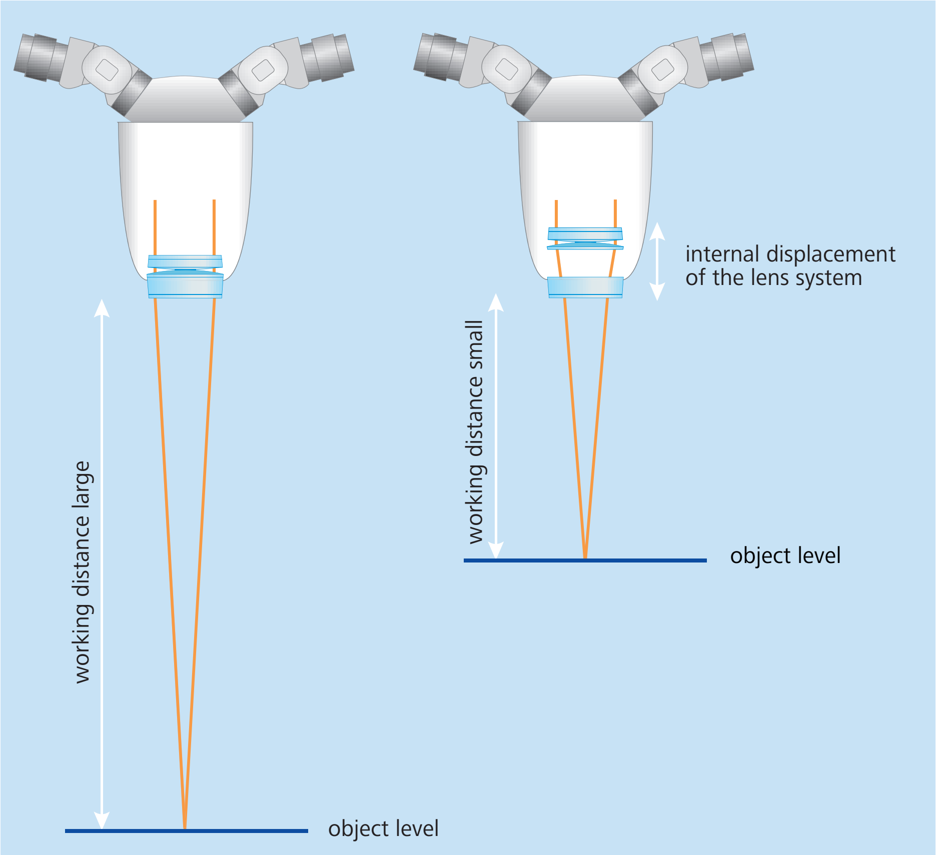


Fig. 1: The working distance can be changed according to the internal displacement of the Varioskop's second lens system.

> **"The Varioskop objektive lens system has changed the way surgeons perform surgery."**

250 mm for ear applications or 400 mm for larynx applications). Moreover, surgical microscopes with varioscope lenses offer a greater depth-of-field with the same working distance compared to exchangeable lenses with a fixed working distance. Varioscope objective lenses have also recently been finding their way into other disciplines, including dental therapy. Here, the varioscope allows the dentist to work in a more relaxed working position – especially important during longer procedures. In the field of ENT surgery, Carl Zeiss has equipped the manual system, OPMI® Movena®, as well as the two motorized systems, OPMI® Sensera® and OPMI® Vario®, with Varioskop technology, which provides the surgeon with improved procedural efficiency. The latest innovation in this field is the newly developed Varioskop technology in OPMI® Pentero® (range: 200 to 500 mm), meeting the most demanding requirements for longer working distances in spinal and ENT-larynx surgeries. The new motorized Varioskop zoom system provides a longer working range and ergonomics which can be especially critical when using longer instrumentation, or when the patient's anatomy demands it.

Since its introduction, the Varioskop objective lens system has changed the way surgeons perform surgery. By enabling the seamless adjustment of the working distance and focus, surgeons can better focus on their surgical procedures.

Honor to Whom Honor Is Due

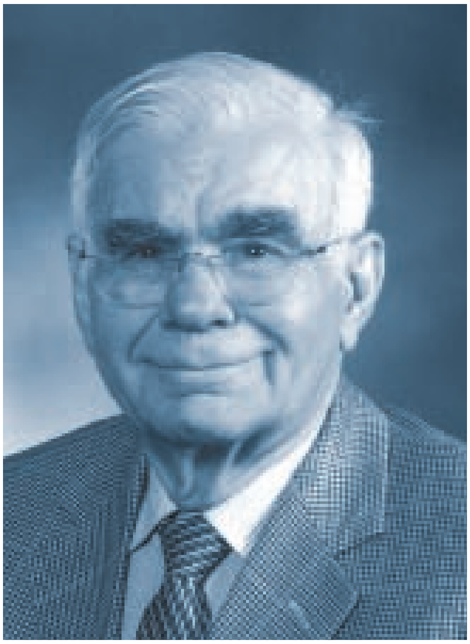
Volker Seifert, M.D., Ph.D. describes the Carl Zeiss Honorary Lecture and Visiting Professorship initiated and hosted by the Department of Neurosurgery of the Johann Wolfgang Goethe-University

Modern microneurosurgery owes its existence not only to a combination of key technological and application developments, but also to the contributions of a select group of pioneering neurosurgeons. Recognizing their achievements and the importance of the medical field, the Department of Neurosurgery of the Johann Wolfgang Goethe-University in Frankfurt am Main, Germany, initiated and hosted an honorary lecture series and visiting professorship co-sponsored by Carl Zeiss.

Modern microneurosurgery was created and shaped by three defining aspects: the development of special microneurosurgical techniques, the emergence of the surgical microscope, and the exact reappraisal and visualization of the complex microneuroanatomy from a surgical viewpoint. It was also shaped by three surgeons who played a decisive role in stimulating microsurgery and defining the direction it has taken right from the outset: Professors Gazi Yasargil, Majid Samii and Albert L. Rhoton. These renowned surgeons can truly be described as "giants of microneurosurgery."

In the mid-1990s, I started to think about how these founding fathers and early developers of modern microneurosurgery could be honored within an academic university framework. The Carl Zeiss company offered its services as a partner and co-sponsor, and gave its name to this initiative. In my opinion, no other company is so inextricably linked to the development of the surgical microscope and microtechnology.

Together with Harvey Cushing, Professor Gazi Yasargil has been rightly honored as the neurosurgeon of the 20th century. Without Gazi Yasargil's pioneering achievements, modern microneurosurgery would certainly not exist in the form in which we practice it today. Not only was it his fundamental idea to use the surgical microscope consistently in all surgical procedures on the brain, and to constantly enhance its design. It was also his principle, on the basis of an in-depth understanding of microanatomy, particularly the anatomy of the brain's basal cisternae, to use an approach based on maximum anatomical orientation and minimally traumatic exposure of the site of surgery. This is demonstrated not only in numerous scientific publications, but also, and above all, in his six-volume lifework "Microneurosurgery" – and also, of course, by the huge number of patients he has helped with his surgical genius. Many microneurosurgeons, and I am one of them, have frequently visited Professor Yasargil's hospital in Zurich, Switzerland, and spent many hours in his operating room. I conducted many long and fruitful discussions with him there, to which I think back with great pleasure today. In view of Professor Yasargil's very close relationship with Carl Zeiss and his direct influence on the development of the surgical microscope, it was a great pleasure to commend him as the first honorary lecturer.



M. Gazi Yasargil, M.D.

At a ceremony held at the Frankfurt University Hospital on September 21, 2004, Professor Yasargil gave the first Carl Zeiss Honorary Lecture titled "Origin, Development and Future of Microneurosurgery."

One year later, Professor Majid Samii was the second lecturer selected for this honor. There can be no doubt among surgeons that the importance

Majid Samii, M.D., Ph.D.

of Professor Samii's clinical and scientific lifework for the daily work of neurosurgeons around the globe is comparable to that of Professor Yasargil's achievements. Over the decades, the focus of Professor Samii's work has been, and continues to be, surgery of complex processes of the skull base. His achievements are centered in particular on the field of difficult tumor identities such as petroclival meningeomas and, of course, surgery of acoustic or, as it is now correctly termed, vestibular schwannomas. Apart from his direct impact on skull base microsurgery, Professor Samii is also seen as one of the great visionaries of neurosurgery. By founding the International Neuroscience Institute in Hanover, Germany, he laid the basis for concentrating all areas of neuromedicine in one location: from the experimental neurosciences, basic research, clinical research and clinical-surgical routine, to the development of future-oriented projects such as neurobionics.

During the award ceremony on October 26, 2005, Professor Samii gave a lecture titled „Challenges of Neurosurgery in the Future."

Professor Albert L. Rhoton was the third honorary lecturer to be invited. As previously noted, modern microneurosurgery has been shaped not only by the development of the surgical microscope and the emergence of microneurosurgical techniques, but also, in the past twenty years, by an increasingly profound understanding of the extremely complex microanatomy. No other surgeon has contributed more to modern, surgically oriented microanatomy than Professor Albert L. Rhoton. With his staff and guest physicians, he has worked out practically the entire microanatomy of the brain and documented it in wonderful drawings and photos. All responsible neurosurgeons repeatedly refer to this excellent work not only during their training to become neurosurgeons, but also in everyday practice. It is described and combined in detail in the book „Cranial Anatomy and Surgical Approaches" which covers Professor Rhoton's lifework.

I have always found it impressive how Professor Rhoton derived his intraoperative microsurgical approach from his studies in microanatomy and presented it in his written work. Anyone leafing – or even better, working through his book – will soon be overcome by the wealth of information, and in particular, by the instructive anatomical illustrations.

Albert L. Rhoton, M.D.

During the award ceremony on November 25, 2006, Professor Rhoton gave a lecture titled “The Art and Beauty of the Brain – Reflections of a Neurosurgeon.”

With this lecture, Professor Rhoton ended the series of Carl Zeiss Honorary Lectures. The Carl Zeiss Honorary Lectures honored the achievements of the three key founding fathers of modern microneurosurgery. Although the actual honorary lectures have now been concluded, the lecture series focus on microneurosurgery will be continued. At the same time as the Carl Zeiss Honorary Lectures were ended, therefore, the Carl Zeiss Visiting Professorship was created. Twice a year, in the spring and in fall, world-renowned clinical neurosurgeons with special expertise in microneurosurgery will be invited to Frankfurt, Germany, for several days as guest professors. The event is combined with lectures and, where necessary, with workshops and joint operations with the guest professor.

The major goal is to convert the one-time lecture into the dynamic form of a Visiting Professorship in order to also welcome and honor outstanding microneurosurgeons of the younger generation within a university and academic framework here at the Frankfurt University Hospital. The first Carl Zeiss Visiting Professor in the spring of 2007 was Professor Necmettin Pamir, professor and chairman of the Department of Neurosurgery at the Marmara University in Istanbul, Turkey. He was a guest at our hospital from April 16-19, 2007.

We think that, with this new approach, we have found a way of further intensifying the many years of cooperation between outstanding microneurosurgeons, Frankfurt University Hospital and Carl Zeiss. At the same time, we would like to create a forum where current and future advances in microneurosurgery can be presented within an academic framework.

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Facts and Figures

Year ear trumpets were described first: **1627**

Year of the first attempt to use an artificial substitute for the tympanic membrane: **1640**

Year the first glottiscope was developed: **1829**

Year Carl Zeiss developed the first microscope: **1847**

Year laryngoscopy was developed: **1855**

Year of the first audiometer: **1879**

Year of the first electric hearing device: **1898**

Year Albert Einstein described the theoretical preconditions for the laser principle: **1917**

Year OPMI 1 was developed by Carl Zeiss as the first surgical microscope for ENT: **1953**

Year of the first cochlear implantation: **1957**

Year the laser was combined with a ZEISS surgical microscope: **1969**

Year since the laser is used in ENT routinely: **1972**

Year of the first digital hearing aid: **1983**

Estimated number of cochlea implants worldwide by 2006: **40,000**

Estimated number of people in the world with a hearing loss by 2006: **560 million**

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