

# Advancing spine surgery with Synaptive's Modus X™ robotic exoscope

Immersive 4K 3D optics, robotics, and automation for enhanced patient care



## Clinical evidence summary

Synaptive is a leading medical technology company pioneering digital microsurgery with the Modus X robotic 4K 3D exoscope to revolutionize microsurgical visualization. With over 30,000 exoscope procedures performed across 160+ centers since 2017 and 16,000+ dedicated to spine procedures alone, Synaptive's Modus X sets the industry standard for the robotic digital microsurgery landscape. Numerous peer-reviewed publications highlight its **positive impact on microsurgical ergonomics, operative complication rates, procedure time, and postoperative length of stay** during various adult and pediatric spine procedures.

## Immersive 4K 3D optics



Experience unparalleled depth and detail with 2X the depth of field (DoF) of traditional ocular microscopes, keeping more in focus during delicate procedures like ACDFs<sup>3,4</sup>



Tailor your camera settings to digitally enhance contrasting nerve roots, ligament, dura, and bone<sup>4,6</sup>



With uniform LED illumination superior to loupe or microscope lighting, monitor peripheral bleeds and hemostasis more effectively to reduce blood loss<sup>2</sup> without need for headlamps



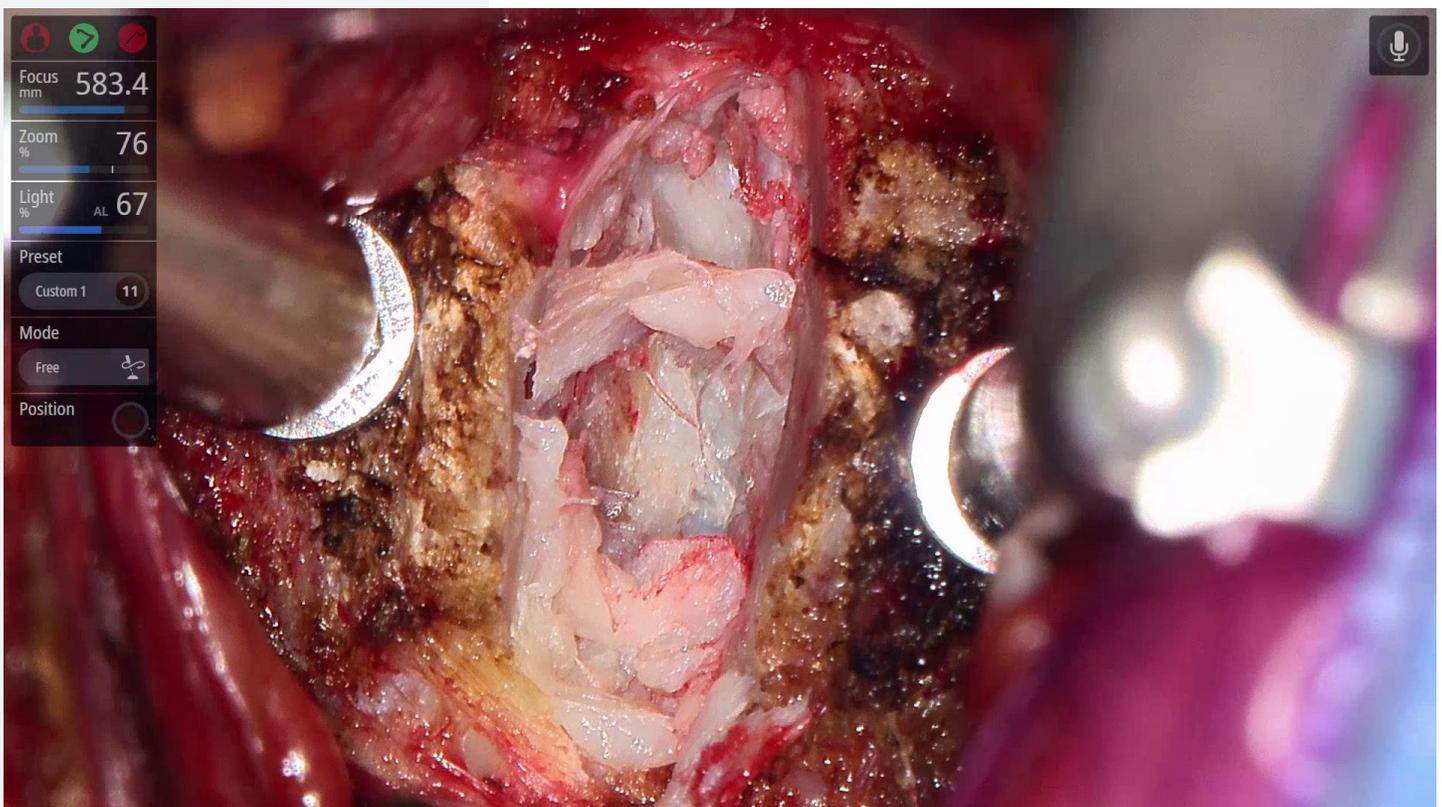
Facilitate collaborative visualization for access surgeons and implant representatives during instrumented fusions like ALIFs and XLIFs



Ensure safety with side-by-side microsurgical views with spine navigation displays<sup>7</sup>



An exceptional teaching demonstration tool for academic communication and training<sup>4</sup>



## Improved clinical outcomes

A cohort study published by Nawabi et al (2024) in *World Neurosurgery* comparing exoscope and microscope cases demonstrated substantial benefits of using Synaptive's exoscope across 246 spine procedures.<sup>2</sup> The study revealed that the exoscope cohort experienced:

**19%** reduction in operative time   **40%** shorter hospital stay   **79%** decrease in blood loss

Dr. Sunil Patel, principal investigator from Medical University of South Carolina (MUSC), credits these outcomes directly to the advanced capabilities of Synaptive's exoscope.

Discover how Synaptive's immersive 4K 3D display enhances safety in spine surgery through a detailed case video by Drs. Rodolfo Maduri and Alberto Vandenbulcke from Switzerland, featured in *World Neurosurgery* (2024).<sup>7</sup> The video highlights the benefits of a navigated exoscopic transtubular approach (NETA) for lumbar decompression, showcasing its efficacy and precision with side-by-side operative views.

Dr. Paul Licina from Brisbane, Australia, emphasizes these advantages during ALIFs, particularly in collaborative settings with access surgeons to mitigate vascular risks.



Scan to read the Nawabi et al. (2024) study



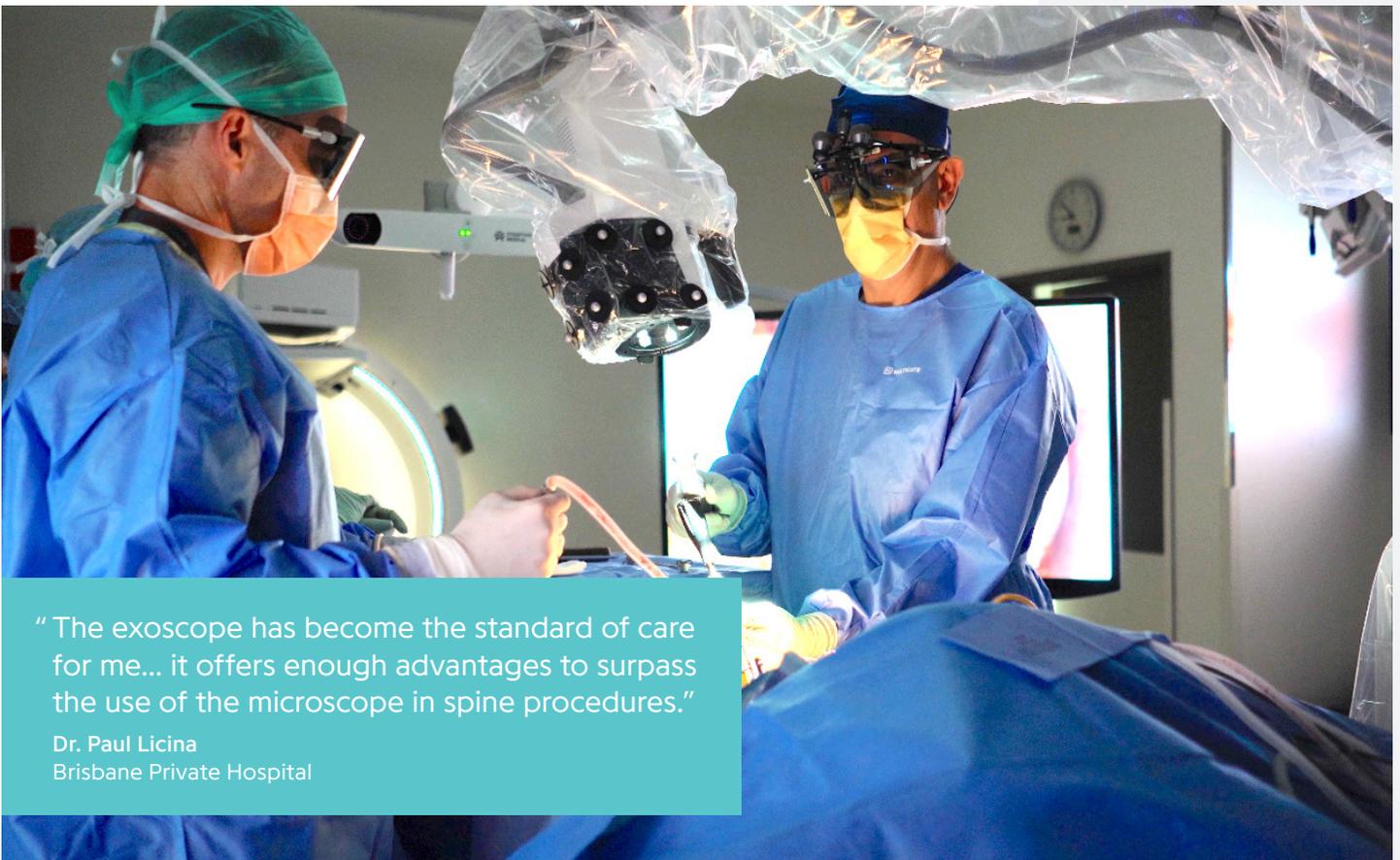
Watch Dr. Sunil Patel discuss study findings



Scan to watch operative video of the NETA approach



Scan to watch Dr. Licina's commentary on ALIFs



"The exoscope has become the standard of care for me... it offers enough advantages to surpass the use of the microscope in spine procedures."

Dr. Paul Licina  
Brisbane Private Hospital

27x  
magnification

650mm  
working distance

4K  
cameras

2x  
DoF of conventional  
systems



## Advanced microsurgical robotics

- Revolutionize surgeon comfort and efficiency by enhancing ergonomics<sup>1,3</sup> with integrated robotics providing a generous working distance of up to 650mm, simplifying the use and exchange of long instrumentation during multilevel procedures
- Eliminate the risk of neck strain when navigating challenging oblique or off-axis viewing angles, especially during ACDFs,<sup>3</sup> or ALIFs and microdiscectomies at L5-S1
- Streamline complex lateral approaches like XLIFs and TLIFs by gaining clear visualization of deep disc spaces from a significant camera distance
- Attain unrivaled accuracy of desired views when performing MIS microdiscectomies and over-the-top decompressions<sup>7</sup>

## Improved Surgeon Ergonomics

A prospective cohort study by Kusyk and colleagues (2024) directly compared exoscope versus microscope use during ACDF procedures with motion sensor data to quantitatively demonstrate that spine surgeons using traditional microscopes frequently adopt "at-risk" deviated postures.<sup>3</sup> In contrast, the exoscope's superior ergonomics alleviate the need for surgeons to crane their necks or strain their backs, thereby reducing the risk of workplace injuries. The study revealed a significant:

**65%** decrease in the likelihood of neck or back pain

**75%** reduction in deviated flexion and extension postures

**70%** decrease in lateral bending postures

Similarly, a prospective multicenter case series involving 155 cranial and spine procedures led by Mount Sinai Hospital reported that surgeons experienced superior ergonomic benefits with the exoscope.<sup>1</sup> This improvement suggests a potential decrease in the likelihood of work-related injuries and fatigue.



Scan to read the  
ACDF study from  
Kusyk et al. (2024)



Scan to view  
the multi-site  
ergonomics study

## Powered by automation

- Effortlessly adjust precise camera angles and focal points using tracked instruments and focus-to-tip automation
- Increase magnification up to 27× and revisit critical memory positions with simple verbal commands
- Operate skin-to-skin to save operative time by obviating loupes during exposure and cumbersome microscope adjustments during the approach

## Maximize ROI on capital

- Modular system upgrades available at a fraction of the cost of purchasing a new microscope
- Increase case throughput, reduce length of stay,<sup>2</sup> and improve the overall health and longevity of your surgical career with superior musculoskeletal ergonomics<sup>1-7</sup>
- Translate decreased OR time from added operative efficiency in MIS procedures<sup>2</sup> to increase hospital revenue
- System versatility for fluorescence-guided surgery (Blue and Near-Infrared) broadens spectrum of applications across various surgical specialties (cranial, ENT, plastics)

## Journal of Neurosurgery case series from Johns Hopkins

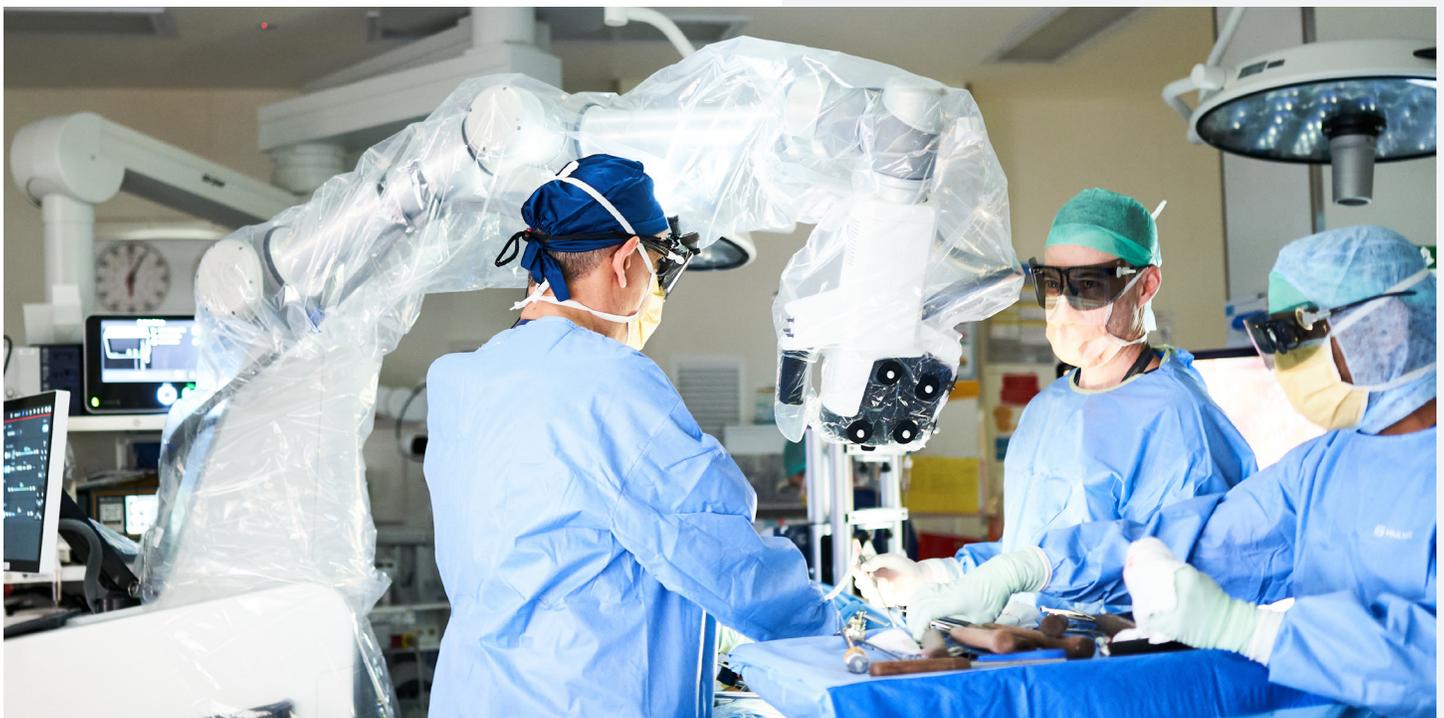
The neurosurgery department at Johns Hopkins published their initial institutional experience when using Modus X in a variety of cranial and spinal neurosurgical operations, namely Chiari decompression, microvascular decompression for trigeminal neuralgia, anterior cervical discectomy, and lumbar decompressions.<sup>4</sup> The surgeons conclude that the exoscope is “a versatile alternative to traditional optical microscopy”.



Scan to watch  
the JNS video

“The Synaptive exoscope is an example of a disruptive tool that will make surgery better for our patients and is ergonomically superior for the surgeon.”

Dr. Nicholas Theodore  
The Johns Hopkins Hospital



## Exoscopy-guided Minimally Invasive Spine Surgery (X-MISS) registry overview

**Project aims:** Collect largest multisite series of real-world operative data from exoscopy-guided minimally invasive spine surgery (X-MISS) procedures in adult patients undergoing MISS at cervical or lumbar levels using Synaptive’s Modus X.



Procedure	Number of cases (%)	MIS Tube Used? (Y/N)	Mean Operative Time (mins)	Time under scope (%)	Dural Tears (%)	Nerve Root Injury (%)	At-Risk Ergonomics (%)	Incision Size (mm)	Mean Estimated Blood Loss (mL)
Cervical	56 (40%)	Yes = 8	86	67%	0 (0%)	0	0	21.9	7.3
		No = 48	135	48%	1 (2%)	0	0	45.4	36
Lumbar	85 (60%)	Yes = 30	95	64%	1 (3.3%)	0	0	51.6	16.4
		No = 55	99	39%	1 (1.8%)	0	0	42.5	25.7
Totals	141	Yes = 38 No = 103	110 mins	49%	3 (2.1%)	0%	0%	44.2mm	26.2mL

With 141 enrollments from 6 participating institutions submitted from January to July, 2024, the study found a **low rate of operative complications**; only 2% of patients experiencing incidental durotomy and 0% rate of vascular or nerve root injury. Surgeons spent an average of 49% of procedure time operating under the exoscope, with a much higher percentage (66%) when using a minimally invasive surgery (MIS) tube – emphasizing the dependence on Modus X during tubular MIS surgery.

Surgeons reported a **0% rate of “at-risk” ergonomics** when using the exoscope and a **0% conversion rate to a traditional ocular microscope**. The most common cervical procedures were ACDFs (66%) and decompressions (18%), while the top lumbar procedures were decompressions (63%), cord detetherings (22%), and instrumented (TLIF/XLIF) fusions (14%).

Overall, the study highlighted the benefits of exoscopy in improving lighting, optics, ergonomics, and angulation capacity especially during port-based MIS surgery, leading to more efficient and safe procedures evidenced by the low complication rate and estimated blood loss across the series.

**Conclusion:** Synaptive's technology portfolio is supported by robust clinical evidence and post-market surveillance reports. Our solutions have been proven to enhance surgical outcomes, improve patient care, and provide value to healthcare providers. By leveraging our innovative technology, healthcare professionals can achieve better outcomes for their patients and optimize their surgical workflow.



Indiana University Health



JOHNS HOPKINS  
UNIVERSITY



MUSC Health  
Medical University of South Carolina



HOME OF SIDNEY KIMMEL MEDICAL COLLEGE

## Peer-reviewed publications

1. Schupper AJ, Eskandari R, Kosnik-Infinger L, Olivera R, Nangunoori R, Patel S, Williamson R, Yu A, Hadjipanayis CG. A Multicenter Study Investigating the Surgeon Experience with a Robotic-Assisted Exoscope as Part of the Neurosurgical Armamentarium. *World Neurosurg* 2023.
2. Nawabi NLA, Saway BF, Cunningham C, Rhodes S, Kodali P, Pereira M, Patel SJ, Kalhorn SP. Intraoperative Performance with the Exoscope in Spine Surgery: An Institutional Experience. *World Neurosurg* 2024.
3. Kusyk DM, Jeong S, Fitzgerald E, Kaye B, Li J, Williamson R, Yu AK. Surgical Posture with Microscopic Versus Exoscopic Visualization in Anterior Cervical Procedures. *World Neurosurg* 2024.
4. Khalifeh, J. M., Ahmed, A. K., Ishida, W., Materi, J., Kalluri, A., Lubelski, D., Witham, T., Theodore, N., Mukherjee, D., & Huang, J. (2024). Initial institutional experience using a robotic arm– enabled 4K 3D exoscope in neurosurgical operations. *Neurosurgical Focus: Video*.
5. Cunningham CM, Nawabi N, Saway BF, Sowlat MM, Pereira MP, Hubbard ZS, Lajthia OM, Porto G, Patel S, Kosnik-Infinger L, Eskandari R. Exoscope Efficacy and Feasibility in Pediatric Spinal Neurosurgery: A Single-Institution Cohort Case Series. *World Neurosurg* 2024.
6. Lim JX, Seow WT, Ng ZM, Low SYY. Selective dorsal rhizotomy using a 3D high definition exoscope. *Neurosurg Focus Video* 2024.
7. Maduri, Rodolfo, and Alberto Vandenbulcke. "Navigated Exoscopic Transtubular Approach (NETA) for lumbar decompression: surgical video." *World Neurosurg* 2024.



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# Advancing neurosurgery with Synaptive's integrated suite

Featuring advanced fluorescence visualization and automated tractography integration for enhanced patient care



Synaptive is a leading medical technology company, pioneering digital microsurgery with the **Modus X** robotic 4K 3D exoscope to redefine the art of microsurgical visualization. Integrated with our advanced subcortical segmentation software for surgical planning (**Modus Plan**) and tractography-guided neuronavigation system (**Modus Nav**), this platform is designed to enhance patient care by reducing adverse neurological deficits when operating in essential brain areas. With over 30,000 procedures completed across 160+ centers, Synaptive sets the standard for patient safety in neurosurgery, combining surgical planning, neuronavigation, and advanced visualization.

## The Synaptive difference



Customize use of products as stand-alone or integrated suite for ultimate flexibility across a broad range of case types.



Ensure safety with side-by-side microsurgical views with integrated tractography through navigation displays.



Experience an exceptional teaching and demonstration tool for academic communication and training.



Apply advanced 4K 3D optics and fluorescence visualization to improve tissue differentiation in real-time.



Tailor your camera settings to digitally enhance contrasting healthy and tumorous tissue.



Experience unparalleled depth and detail with 2X the depth of field of traditional ocular microscopes, keeping more in focus, including multiple cranial nerves during MVDs.



# Safe minimally invasive surgery at scale

## Modus Plan: Automated tractography software

- Save time and dependence on radiology resources by automating white matter tract segmentations from diffusion MRI data
- Tailor minimally invasive approaches to each patient's individual anatomy
- Support safe evacuation of intracerebral hemorrhages
- Perform accurate targeting of DBS implants or focused ultrasound for essential tremor
- Customize laser ablation zones for epilepsy
- Facilitate safe maximal resection of skull base and subcortical tumors
- Strengthen neurosurgery resident education with detailed insight on subcortical anatomy and mass effect patterns

## Combined with Modus Nav: Integrated cranial navigation

- Confidently navigate preoperative MRI data with advanced tractography overlays
- Guide precise resection margins with improved delineation of tumor from healthy tissue
- Enhance overall survival through preservation of critical white matter infrastructure

>1M

tracts created by patented whole-brain seeding algorithm

13

automatically segmented patient-specific bundles

30s

for tractography review



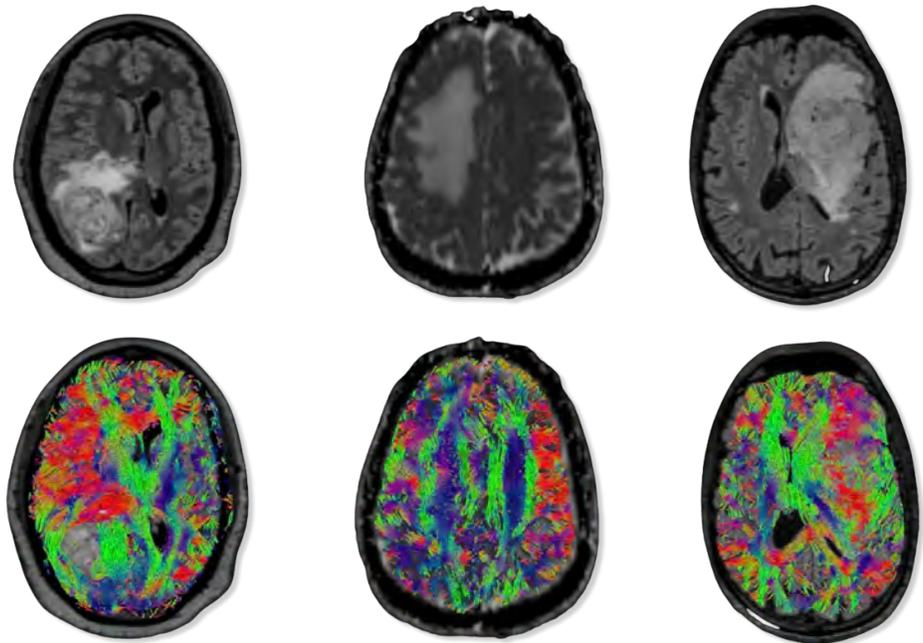
# Increase confidence during complex subcortical surgery

## Gain insight into subcortical mass effect patterns of different tumors in the presence of edema

A recent peer-reviewed study published in *Frontiers in Neurology* (Koga et al., 2024) highlights how Synaptive's edema-corrected tractography algorithm (Reveal) enhances visualization of the brain-tumor interface, aiding in the accurate delineation of tumor margins and with the selection of optimal surgical plans for complex malignancies.<sup>2</sup>



Scan to read the Koga et al. (2024) study



Low Grade Glioma

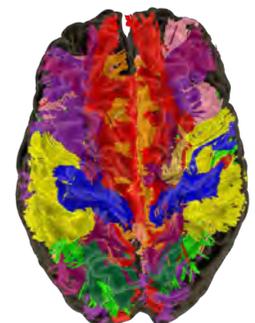
Metastasis

Glioblastoma

## Map eloquent fibers to inform safer intervention

Guide safer circuit-based neurosurgical interventions for tumors or epileptic foci<sup>13</sup> in critical brain areas<sup>2,12</sup> and neuromodulation procedures to treat essential tremor; explore the following case studies to learn more:

- Subcortical language localization using sign language and awake craniotomy for dominant posterior temporal glioma resection in a hearing-impaired patient (Lau et al., 2023)<sup>12</sup>
- Safe maximal resection of a left frontal glioma in an awake bilingual patient guided by language mapping & tractography, by David Adler, MD
- Direct targeting of bilateral thalamic VIM nuclei with tractography in intraoperative MRI-guided DBS in an asleep patient with essential tremor, by Joshua Aronson, MD



Scan to read the Lau et al. (2023) study



Scan to read the Adler case report



Scan to read the Aronson case report

# Enhanced visualization with advanced microsurgical robotics

## Robotic control with Modus X

- Enhance surgeon ergonomics with an expansive working distance of up to 650mm
- Hands-free robotic positioning of 4K 3D camera for optimal oblique views
- Simplify access to challenging areas in the skull base
- Illuminate views through narrow minimally invasive surgery (MIS) corridors

## Advanced 4K 3D visualization

- View increased detail in focus with 2X the depth of field of conventional microscopy
- Achieve 27X magnification power with simple voice commands
- Complete a wide range of surgical procedures, ranging from cranial to spinal applications

Peer-reviewed articles showcase how surgeons leverage the advanced robotics of Modus X to enhance access to skull base tumors<sup>5-7,14,17,18,20,21</sup> and maximize the extent of resection in anterior temporal lobectomies,<sup>8</sup> all while optimizing surgeon ergonomics.<sup>1,9,11,18,20,21</sup>

## Journal of Neurosurgery case series from Johns Hopkins

The neurosurgery department at Johns Hopkins published their initial institutional experience when using Modus X in a variety of cranial and spinal neurosurgical operations, namely Chiari decompression, microvascular decompression for trigeminal neuralgia, anterior cervical discectomy, and lumbar decompressions.<sup>1</sup> The surgeons conclude that the exoscope is “a versatile alternative to traditional optical microscopy”.



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# Robotic assisted fluorescence-guided surgery

## Powerful LED light source

- Precisely tuned to excitation wavelengths for each fluorophore to optimize visibility and improve tissue differentiation during fluorescence-guided surgery (FGS)
- Greater fluorescence sensitivity than Xenon-based conventional microscopy

## Improved workflow for optimized FGS

- Large standoff enables effective operation under blue light while providing maximal tissue differentiation
  - Allows evaluation of vascular perfusion patterns and seamless review of ICG recordings from sterile field
- Enhances operative workflow and efficiency with simple voice commands to toggle between FGS filters and white light visualization



## Integrated tractography-guided navigation

- Provides real-time visualization of eloquent fiber tracts, alongside operative views
- Designed to increase overall safety profile of complex cranial procedures to improve survival



Watch IR fusion module used to ensure accurate aneurysm clipping



Watch gross total GBM resection under blue light



"We've learned with FGS that the tumor is not uniformly fluorescent, there is heterogeneity of the fluorescence and with Modus X we completely appreciated that."

Dr. Costas Hadjipanayis  
UPMC

# The Synaptive suite in action

## Patient stories

### Intracerebral Hemorrhage

Discover how Synaptive Medical's technology revolutionized the ENRICH (Early miNimally-invasive Removal of IntraCerebral Hemorrhage) trial. Using Modus Plan, surgeons can now choose safer trajectories for their procedures. Watch the video to see how the principal investigators applied this innovative approach to a 49-year-old patient with a hemorrhagic stroke.



Watch ENRICH video

### Tractography-guided focused ultrasound

Learn how a functional neurosurgeon leverages Synaptive's Modus Plan during MRI-guided focused ultrasound to safely ablate the thalamic VIM nucleus, minimizing adverse neurological deficits in a patient with essential tremor.



Watch Tractography-guided FUS video

## Educational webinars

### Panel discussion on the clinical use of tractography in neurosurgery

Dr. Chaichana (Mayo Clinic), Dr. Schulder (Northwell Health), and Dr. Dickinson (Sutter Eden) discuss the importance of white matter and their experience using tractography in neurosurgery.



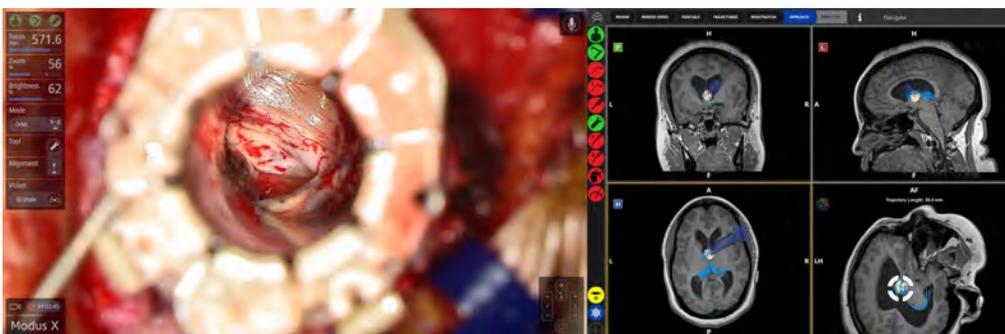
Watch panel discussion on tractography

### Case review using the robotic digital microscope Modus V™ in brain and spine surgery

In partnership with The Neurosurgical Atlas, Dr. Costas Hadjipanayis (Mount Sinai Hospital, NYC), Dr. Raj Nangunoori (Mercy Health), and Dr. Peter Fecci (Duke Health) present an immersive surgical case review and participate in a panel discussion on their experience using Synaptive's surgical products in cranial and spine surgery.



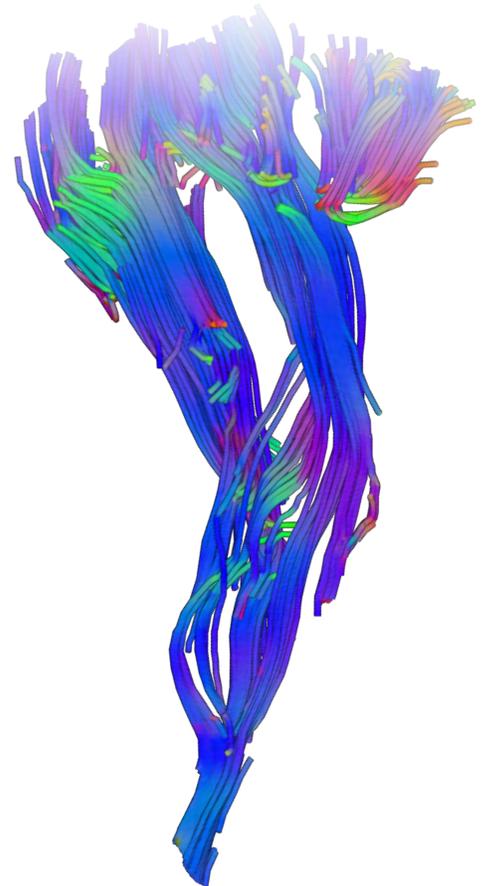
Watch panel discussion on exoscopes



Synaptive's technology portfolio is supported by robust clinical evidence and post-market surveillance reports. Our solutions have been proven to enhance surgical outcomes, improve patient care, and provide value to healthcare providers. By leveraging our innovative technology, healthcare professionals can achieve better outcomes for their patients and optimize their surgical workflow.

# Peer-reviewed publications

1. Khalifeh, J. M., Ahmed, A. K., Ishida, W., Materi, J., Kalluri, A., Lubelski, D., ... & Huang, J. (2024). Initial institutional experience using a robotic arm-enabled 4K 3D exoscope in neurosurgical operations. *Neurosurgical Focus: Video*.
2. Koga, S. F., Hodges, W. B., Adamyan, H., Hayes, T., Fecci, E., Tsvankin, V., ... & Baboyan, V. G. (2024). Preoperative validation of edema-corrected tractography in neurosurgical practice: translating surgeon insights into novel software implementation. *Frontiers in Neurology*.
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6. Mallela, A. N., Plute, T. J., Abou-Al-Shaar, H., Fernandes Cabral, D. T., & Hadjipanayis, C. G. (2024). Exoscope-based supracerebellar infratentorial approach for a pineal meningioma in the prone position. *Neurosurgical Focus: Video*.
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12. Lau, R., Malhotra, A. K., McAndrews, M. P., & Kongkham, P. (2023). Subcortical language localization using sign language and awake craniotomy for dominant posterior temporal glioma resection in a hearing-impaired patient. *Acta Neurochirurgica*.
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