NYU Langone Health

OUR COVID-19 EFFORTS

Read about NYU Langone Health's response to the challenges of the COVID-19 pandemic.
See insert.

Neurosurgery

2020 HIGHLIGHTS

Cover image: Anatomy of the human brain.
RENDERING: SKETCHFAB

JOHN G. GOLFINOS, MD

Joseph Ransohoff Professor of Neurosurgery
Chair, Department of Neurosurgery
Professor of Otolaryngology—Head and Neck Surgery

MESSAGE FROM THE CHAIR

The arrival of COVID-19 in New York City in early 2020 was swift and unrelenting, with significant impacts across the continuum of care. As we adapted models to meet the needs of COVID-19 patients—and our department readily supported the all-hands-on-deck response—we continued to push the boundaries of neurosurgical outcomes for patients whose complex conditions demanded immediate intervention, pandemic or not.

Our excellent outcomes reached new heights for patients with precarious clinical pictures most surgeons would not be willing or equipped to treat. We achieved successful resections for lesions in the most delicate and inextricable locations while preserving function and quality of life—a credit to our wealth of world-leading surgical expertise combined with leading-edge imaging technologies. All of this was further fueled by the launch of our bold new initiative aimed at harnessing the power of artificial intelligence to enhance clinical outcomes—not only in neurosurgery, but also with potential applications across medicine.

Pursuing optimal outcomes and enhancing quality of life for our patients is our foremost responsibility. How we get there as a multidisciplinary team is a conscious choice: to continually apply innovation, reimagine our approaches, and uncover new possibilities for the patients who depend on us.

BEST HOSPITALS U.S.News NATIONAL NEUROLOGY & NEUROSURGERY 2020-21

#6

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30

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3

NEUROSURGERY RESIDENTS IN TRAINING ANNUALLY

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Howard A. Riina, MD
PHOTO: KEIJI DRYSDALE

Unmatched Surgical Expertise, Advanced Neurovascular Imaging Combine to Enable Risky Resection

Prognosis Transformed for Patient with Cavernous Malformation Considered Unresectable

When other, less invasive measures failed to contain an aggressive, deep-seated cavernous malformation, a patient with worsening neurological complications sought the expertise of NYU Langone Health neurosurgeons with experience in successfully removing such high-risk lesions. Aided by advanced imaging and a high degree of surgical skill, a multidisciplinary team carefully planned and executed the safe resection of the lesion, which others had considered inoperable—preserving the patient's function and transforming his prognosis.

WEIGHING THE RISKS OF A COMPLEX RESECTION

The patient, a 38-year-old male, had been diagnosed with the cavernous malformation in 2004 after presenting with acute hemorrhage in his right basal ganglia. Over time, the lesion grew larger and began to compromise the patient's function, causing sensory loss and left-side deterioration that impacted his gait and upper-extremity strength. A repeat MRI performed at NYU Langone in 2019 revealed what had become a very large cavernoma in the thalamus with associated hemorrhage.

In the 15 years since his diagnosis, the patient had sought treatment at other institutions. With watchful waiting as the primary recommended management approach, the patient had a shunt placed in 2010 when he developed obstructive hydrocephalus, and Gamma Knife® radiosurgery was performed to prevent recurrent bleeding. Surgery to remove the lesion had been deemed too risky due to the location of the malformation in the thalamus, with an increased risk for postoperative hemiplegia due to the lesion's anticipated close proximity to the corticospinal tract and other critical structures. However, Howard A. Riina, MD, professor in the Departments of Neurosurgery, Radiology, and Neurology and director of the Center for Stroke and Neurovascular Diseases, saw surgery as the only option and charted a path toward a safe resection with the multidisciplinary expertise in place at NYU Langone.

"These lesions are typically much smaller, but this one was upwards of 8 centimeters, compromising a significant portion of the patient's brain—meaning he was already hemiparetic from the lesion itself despite the outside interventions he received," notes Dr. Riina. "So the question was, could we get this out and preserve most of his function? We felt that we had the right team in place to safely achieve that delicate balance."

DIVISION OF LABOR INFORMS COMPREHENSIVE SURGICAL PLAN

The procedure—a right frontal craniotomy, shunt removal, and resection of the cavernous malformation—required a "tumor mentality" to remove the vascular lesion. "Cavernous malformations can grow like a neoplasm, destroying the brain's structures as they increase in size and bleed," explains Dr. Riina. "So the approach itself was just as important as the lesion's removal, in order to preserve healthy tissue."

For that reason, the surgical team included John G. Golfinos, MD, the Joseph Ransohoff Professor of Neurosurgery and chair of the Department of Neurosurgery, who would complement Dr. Riina's vascular expertise and perform the delicate approach. Careful, coordinated surgical planning would utilize NYU Langone's most advanced technical capabilities, imaging modalities, and multidisciplinary talent to achieve the best possible outcome. "This is not a procedure where you look at an image and say right away, 'I'm going to perform the operation this way,'" notes Dr. Riina. "It's about creating an initial plan, then adding layers of imaging, and revisiting your thought process. Only then do the team and the plan start to come together."

Functional MRI combined with advanced tractography would define the proximity of the lesion to the brain's eloquent cortex and white-matter pathways to identify a safe anatomical corridor to reach and then resect the deep-seated lesion.

"Before you reach the lesion, you have to traverse or avoid several brain anatomy structures that control movement, coordination, sensation, and potentially language—so my role was to guide Dr. Golfinos and Dr. Riina to a safe window toward a lesion perilously close to the cortico-spinal tract," explains Timothy M. Shepherd, MD, PhD, assistant professor in the Department of Radiology and director of brain mapping. "The functional MRI and tractography provide maps of key brain anatomical structures, information that must then be interpreted and applied correctly by experienced surgeons."

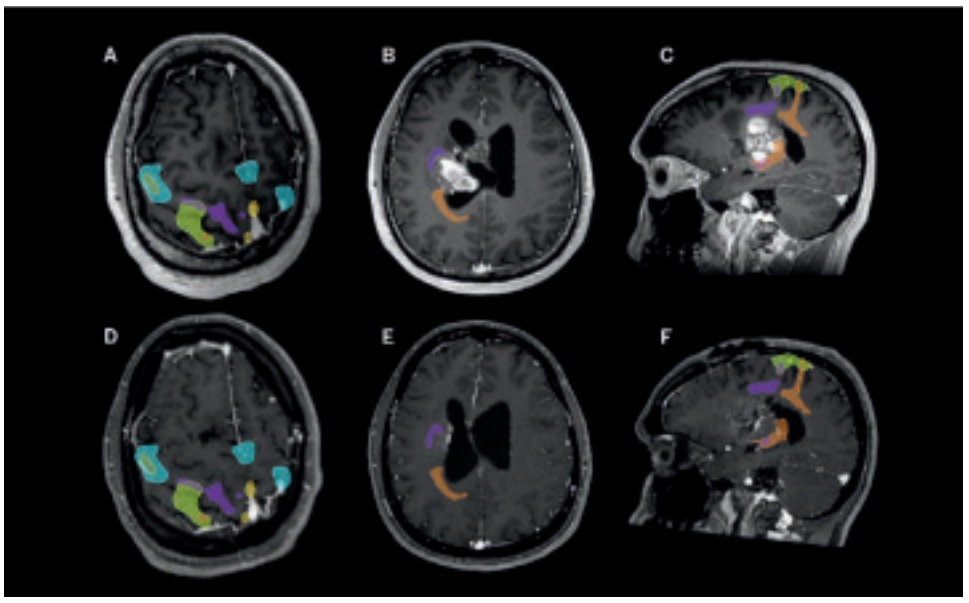
EVERY CELL RESECTED, THROUGH CAREFUL EXECUTION

With the carefully crafted plan in place, Dr. Golfinos began the surgical approach, using image guidance to reopen the patient's right frontal incision, performing a right frontal craniotomy and removing the previously placed shunt catheter.

Dr. Riina then moved in toward the lesion, using the Brainlab system to map the contours of the tumor. He performed initial dissection and removed residual evidence of prior hemorrhage. With the gross resection complete, the perimeter of the cavity was again mapped using intra-operative MRI to ensure no residual malformation remained. "You have to make sure you've gone deep enough and removed the entire lesion because if you leave even one cell behind, it will come back," explains Dr. Riina.

When a small, deep residual portion of the cavernous malformation was identified on the intraoperative MRI, the resection continued and the lesion was further resected using residual as a new image guidance target from the updated MRI, projected into the operating microscope. When complete resection was confirmed, the dura and wound were closed, and the patient was taken to the intensive care unit in stable condition, able to follow commands and move his right side with normal power. The patient recovered well and maintains his preoperative leg and arm movement—function he would have lost without intervention.

"This lesion was allowed to grow uninhibited for far too long—nearly 20 years—and eventually it would have killed this patient," says Dr. Riina. "Despite the risks, we knew that we had to take it out, not only to preserve function but also to save his life. And fortunately, here at NYU Langone, we had the right team and technology to give him the best possible outcome." ■



Functional MRI and diffusion tractography superimposed on preoperative (top row) and postoperative (bottom row) postcontrast volumetric T1-weighted MRI. Images demonstrate an oblique axial craniotomy view before (A) and after surgery (D). The corridor to reach the cavernoma was lateral to the supplementary motor area and anterior to the corticospinal tract and central sulcus. The middle and right images demonstrate the cavernoma in axial (B and E) and oblique sagittal planes (C and F) relative to the corticospinal and thalamocortical tracts; postoperative images demonstrate removal of the cavernoma with the white-matter pathways preserved.

Artificial Intelligence Fuels Unprecedented Neurosurgical Progress, with Broad Potential Impact

With a deepening focus on unleashing novel applications of artificial intelligence (AI) across—and beyond—neurosurgery, a multidisciplinary team of physicians and mathematicians is collaborating on advanced approaches to diagnosis and patient care, developing data-driven methods that hold potential for progress across the continuum of medicine.

A SPECIALTY UNIQUELY POISED TO LEAD WITH DATA

Investigations into clinical applications for AI, with a focus on neurosurgical care, have gained significant momentum with the recruitment of Eric K. Oermann, MD, assistant professor in the Departments of Neurosurgery and Radiology and a leading expert in AI applications in medicine. Dr. Oermann brings deep expertise at the intersection of neurosurgery and mathematics to research projects that apply data science and algorithms to answer pressing neurosurgical questions as well as those that apply to medicine far beyond neurosurgery.

"Neurosurgery tends to be the technical spearhead of the broader medical world, innovating to benefit our own patients and medicine with a capital *M*," he says. "So our discoveries in AI are at the next forefront of technological innovation in medicine, writ large."

Dr. Oermann developed the vision for his research in close partnership with Daniel A. Orringer, MD, associate professor in the Departments of Neurosurgery and Pathology. Their combined clinical and mathematical expertise will enable them to tackle questions that neither researcher could effectively address alone. "Together, we bridge

Eric K. Oermann, MD (left), Daniel A. Orringer, MD (right)

the gap between science and patient care," notes Dr. Orringer. "Our collaboration plays to Eric's strengths as an applied mathematician, so there's complete integration—patient to bench to computer chip to bedside."

GLEANING MORE KNOWLEDGE FROM FEWER INPUTS

In one research vertical, Dr. Oermann is working to expand the Department of Pathology's molecular diagnostic capacity. Building on intraoperative data gathered using stimulated Raman histology (SRH)—the laser-based imaging technique pioneered by Dr. Orringer—the new approach applies data modalities focused on maximum tumor resection and patient safety to help surgeons make more informed real-time decisions. It will enable more accurate intra-operative pathological diagnosis while reducing procedure times—ultimately increasing overall gross margins. While this research is initially focused on glioma resection, it is expected to have impact far beyond that single tumor type. "It's really applicable to pathology affecting any organ," notes Dr. Orringer. "We are creating a framework so clinicians can utilize algorithms to make surgeries safer and more effective."

At the same time, Dr. Oermann is working to uncover alternative means of statistical sampling for clinical trials, using data efficiency approaches to get more scientific benefit from smaller sample sizes. One such approach, self-supervision, trains an algorithm to glean generalizable signals from the data set itself. "This is an issue germane to neurosurgery, as there are only so many patient sets you might see in a week or a year," Dr. Oermann notes. "But it's really applicable to any clinical trial, which makes the solutions we're building much bigger than the actual problems we're solving."

If the approach can be proved further, it could make clinical research more efficient and value driven in elucidating other rare or novel diseases like COVID-19 with smaller patient populations. "Our research related to the coronavirus is in many ways a metaphor for all of our AI work, where one clinical problem yields a mathematical project," concludes Dr. Oermann. "The theme of our research is that we're starting with neurosurgical problems, but in this case our approaches have proved very relevant to COVID-19—and really to medicine at large."

SHORTCUTTING TUMOR CLASSIFICATION, GENETICALLY

Dr. Oermann and Dr. Orringer are creating an algorithm to predict tumor treatment response based on genetic classification, building on previous clinical research that classified tumors into 10 categories based on molecular characteristics. The AI approach may ultimately circumvent the need for traditional genetic testing to determine tumors' specific mutations.

"There's a growing acceptance that genetics most efficiently predicts prognosis in response to treatment," says Dr. Orringer. "Many of these mutations are associated with a phenotype, and we can train algorithms to identify these based on morphological changes, intraoperatively, in a fraction of the standard time."

Equipped with this information at the time of surgery, clinicians can make more targeted decisions. A tumor identified as benign with a good surgical prognosis, for example, could be aggressively treated, ensuring full resection when safe. In addition, clinical trials for brain lesions increasingly incorporate an intraoperative component, so patients could potentially receive a novel agent in trial during surgery, driven by advances in AI-based diagnosis.

"This AI-based approach has the potential to fuel personalized medicine in a way that simply wasn't conceivable in the past," adds Dr. Oermann.

BUILDING EFFICIENCIES INTO SPINE CARE

An AI-assisted platform for spine surgery, currently under development, will subsume methods to stratify risk, predict outcomes, and prevent complications by guiding decision-making, optimizing patient workflow, and applying advanced imaging.

Dr. Oermann is investigating the use of AI in reconstructing CT scans based solely on MRI or in-office, three-dimensional EOS radiography, both to enhance care and to reduce unnecessary radiation exposure. "This would be a game changer for taking care of our spine patients," he says. "They'd come with the existing imaging, and we'd virtually conjure up the CT scan without an additional trip or extra imaging for the patient."

AI-enabled efficiencies are also under investigation for endovascular surgeries. Focal robotic applications have the potential to reduce surgical time and enhance precision by automating discrete techniques, such as a translabyrinthine approach—reduced to five minutes from an hour or more—as well as by placing instrumentation, such as pedicle screws, in the spine. "You have a pedicle, which is a circular tube, and the directions are forward, backward, rotate. It's a simple neurosurgical problem that we've translated into an engineering problem, which becomes a mathematical problem and solution," notes Dr. Oermann.

AI-INFORMED CROSS-CAMPUS COLLABORATIONS

In two projects with the NYU Center for Data Science, the team is investigating the application of AI to surgical endoscopy and to decoding signals from the human brain. The latter project, which Dr. Oermann has been working on for years, is developing tools for reverse engineering microprocessors that the team hopes will be immediately applicable to reverse engineering neural circuitry as well. "The beauty of mathematics is its universality. We believe that the techniques we develop for reverse engineering computers may one day be helpful for reverse engineering the human brain," says Dr. Oermann.

Chandra Sen, MD
PHOTO: JOSHUA BRIGHT

For a Rare Meningioma, Deep Experience Guides Successful Resection and Vision Restoration

When intensifying symptoms associated with a right-sided meningioma involving the orbit and brain led to functional decline, a 44-year-old female patient traveled to New York City from the United Arab Emirates for treatment. The tumor's magnitude and rare orbital location presented a surgical challenge that necessitated an open approach—a complicated operation requiring the delicate hands of an experienced, multidisciplinary surgical team capable of resecting the tumor and mitigating postsurgical cosmetic effects. Combining neurosurgical precision and nuanced reconstruction techniques, the team executed a carefully planned approach, safely resected the patient's tumor, and restored both her function and her appearance.

MENINGIOMA LOCATION COMPOUNDS SURGICAL COMPLEXITY

A 2014 MRI had revealed a rare, right-sided spheno-orbital meningioma in the context of recurring symptoms that included neck pain and headaches. In light of the complexities of resection and the patient's otherwise good health, her care team in the United Arab Emirates recommended watchful waiting.

Over time the patient's symptoms progressed, leading to proptosis of the right eye, facial numbness, and increasing pain. Serial imaging showed progression of the tumor. The patient traveled to the United States for consultation with NYU Langone neurosurgeons and scheduled surgery with Chandra Sen, MD, the Bergman Family Professor of Skull Base Surgery and co-director of the Anterior Skull Base Surgery Center.

With an in-depth review of the patient's history and new imaging studies, Dr. Sen confirmed a right-sided en plaque sphenoid wing meningioma with marked hyperostosis of the lateral and superior orbital walls. Though a thin layer of the tumor involved the periorbita on the right side, it did not appear to involve the optic nerves or the cavernous sinus.

The surgical challenge of resecting this type of benign tumor lies in both its extent and its delicate location at the base of the brain and orbit; aggressive action must be balanced with the preservation of critical function. "This was not a minimally invasive surgery—the tumor was like a pancake expanding over a large surface area, which necessitated a large craniotomy," explains Dr. Sen. "Navigating around critical structures to remove a tumor like this relies purely on expertise developed through experience."

WEIGHING THE RISKS OF A COMPLEX SURGICAL INTERVENTION

Dr. Sen counseled the patient on the complexities of the extensive cranial resection—including risk of injury to the eye, optic nerve, and brain—and the cosmetic implications of reconstructing the orbital wall. Although the team's depth of experience would mitigate much of that risk, he explained, long-term postsurgical effects, such as double vision, were possible.

Inaction, on the other hand, carried its own risks. Although the tumor was benign, its progressive growth would eventually lead to vision loss and neurological issues, and the protrusion of the eye would become disfiguring. An incomplete tumor resection would likely result in its regrowth, potentially necessitating radiation treatments that could be detrimental to the eye and the brain.

With the risks weighed, an aggressive surgical approach, in collaboration with plastic surgery for facial reconstruction, was deemed the best option for tumor removal, vision preservation, and a good aesthetic outcome. The surgery was scheduled for a subsequent trip.

CAREFUL RESECTION AND RECONSTRUCTION TARGET FUNCTION AND APPEARANCE

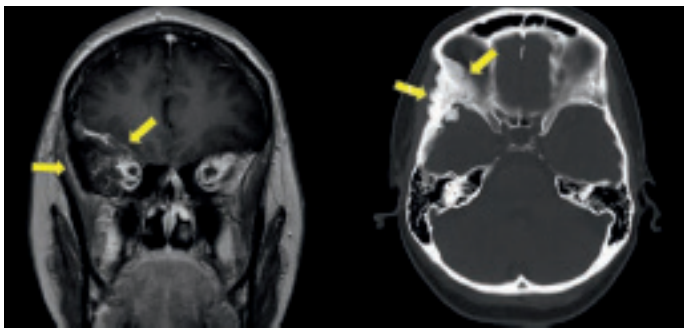
A surgical plan was developed, with the assistance of David A. Staffenberg, MD, professor in the Hansjörg Wyss Department of Plastic Surgery and Department of Neurosurgery, wherein complete tumor removal would be followed by reconstruction of the surgical defect to restore the patient's appearance and function.

Dr. Staffenberg began the skin incision with Dr. Sen—in order to properly perform the closure after reconstruction—opening the patient's cheekbone and orbit. Dr. Sen raised a wide frontotemporal bone flap to gain access to the plaque extension of the tumor into the convexity dura.

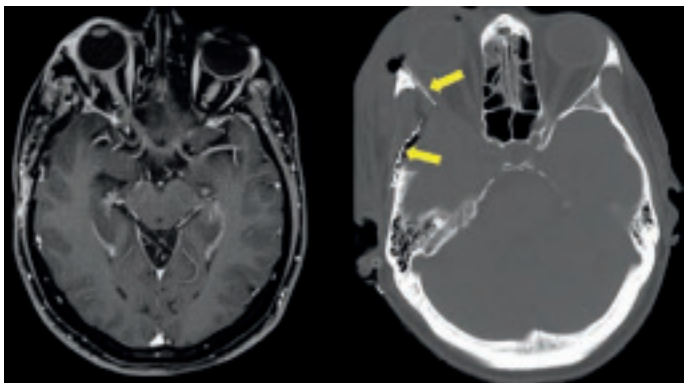
The lateral wall of the orbit and the involved bone were drilled away under magnification, exposing the superior orbital fissure where the tumor was involved. The periorbita involved by the tumor was removed, with the muscles and nerve of the orbit preserved. The convexity dura was excised along with the en plaque meningioma. Dr. Sen inspected the dural edges to ensure complete resection, and the orbital apex was observed to be free of tumor. With complete resection confirmed, the reconstruction process could begin.

Dr. Staffenberg harvested fat from the patient's abdomen, and the dura was reconstructed with pieces of AlloDerm™, flapped downward toward the orbital apex. "We wanted to fill in the defect that was left behind once the tumor was removed," explains Dr. Staffenberg. "It's important to have good contour and support for the eye."

The orbital wall was reconstructed with an implant, with careful inspection for good symmetry between the two orbits. The AlloDerm™ over the orbital apex was laid on top of the implant, and the fat graft was placed. The temporalis muscle was resuspended, and the orbital zygomatic bone was plated back with the orbital reconstruction. With a subgaleal drain left in place and the abdominal wound and scalp closed, the eight-hour surgery was complete, and the patient was moved to recovery.



A preoperative coronal MRI shows the tumor pushing into the right orbit, and a preoperative axial CT shows bony hyperostosis involving both the orbit and the skull.



A postoperative axial MRI shows that the tumor has been fully removed, and a postoperative axial CT shows the titanium plates used to reconstruct the skull and orbit after removing the involved bone.

EXPERIENCE INFORMS AN EXCELLENT OUTCOME

Preoperatively, Dr. Sen cautions patients that their postoperative course may be more challenging than anticipated. "Before the operation, these patients' involved eye is fully open and everything is more or less working except for some vision impairment," he says. "After the surgery, the eye is closed and they can't see properly. So I prepare them for the challenges that accompany a normal course of recovery."

As expected, this patient's right eye was completely closed due to the surgical trauma to the oculomotor nerve, but she was otherwise alert with mental function intact, and she was ready for discharge five days after surgery. Her eye began opening approximately one month postoperatively, and she was able to travel home about two and a half months after surgery, following minor reconstructive procedures performed by Dr. Staffenberg. Once home, the patient continued to regain her vision, with full recovery of eye function.

"Notably, most of the recovery occurs naturally as the eye muscle returns to normal strength and the brain's wiring intrinsically works to move both eyes in tandem," explains Dr. Sen. "Like all patients, she had to wear a patch initially as she walked so her double vision wouldn't cause dizziness, but she did not require any special rehabilitation."

For this patient, it was Dr. Sen's expertise, gained through deep experience with this complex open surgery, that informed the careful navigation of critical neural and orbital structures needed to safely and completely remove her tumor. "Even as technology enhances our approach and outcomes in the context of other conditions, there remain some operations, like this one, that rely completely on the skill and precision of an experienced multidisciplinary surgical team," concludes Dr. Sen.

A Complex Clinical Picture Demands Close Collaboration to Diagnose and Treat a Rare Pituitary Tumor

When a patient presented with a series of increasingly severe idiopathic symptoms, a multidisciplinary team of endocrinologists, neurosurgeons, and radiologists pursued an elusive diagnosis to identify her condition's root cause: a rare pituitary tumor. Supported by advanced diagnostics and intraoperative imaging, the team collaborated to plan a minimally invasive surgical resection—and halt the patient's decline.

ACCURATE DIAGNOSIS REQUIRES EXTENSIVE DIAGNOSTIC SLEUTHING

The 38-year-old patient had a complex history, with a range of comorbidities including prior stroke, hypertension, cardiomyopathy, and treatment-resistant type 2 diabetes mellitus with hyperglycemia. Despite several hospitalizations at other centers, her symptoms continued to elude a definitive diagnosis. She consulted with a multidisciplinary team at NYU Langone, including endocrinologist Eliud Sifonte, MD, that suspected and confirmed hypercortisolism and a right-sided adrenal adenoma thought to be benign and unrelated to the hypercortisolism. Indications pointed to Cushing syndrome. However, the source of the hormonal irregularity remained unconfirmed, and the patient's symptoms persisted, threatening her life and demanding swift diagnosis.

"With a case like this, it's critical to really nail down the diagnosis and determine what is essentially giving this 38-year-old patient the clinical profile of a sick 75-year-old," says Nidhi Agrawal, MD, clinical assistant professor in the Department of Medicine and director of pituitary diseases at the Pituitary Center. "And that diagnosis necessitates far more than a single blood test in isolation—you need a combination of clinical suspicion and the right advanced tools to confirm it."

Donato R. Pacione, MD

In this case, clinical suspicion focused on the patient's pituitary gland. Physicians used a combination of analytical tools including the highly sensitive adrenocorticotropic hormone (ACTH) assay, which is offered at few centers outside NYU Langone. This assay is critical to diagnostic specificity.

With diagnostic indicators pointing almost certainly toward pituitary involvement, Donato R. Pacione, MD, assistant professor in the Department of Neurosurgery, collaborated with Eytan Raz, MD, PhD, assistant professor in the Department of Radiology, to perform inferior petrosal sinus sampling, which would confirm the diagnosis. Response from the pituitary to microcatheter-injected hormone confirmed it was the source of the patient's symptoms, and imaging subsequently revealed a pituitary microadenoma, a rare type of pituitary tumor.

RESECTING THE ROOT CAUSE, CAREFULLY

Diagnosis in hand, the surgical planning began. "After the long road to diagnosis, surgery should be the simpler part—except that you're working with something that's 6 millimeters in size, and if you don't resect every trace of the tumor, it still secretes hormone," notes Dr. Pacione.

Understanding the historically high recurrence rate of such pituitary tumors, Dr. Pacione recommended an endoscopic endonasal approach for tumor resection, a minimally invasive approach that would enable precise navigation. Dr. Pacione worked closely with Elcin Zan, MD, assistant professor in the Department of Radiology, to develop a detailed anatomical map that would inform his surgical target.

During the procedure, the approach was performed by Seth M. Lieberman, MD assistant professor in the Department of Otolaryngology—Head and Neck Surgery. The gland was identified and elevated to reveal inferiorly the tumor tissue, which Dr. Pacione dissected and removed. He also observed two other firm nodules anterior to the gland, in an area Dr. Zan had identified as a potential site of additional abnormal tissue, and removed them. When an intraoperative MRI demonstrated no evidence of residual tumor, the patient returned to the operating room (OR), where Dr. Lieberman performed the closure, and then moved to recovery.

Along with the careful multidisciplinary planning, advanced intraoperative imaging was critical to confirming full resection of the tumor. The intraoperative MRI, stereotactic navigation, and an advanced intraoperative histology system—which quickly and accurately identifies residual tumor while sparing healthy tissue—worked in tandem in a surgery that demanded extreme precision to achieve a positive outcome.

"Real-time, intraoperative feedback is the game changer—it enables us to both make faster surgical decisions and leave with a higher degree of confidence that the tumor is completely out," observes Dr. Pacione.

EXPERTISE AND ACCESS CHANGE CLINICAL TRAJECTORY

Within a day of surgery, the patient's hormone level normalized, and she lost 30 pounds in four weeks. For this patient, multidisciplinary coordination of care, access to leading-edge diagnostic tools and imaging, and a collaborative pursuit of differential diagnosis reversed a precipitous decline in health toward a better outcome.

"This patient was already in heart failure and probably would have died if we hadn't pinpointed and corrected her root issue," notes Dr. Pacione. "It's the difference between care that simply solves whatever is immediately broken on a given day, and finding the underlying cause. That's what changes the course and saves a patient."

Intraoperative MRI Enables Safer, More Successful Pituitary Tumor Resections

A recent quality-improvement review emphasizes the safety and efficacy of pituitary tumor resection supported by intraoperative MRI.

To determine whether the use of intraoperative imaging achieved the desired balance of complete resection and gland preservation, Dr. Pacione followed patient outcomes over one year, finding a return-to-OR rate for resection of residual tumor of 0 percent in patients whose resection was aided by intraoperative MRI, compared with 3 percent in cases without MRI confirmation of resection.

Notably, this improvement was achieved despite tumors with 20 percent larger volume observed in the MRI group. The use of intraoperative MRI not only has resulted in improvements in tumor resection but has also led to a reduction in gland injury and a 30 percent reduction in the need for postoperative hormone replacement.

"With the intraoperative imaging, we can better preserve normal gland function while achieving a higher rate of gross total resection and hormonal remission—important for patients' long-term outcomes," notes Dr. Pacione. "It enables us to achieve better results with a single, safer surgery."

Anthony K. Frempong-Boadu, MD

Surgical Planning, Next-Generation Technology Enable Treatment of Spinal Tumor with Rare Presentation

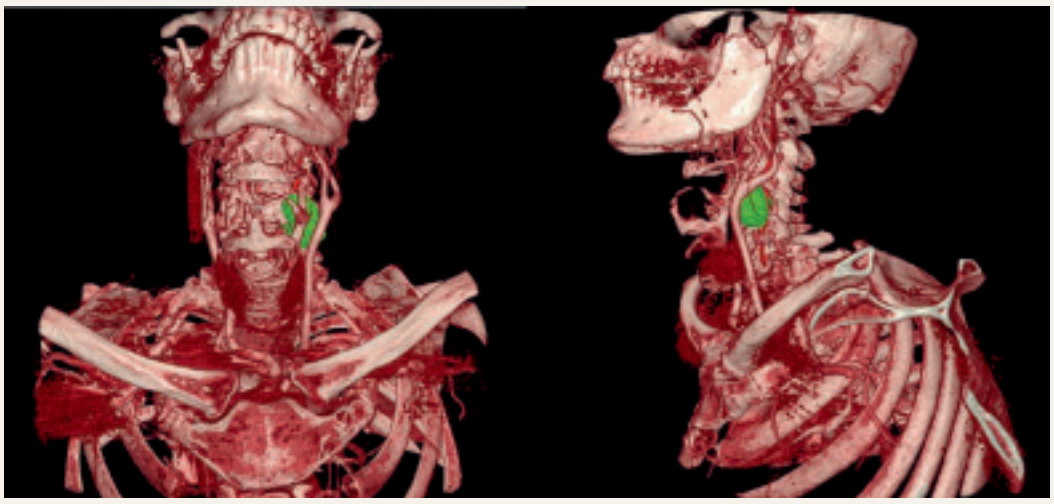
When a patient with intensifying neuromuscular symptoms was diagnosed with an aggressive malignant tumor in a highly vascularized location, a multidisciplinary surgical team mobilized to plan a swift intervention and execute a high-risk surgery. With skilled use of advanced imaging and intraoperative technologies to support planning, the team carried out a complex strategy to safely remove the tumor and restore the patient's function.

A COMMON SPINAL TUMOR IN AN UNCOMMON LOCATION

With progressively worsening left-side neck pain radiating into his shoulder and upper arm for six months, the 72-year-old patient also began to experience progressive muscle weakness that limited his mobility. His physician suspected deltoid palsy and recommended physical therapy. When that failed to elicit improvement, MRI imaging was ordered, and this revealed a large spinal mass surrounding the patient's left vertebral artery. At that point, the patient was referred to Anthony K. Frempong-Boadu, MD, associate professor in the Departments of Neurosurgery and Orthopedic Surgery and co-director of the Spine Center.

A biopsy revealed a chordoma—a locally aggressive primary malignant tumor with a high recurrence rate. This tumor is commonly found in the clivus and sacrum; its presentation above the sacrum in the C4 and C5 vertebral bodies, where spine compression was causing the patient's deltoid palsy, was unusual. "These lesions look benign but behave malignantly," notes Dr. Frempong-Boadu. "We aim to achieve the most complete resection possible to prevent recurrence, but this patient's large tumor in the thick of the major blood vessels that feed critical brain areas made surgical intervention extremely risky and technically challenging."

However, the tumor's location and the patient's progressive symptoms indicated action. As the tumor grew, it would threaten the vertebral and carotid arteries, potentially causing a catastrophic stroke or death. With the risks of both surgery and watchful waiting discussed with the patient, a wide resection and anterior reconstruction were planned.



Surgical Theater preoperative imaging indicates the tumor (green) above the sacrum in the C4 and C5 vertebral bodies.

The preoperative angiogram indicates the close proximity among the tumor, bony structures, and vessels.

MAPPING A DELICATE ANATOMY FOR REAL-TIME VISUALIZATION

The site of the tumor precluded en bloc resection in favor of a more precarious intralesional resection, in order to reduce the risk of complications and achieve a better functional outcome. The approach would require a precise multidisciplinary surgical plan aided by microsurgical techniques and a cache of leading-edge technologies working together to map every inch of the delicate anatomy. "In a case like this one, you need to go into surgery with a clear plan and a realistic assessment of potential pitfalls," notes Dr. Frempong-Boadu. "It's like a military operation—you really need to know what your contingencies are, so you don't get in there and realize there are land mines you didn't expect."

In this procedure, the greatest area of risk was in navigating the intradural and paraspinal structures, including the vertebral artery. A preoperative angiogram provided a three-dimensional view of the relationship among the tumor, bony structures, and vessels—revealing the proximity of the dominant-right and left vertebral arteries. During the surgery, Airo® intraoperative CT scanning with Brainlab computer-assisted spinal navigation would combine to inform real-time, augmented-reality navigation through Surgical Theater.

Beyond advanced technology, the carefully formulated plan relied heavily on surgical experience. For his expertise in highly technical head and neck surgery, Dr. Frempong-Boadu collaborated with Mark D. DeLacure, MD, the George E. Hall Associate Professor of Head and Neck Cancer Research in the Department of Otolaryngology—Head and Neck Surgery and associate professor in the Hansjörg Wyss Department of Plastic Surgery and Department of Neurosurgery, to perform the anterior neck dissection and subsequent approach.

"Seconds matter in these operations, so you make sure you're prepared by having aneurysm clips in the operating room and neurointerventional radiology and surgical partners on call," says Dr. Frempong-Boadu. "Even with the ideal multidisciplinary team in place, you need to think of everything before you get to the operating room because the stakes are just so high if you encounter complications."

CAREFUL SURGICAL PLANNING CIRCUMVENTS COMPLICATIONS

With the detailed plan in place, the patient was brought to the operating room, where Surgical Theater imaging, made possible by generous support from Sidney and Phyllis Bresler, was projected onto the target anatomy and the structures drawn on his skin. With the incision planned, Dr. DeLacure performed the approach to the anterior cervical spine. The team's careful planning expedited the identification of the tumor and proximal vessels.

Dr. Frempong-Boadu then performed a definitive resection of the anterior neck tumor, debulking the tumor using spinal navigation and microscope integration with an advanced Zeiss microscope. "The tumor was integrated into my eyepieces so I could see the outline of the tumor and achieve more precise control while working," he notes.

After completing initial debulking of the lesion, Dr. Frempong-Boadu dissected out the left vertebral artery and removed the remaining soft tissue neck component of the tumor around the artery, aided by the Airo® CT scan. "Fortunately, when we picked up the vessel it turned out there was a nice capsule between the vessel and the tumor providing some leeway, and we took our time in removing the tumor from around it," he says.

With the anterior tumor resected, Dr. Frempong-Boadu turned his attention to resecting fractured vertebrae and the epidural tumor and performing the anterior spinal reconstruction. The patient was then turned for posterior reconstruction, including a posterolateral fusion of C3–C6. A repeat intraoperative CT scan confirmed both complete resection and excellent anteroposterior cervical reconstruction and hardware placement, and the patient was taken to recovery.

EXPERIENCE, INTRAOPERATIVE TOOLS COMBINE FOR POSITIVE OUTCOME

With the surgery successfully completed, the patient began the work of regaining function. He spent time postoperatively as an inpatient at Rusk Rehabilitation to receive physical and occupational therapy to support his independence during recovery. He reported symptom relief immediately after surgery and ambulated readily. Though he experienced some weakness over the course of proton beam therapy, used adjuvantly to reduce recurrence risk, he has experienced gradual recovery from his left deltoid weakness and continues to gain strength.

In addition to the benefits of careful preoperative planning, surgical expertise played a pivotal role in delivering a positive outcome for his patient despite a high-risk tumor in a challenging location. "When structures are disrupted by a tumor, the challenging aspect of surgery is to determine where you are and what you are seeing—to have that anatomy imprinted in your head," says Dr. Frempong-Boadu. "My training in trauma and tumors taught me to find a normal structure, then work backward toward abnormal, so in this case I was able to visually resect the tumor from experience and confirm success with technology."

New and Notable Recruits

Darryl Lau, MD
Director, Complex Spine and Adult Spinal Deformity
Director, Spinal Neurosurgery Research

Dr. Lau completed his neurosurgery residency at the University of California San Francisco, and brings expertise in both complex spine surgery and spinal deformities.

Ilya Laufer, MD
Director, NYU Langone Spine Tumor Program

Dr. Laufer comes from Memorial Sloan Kettering Cancer Center in New York City. He brings extensive experience in both spinal neurosurgery and cancer treatment, and will develop a new Spine Tumor Oncology Program.

Antonios Mammis, MD
Associate Professor, Neurosurgery

Dr. Mammis completed his fellowship at Northwell Health on Long Island. He brings vast experience in deep brain stimulation, treating patients with a wide spectrum of neurological conditions.

Eric K. Oermann, MD
Assistant Professor, Neurosurgery and Radiology
Assistant Professor, NYU Langone Center for Data Science

Dr. Oermann is a leading expert in artificial intelligence (AI) applications in medicine. The only neurosurgeon in the country with a focus on AI research, he is the co-founder of the OLAB at NYU Langone. His research focuses on applying data science and algorithms to answer pressing neurosurgical questions, as well as those that apply to medicine far beyond neurosurgery.

Caleb Rutledge, MD
Director, Cranial, Vascular, and Skull Base Neurosurgery

Dr. Rutledge completed his neurosurgery residency at the University of California San Francisco, and trained in cerebrovascular, endovascular, and skull base surgery at Barrow Neurological Institute. He will be instrumental in the continued expansion of the neurosurgery program at NYU Langone Hospital—Brooklyn.

COVID-19–related Publications from the Department of Neurosurgery

NYU Langone researchers have led many efforts to better understand the impact of COVID-19 across nearly every medical specialty, with 617 publications in 2020. The Department of Neurosurgery contributed to this research with publications that included:

Agarwal S, Scher E, Rossan-Raghunath N, Marolia D, Butnar M, Torres J, Zhang C, Kim S, Sanger M, Humbert K, Tanweer O, Shapiro M, Raz E, Nossek E, Nelson PK, Riina HA, de Havenon A, Wachs M, Farkas J, Tiwari A, Arcot K, Parella DT, Liff J, Wu T, Wittman I, Caldwell R, Frontera J, Lord A, Ishida K, Yaghi S. Acute stroke care in a New York City comprehensive stroke center during the COVID-19 pandemic. *Journal of Stroke & Cerebrovascular Diseases*. September 2020; 29(9): 105068.

Cavalcanti DD, Raz E, Shapiro M, Dehkharghani S, Yaghi S, Lillemoe K, Nossek E, Torres J, Jain R, Riina HA, Radmanesh A, Nelson PK. Cerebral venous thrombosis associated with COVID-19. *American Journal of Neuroradiology*. August 2020; 41(8): 1370–76.

Kessler RA, Oermann EK, Dangayach NS, Bederson J, Mocco J, Shrivastava RK. Changes in neurosurgery resident education during the COVID-19 pandemic: An institutional experience from a global epicenter. *World Neurosurgery*. August 2020; 140: 439–40.

Kvernland A, Kumar A, Yaghi S, Raz E, Frontera J, Lewis A, Czeisler B, Kahn DE, Zhou T, Ishida K, Torres J, Riina HA, Shapiro M, Nossek E, Nelson PK, Tanweer O, Gordon D, Jain R, Dehkharghani S, Henninger N, de Havenon A, Mac Grory B, Lord A, Melmed K. Anticoagulation use and hemorrhagic stroke in SARS-CoV-2 patients treated at a New York healthcare system. *Neurocritical Care*. August 24, 2020.

Pandey AS, Ringer AJ, Rai A, Kan PT, Jabbour PM, Siddiqui A, Levy E, Snyder KV, Riina HA, Tanweer O, Levitt MR, Kim LJ, Veznedaroglu E, Binning M, Arthur AS, Mocco J, Schirmer CM, Thompson BG, Langer D. Considerations for performing emergent neurointerventional procedures in a COVID-19 environment [letter]. *Neurosurgery*. August 2020; 87(2): E203–06.

Pandey AS, Ringer AJ, Rai A, Kan PT, Jabbour PM, Siddiqui A, Levy E, Snyder KV, Riina HA, Tanweer O, Levitt MR, Kim LJ, Veznedaroglu E, Binning M, Arthur AS, Mocco J, Schirmer CM, Thompson BG, Langer D. Minimizing SARS-CoV-2 exposure when performing surgical interventions during the COVID-19 pandemic. *Journal of NeuroInterventional Surgery*. July 2020; 12(7): 643–47.

ABOUT NYU LANGONE HEALTH

Leader in Quality

NYU Langone's emphasis on continuous improvement inspires teams to continually raise the bar on quality and safety across our growing network in Manhattan, Brooklyn, Queens, Long Island, Staten Island, and Florida. NYU Langone's Tisch Hospital, Kimmel Pavilion, NYU Langone Hospital—Brooklyn, and NYU Langone Hospital—Long Island were awarded an "A" as well as a Top Hospital award as part of the fall 2020 Leapfrog Hospital Safety Grades. NYU Langone Hospitals achieved Five Star ratings on CMS Hospital Compare effective October 2019 and is the only major academic medical center in the New York metropolitan region to attain a Five-Star Quality rating.

NATIONALLY RECOGNIZED A FALL 2020 LEAPFROG HOSPITAL SAFETY GRADE

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CMS CENTERS FOR MEDICARE & MEDICAID SERVICES Five-Star Quality Rated

#9 in the Nation

#4 in the Nation

Ranked ninth by *U.S. News & World Report* for Best Hospitals; and ranked fourth for Best Medical Schools (Research).

BEST HOSPITALS U.S.News NATIONAL 2020-21

BEST GRAD SCHOOLS U.S.News MEDICAL 2021

Transforming Medical Education

As COVID-19 has added new urgency to nationwide physician shortages, debt burden, and lack of diversity, we remain committed to our accelerated pathways to the MD degree and full-tuition scholarships regardless of need or merit at the recently renamed NYU Grossman School of Medicine and the new primary-care focused NYU Long Island School of Medicine.

For more information about our physicians, services, and locations, visit **nyulangone.org**

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Neurosurgery

2020 HIGHLIGHTS

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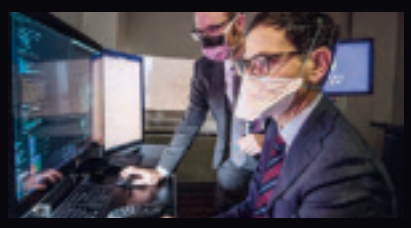

Artificial Intelligence Fuels Unprecedented Neurosurgical Progress, with Broad Potential Impact
See page 2.

For a Rare Meningioma, Deep Experience Guides Successful Resection and Vision Restoration
See page 4.