



Topic Exploration Report ¹

4K three-dimensional (3D) exoscope systems for neurosurgery

What is a Topic Exploration Report?

Topic Exploration Reports are not health technology assessments. These reports provide a high-level briefing on new topics submitted to Health Technology Wales and are not based on exhaustive or systematic literature searches. Instead, they rely on a focussed scan of key resources.

What evidence is used in a Topic Exploration Report?

Priority is given to summarising the most relevant or useful evidence, rather than covering all possible evidence. Information reported is typically based on abstracts and study authors' own conclusions, rather than detailed scrutiny of full texts.

What are the aims of a Topic Exploration Report?

Topic Exploration Reports offer an overview of the available evidence on a topic and aim to highlight any uncertainties or gaps in the evidence. These reports outline the quantity and type of evidence found, but no critical appraisal or formal evidence synthesis is conducted.

How should a Topic Exploration Report be used?

Topic Exploration Reports can be used to indicate what evidence may be available for a topic, and do not provide definitive guidance on how a technology should be used. The evidence presented within the reports should be interpreted with caution.

¹ [Cyfieithu dogfennau HTW wedi'u cyhoeddi o'r Saesneg i'r Gymraeg](#)
Translation of published technical HTW documents from English into Welsh

Topic exploration report number	TER688
Topic	4K 3D exoscope systems for visualisation during neurosurgery
Summary of findings	<p>Prolonged use of microscope eyepieces may contribute to poor surgeon posture and musculoskeletal strain during surgical procedures. 4K 3D digital exoscope systems such as ORBEYE are an alternative to conventional surgical microscopes which allow surgeons to operate using a heads-up posture while viewing the surgical field on a large 3D screen. The technology is intended for use across a range of surgical specialties, including neurosurgery. Although ORBEYE was the subject of the topic suggestion, evidence from other comparable 3D exoscope systems were included where relevant.</p> <p>HTW researchers identified three systematic reviews and ten additional prospective or retrospective studies evaluating a range of 3D exoscope systems, across a variety of neurosurgical procedures. Outcomes were broad and included clinical effectiveness measures such as extent of resection, survival, remission, neurological outcomes, hearing preservation and mortality, as well as operative measures including procedure duration, blood loss, complication rates and theatre time.</p> <p>Exoscope-assisted surgery was generally reported to be feasible and safe, with clinical outcomes comparable to conventional operating microscopy and some evidence of improvements in operative efficiency. One observational study found that using 3D exoscopes shortened operating time and lowered blood loss, although one systematic review found no difference in operating time, complications, or length of stay. One retrospective study reported longer progression-free survival among patients undergoing exoscope-assisted surgery compared with microscopy.</p> <p>Additional benefits commonly reported included enhanced visualisation, surgeon ergonomics, workflow, educational value and collaborative viewing.</p> <p>We did not identify any randomised evidence or formal cost-effectiveness studies.</p>

Introduction and aims

Microsurgical neurosurgical procedures are usually performed using operating microscopes, which remain the current standard of care for many cranial and spinal procedures. However, prolonged use of microscope eyepieces may contribute to poor surgeon posture and musculoskeletal strain. Exoscope systems such as ORBEYE aim to address these issues while maintaining the magnification and image quality required for microsurgery. Potential applications include brain tumour resection, cerebrovascular surgery, skull-base surgery and spinal procedures.

The ORBEYE 4K 3D Orbital Camera System (Olympus Medical Systems, Tokyo, Japan) is a digital exoscope designed as an alternative to conventional ocular-based surgical microscopes. The system has a 4K three-dimensional camera mounted on a semi-robotic arm, an image processor and a display monitor, allowing surgeons to operate using a heads-up posture while viewing the surgical field on a large 3D screen. The technology is intended for use across a range of surgical specialties, including neurosurgery.

The topic proposer is not aware of any exoscopes that are being used in Wales.

Health Technology Wales researchers searched for evidence on exoscope systems, including the ORBEYE 4K 3D Orbital Camera System when compared to operating microscopes for microsurgical procedures undertaken in neurosurgical operating theatres.

Evidence overview

HTW researchers identified three systematic reviews, five prospective studies and five retrospective studies on the use of 3D exoscope systems (including ORBEYE) during neurosurgical procedures.

Systematic reviews

HTW researchers identified three systematic reviews on the use of 3D exoscope systems compared with conventional operating microscopes. The reviews included various exoscope systems including HDXO-SCOPE, Brightmatter, VITOM, ORBEYE, MiSPace, BrainPath, ROVOT, and Modus.

Benato et al. (2026) conducted a meta-analysis comparing surgical and clinical outcomes of exoscopic versus microscopic spine surgery for degenerative conditions with procedure-specific subgroup analyses. A total of 785 participants across seven studies were included. It is unclear from the abstract what types of studies were included, although they were published between 2020 and 2024. Outcome measures included operative time, blood loss, length of stay, visual analogue scale [VAS] scores. No significant differences were found in operative time (Mean difference [MD] -5.9 min; 95% CI -16.4 to +4.7), complications (OR 0.83; 95% CI 0.53-1.30), length of stay (MD -0.15 days; 95% CI -0.84 to +0.53), or postoperative VAS scores. Blood loss was slightly reduced with the exoscope (MD -5.9 mL; 95% CI -11.1 to -0.6). The review found that exoscopes may offer ergonomic advantages although no differences were found in operative time, complications, length of stay or postoperative visual analogue scale scores.

Chiang et al. (2022) reviewed six observational studies involving 128 otologic and neurotologic procedures (103 performed using an exoscope and 25 using a microscope). The review found that exoscopes provided comparable safety, visualisation and operative efficiency to conventional microscopes, while offering potential advantages in surgeon ergonomics,

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comfort, teaching and operating room communication.

Montemurro et al. (2022) reviewed 86 studies involving 1,711 neurosurgical procedures, including case reports, case series, clinical studies and cadaveric laboratory studies. Of the 1,711 procedures, 1,534 were clinical cases and 177 were cadaveric procedures. The study included a range of systems and devices and may have included older 2D systems. Across 40 clinical studies comprising 1,328 patients, the overall complication rate during exoscope use was 2.6%, with complication profiles reported to be similar to those seen with conventional operating microscopes. The review concluded that available evidence suggests exoscopes may represent a safe and effective alternative to operating microscopes for brain and spinal surgery, with reported benefits including improved ergonomics, reduced surgeon fatigue, high-quality 3D visualisation and magnification, enhanced educational value, and improved engagement of the wider surgical team through shared visualisation.

Prospective observational studies

Five observational studies on the use of exoscopes during neurosurgery that were not reported in the systematic reviews, were identified. Four studies exclusively evaluated the Olympus ORBEYE 4K 3D exoscope in glioma surgery (n=10), midline brain tumour surgery (n=5), 5-ALA fluorescence-guided glioblastoma surgery (n=9) and the excision of unruptured brain arteriovenous malformations (n=35) (Garufi et al. 2024, Mc Sweeney et al. 2025, Kijima et al. 2021, Witten et al. 2023). One case series (n=18) evaluated several types of exoscopes including ORBEYE (OLYMPUS, Tokyo, Japan), VITOM 3D and Kinevo 900 (Murai et al. 2022). Outcome measures included extent of resection, operative time, blood loss, complications, neurological outcomes, mortality, fluorescence visualisation, ergonomics and workflow.

Across studies, exoscope-assisted surgery was reported as being feasible and safe, with similar rates of complete resection, complications, neurological outcomes and mortality to conventional operating microscopy. One comparative study reported shorter operative times and lower blood loss with the exoscope. Median operating time was 136 minutes and 235 minutes ($p = 0.02$ for the exoscope and operating microscope groups, respectively) (McSweeney et al. 2025). Median blood loss was 75 ml and 200 ml ($p = 0.04$) for the exoscope and operating microscope groups, respectively (Mc Sweeney et al. 2025). Other reported benefits were related to improved visualisation, surgeon ergonomics, workflow and collaborative viewing (Garufi et al. 2024; Kijima et al. 2021; Murai et al. 2022; Witten et al. 2023). No formal cost-effectiveness studies were identified, although one study suggested potential resource or cost advantages compared with microscopy, no quantitative economic evaluation was reported (Garufi et al. 2024).

Retrospective studies

Five additional retrospective studies evaluating ORBEYE were identified across different neurosurgical procedures including glioblastoma surgery (n=177) (Di Cristofori et al. 2023), intracerebral haematoma evacuation (n=43; 12 exoscope, 12 endoscopic, 19 microscopic procedures) (Murakami et al. 2024), intracranial aneurysm surgery (n=185; 44 exoscope cases) (Pantel et al. 2022), transsphenoidal surgery for Cushing's disease (n=388) (Sumiński et al. 2022), and vestibular schwannoma resection (n=39; 13 exoscope, 26 microscope cases) (Veldeman et al. 2023).

Outcome measures included progression-free survival (PFS), overall survival (OS), extent of resection, duration of operation, blood loss, complication rates, mortality, remission rates, hearing preservation and facial nerve outcomes. In glioblastoma surgery, exoscope-assisted surgery achieved similar extent of resection and OS to microscopy but was associated with

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longer PFS (hazard ratio 3.55, 95% CI 1.66 to 7.56, $p = 0.001$) although follow-up duration was approximately one year (median follow-up of 13 months) (Di Cristofori et al. 2023).

In intracerebral haematoma evacuation, exoscope-assisted surgery achieved a 95% haematoma removal rate and no mortality, with significantly shorter operative and theatre times than conventional microscopic surgery (Murakami et al. 2024). In intracranial aneurysm surgery, operation duration was similar in the exoscope and microscope groups, as well as aneurysm occlusion rates and complication rates (Pantel et al. 2022). In Cushing's disease surgery, exoscopic transsphenoidal surgery was associated with higher remission rates but shorter operative duration and a lower incidence of Syndrome of Inappropriate Antidiuretic Hormone Secretion (SIADH)/diabetes insipidus compared with microscopic surgery, while rates of pituitary insufficiency and cerebrospinal fluid leakage were similar (Sumiński et al. 2022). Veldeman et al. (2023) reported the performance of ORBEYE during the microsurgical resection of vestibular schwannoma and found that hearing preservation, facial nerve function and radiological outcomes were comparable between groups, although exoscope use was associated with reduced operative duration.

Cost-effectiveness studies

No formal cost-effectiveness evaluations were identified.

Areas of uncertainty

- It is unclear whether some of the systematic reviews included randomised evidence. No other randomised controlled trials were identified, and follow-up duration was often short.
- Whilst some studies report outcomes that may have economic relevance, such as reduced operative duration, operating room efficiency, and ergonomic benefits, no formal cost-effectiveness studies were identified.
- Most studies focused on technical and process outcomes such as visualisation, ergonomics, operative duration, blood loss and surgeon experience. Relatively few studies evaluated patient-centred outcomes such as quality of life, return to normal activities or survival.
- Although some studies reported improved survival, remission rates or operative efficiency, it is unclear whether these findings were attributable to the exoscope itself or to other factors, such as surgeon experience, case selection, learning effects or differences in surgical technique.
- No evidence was identified from Wales, and there appears to be no current ORBEYE users in Wales. The feasibility, acceptability and resource implications of implementation within NHS Wales are uncertain.

Literature search results

Health technology assessments and guidance
None identified
Evidence reviews and economic evaluations
<p>Benato A, Creatura D, Palombi D, et al. (2026). Exoscope versus microscope in spine surgery: A meta-analysis based on procedure-specific subgroup analysis. <i>Neurosurg Rev.</i> 49(1). doi: 10.1007/s10143-026-04275-0. Available at: https://pubmed.ncbi.nlm.nih.gov/41961171/</p> <p>Chiang H, Ledbetter L, Kaylie DM. (2022). Systematic Review of Otologic and Neurotologic Surgery Using the 3-dimensional Exoscope. <i>Otology & Neurotology Open.</i> 2(4): e024. doi: 10.1097/ONO.0000000000000024. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC10950122/</p> <p>Montemurro N, Scerrati A, Ricciardi L, et al. (2022). The Exoscope in Neurosurgery: An Overview of the Current Literature of Intraoperative Use in Brain and Spine Surgery. <i>Journal of Clinical Medicine.</i> 11(1): 223. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8745525/</p>
Individual studies
<p>Di Cristofori A, Graziano F, Rui CB, et al. (2023). Exoscopic Microsurgery: A Change of Paradigm in Brain Tumor Surgery? Comparison with Standard Operative Microscope. <i>Brain Sciences.</i> 13(7): 1035. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC10377370/</p> <p>Garufi G, Conti A, Chaurasia B, et al. (2024). Exoscopic versus Microscopic Surgery in 5-ALA-Guided Resection of High-Grade Gliomas. <i>Journal of Clinical Medicine.</i> 13(12): 3493. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC11205195/</p> <p>Kijima N, Kinoshita M, Takagaki M, et al. (2021). Utility of a novel exoscope, ORBEYE, in gravity-assisted brain retraction surgery for midline lesions of the brain. <i>Surg Neurol Int.</i> 12: 339. doi: 10.25259/sni_320_2021. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8326087/</p> <p>Mc Sweeney D, Koustaïs S, Murphy N, et al. (2025). Preliminary Experience with the use of a 3-Dimensional Exoscope for Excision of Unruptured Brain Arteriovenous Malformations: Case Series and Comparative Analysis. <i>World Neurosurgery.</i> 200: 124198. doi: http://dx.doi.org/10.1016/j.wneu.2025.124198</p> <p>Murai Y, Shirokane K, Sato S, et al. (2022). Preliminary Clinical Surgical Experience with Temporary Simultaneous Use of an Endoscope during Exoscopic Neurosurgery: An Observational Study. <i>Journal of Clinical Medicine.</i> 11(7): 1753. Available at: https://www.mdpi.com/2077-0383/11/7/1753</p> <p>Murakami T, Toyota S, Okuhara S, et al. (2024). A Keyhole Approach for Intracranial Hematoma Removal Using ORBEYE. <i>World Neurosurgery.</i> 189: e598-e604. doi: http://dx.doi.org/10.1016/j.wneu.2024.06.122</p> <p>Pantel T, Drexler R, Götttsche J, et al. (2022). Single-Center Experience Using a 3D4K Digital Operating Scope System for Aneurysm Surgery. <i>Operative Neurosurgery.</i> 22(6): 433-9. doi: 10.1227/ons.0000000000000150. Available at: https://pubmed.ncbi.nlm.nih.gov/35383707/</p> <p>Sumiślawski P, Piffko A, Huckhagel T, et al. (2022). Exoscopic vs. microscopic transsphenoidal surgery for Cushing's disease: a retrospective single-center study on 388 patients. <i>Neurosurgical Review.</i> 45(6): 3675-81. doi: 10.1007/s10143-022-01866-5. Available: https://link.springer.com/article/10.1007/s10143-022-01866-5</p>

Veldeman M, Rossmann T, Huhtakangas J, et al. (2023). Three-Dimensional Exoscopic Versus Microscopic Resection of Vestibular Schwannomas: A Comparative Series. Operative Neurosurgery. 24(5): 507-13. doi: 10.1227/ons.0000000000000602. Available at: <https://journals.lww.com/onsonline/fulltext/10.1227/ons.0000000000000602~three-dimensional-exoscopic-versus-microscopic-resection-of>

Witten AJ, Ben-Shalom N, Ellis JA, et al. (2023). Optimization of novel exoscopic blue light filter during fluorescence-guided resection of Glioblastoma. Journal of Neuro-Oncology. 161(3): 617-23. doi: 10.1007/s11060-022-04231-0. Available at: <https://link.springer.com/article/10.1007/s11060-022-04231-0>

Ongoing research

None identified

Date of search	20 August 2026
Concepts used	ORBEYE, ORBEYE 4K 3D, digital exoscope, exoscope systems.

Proposed research question and evidence selection criteria (if selected)

Proposed Research question	What is the clinical and cost effectiveness of using a 4K 3D exoscope systems (including ORBEYE) in people undergoing neurosurgical procedures when compared with conventional operating microscopy?
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	Inclusion criteria	Exclusion criteria
Population	Patients undergoing neurosurgical procedures, including: Brain tumour surgery Glioblastoma surgery Skull-base surgery Cerebrovascular surgery Intracranial aneurysm surgery Arteriovenous malformation surgery Transsphenoidal surgery Vestibular schwannoma surgery Spinal neurosurgery	Non-neurosurgical procedures
Intervention	4K 3D exoscope systems used for neurosurgical visualisation, including: ORBEYE Other clinically equivalent 3D digital exoscopes	
Comparison/Comparators	Conventional operating microscopy	Studies without a comparator
Outcome measures	Patient outcomes (e.g., overall survival, progression-free survival, functional outcomes, hearing preservation) Mortality Procedural outcomes (e.g., operating time, theatre time, blood loss, length of stay) Workforce and organisational outcomes (e.g., staff acceptability, strain on surgeons) Health related QoL Resource use Economic outcomes (e.g., capital costs, budget impact)	

Proposed speciality	Nervous system
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