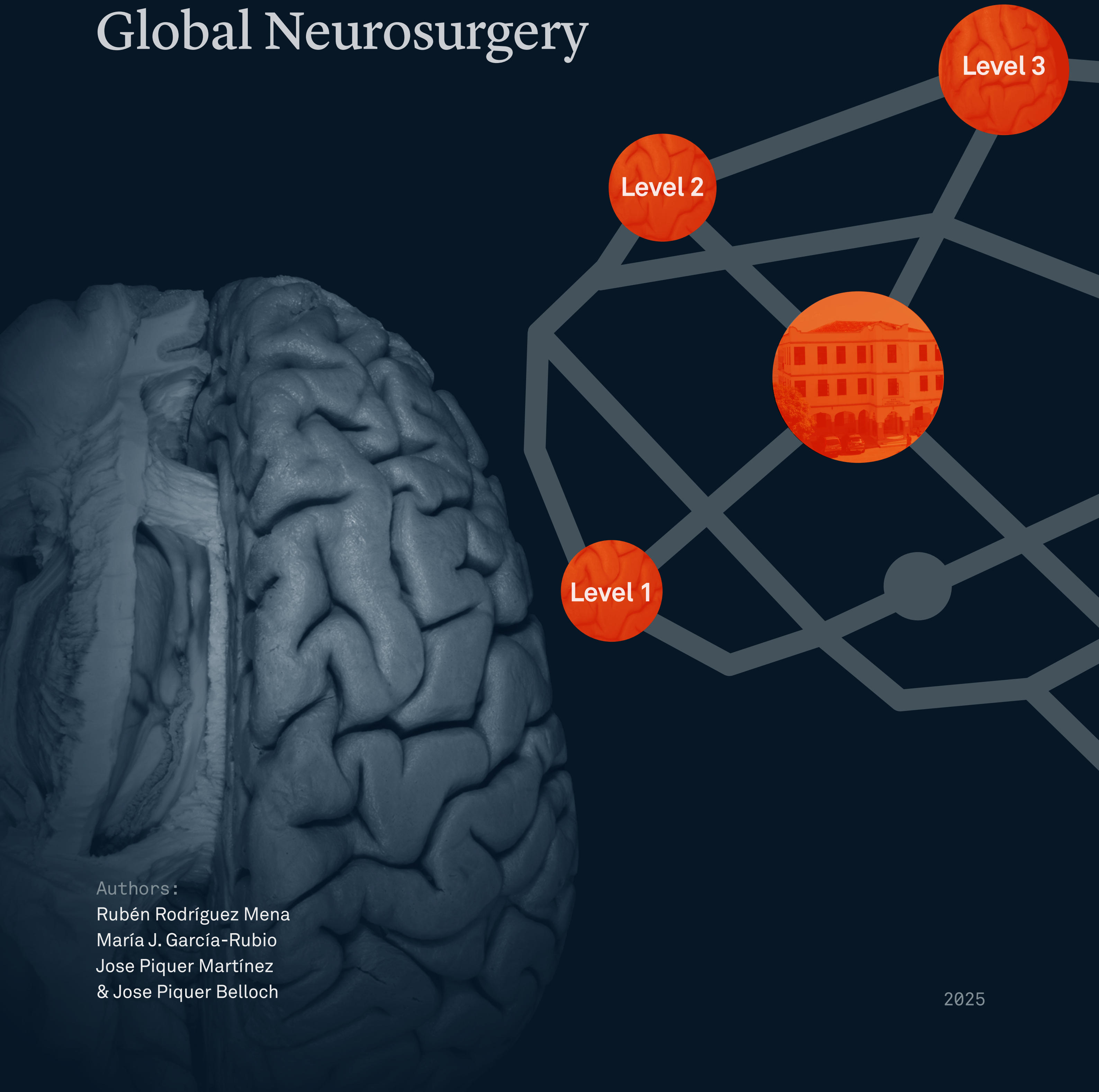
Cátedra VIU-NED de Neurociencia global y cambio social

Universidad Internacional de Valencia

VIU Editorial

Treating to Transform:

A Tiered Model for Global Neurosurgery



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VIU–NED Chair of Global Neuroscience and Social Change.

The VIU–NED Chair of Global Neuroscience and Social Change aims to place neuroscience at the service of social transformation. To achieve this, it promotes research, education, and national and international cooperation in the field of global neuroscience. The Chair is a joint initiative of the International University of Valencia (VIU) and the Neurosurgery, Education and Development (NED) Foundation.

NED

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viu EDITORIAL

Treating to Transform:

A Tiered Model for Global Neurosurgery

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List of Acronyms

DALY(s) – Disability-Adjusted Life Years
COSECSA – College of Surgeons of East, Central and Southern Africa
VPS – Ventriculoperitoneal Shunt
EVD – External Ventricular Drain
ETV – Endoscopic Third Ventriculostomy
ETV ± CPC – Endoscopic Third Ventriculostomy with/without Choroid Plexus Cauterization
ETE – Equip, Treat, Educate
WHO – World Health Organization
MRI – Magnetic Resonance Imaging
CNS – Central Nervous System
CT – Computed Tomography
TBI – Traumatic Brain Injury
ICU – Intensive Care Unit
WFNS – World Federation of Neurosurgical Societie

Methodological note: This report used ChatGPT (OpenAI) to support the preliminary search and organization of scientific references, under the supervision of the authors.

Abstract

Access to neurosurgery remains an unmet need in low-resource health systems. Sub-Saharan Africa bears one of the world's highest burdens of neurological disease but has less than 1% of the world's neurosurgeons. As a result, thousands of people with treatable conditions—such as infant hydrocephalus, traumatic brain injury (TBI), or benign tumors—die or suffer severe disability due to lack of timely treatment.

In response to this reality, the NED Foundation developed the **ETE model (Equip, Treat, Educate)** as an integrated health cooperation strategy. This report focuses on the **Treat** component, organizing neurosurgical care into three progressive levels of increasing complexity: From basic emergencies to advanced local autonomy.

Zanzibar's experience illustrates this trajectory:

Level 1: Beginning in 2008 with no resources and no local neurosurgeons. Basic treatments such as shunt placement for hydrocephalus, burr holes, and drains were introduced. Each procedure saved lives that would otherwise have been lost.

Level 2: From 2014 onwards, with the creation of the NED Institute, craniotomies, spinal surgery, and initial microsurgery were incorporated. Ninety percent of trauma surgeries began to be performed by local physicians, and the first accredited neurosurgery residency program was established.

Level 3: Although still far from reaching the third level, today Zanzibar is advancing towards higher autonomy, with trained neurosurgeons, residents in training, and the capacity to manage more complex pathologies. The increased accessibility of advanced diagnostic equipment such as CT scanners, MRI machines, and microscopes has enabled the successful management of cases that were previously unthinkable.

The results are remarkable: In just over a decade, more than **3,000 surgeries** and **40,000 outpatient consultations** have been performed, transforming a once non-existent service into a **regional training center**. What began with sporadic missions and an unequipped operating room has evolved into an institute capable of saving lives daily and training the next generation of neurosurgeons.

/ Report Structure

1. The problem

2. Application of the Model

3. Lessons

LESSONS LEARNED ARE CLEAR:

- Advancing by levels allows safe and sustainable growth.
- Treating patients is not only immediate care: Every surgery is also training and system-building.
- Sustained international cooperation, aligned with local authorities, is key to success.

The final message is simple but urgent: **Investing in basic neurosurgery saves lives today and strengthens health systems for tomorrow.** The ETE model demonstrates that, with a clear roadmap and shared commitment, it is possible to replicate this success in other low-resource countries.

Key Messages

1. SUB-SAHARAN AFRICA BEARS ONE OF THE HIGHEST NEUROLOGICAL DISEASE BURDENS WORLDWIDE, YET HAS LESS THAN 1% OF NEUROSURGEONS.
The structural deficit of specialists turns treatable conditions—such as infant hydrocephalus and traumatic brain injury—into death sentences or causes of lifelong disability. In 2008, no newborn with hydrocephalus in Zanzibar could be treated locally, revealing a gap costing thousands of preventable lives.

2. LACK OF ACCESS TO SAFE SURGERY CAUSES SUBSTANTIAL GDP LOSSES IN LOW-INCOME COUNTRIES.
The Global Surgery 2030 reports identify neurosurgery as a critical area due to its high DALY burden and its impact on children and working-age adults, generating devastating human and economic costs.

3. EPISODIC SURGICAL MISSIONS DO NOT CREATE SUSTAINABLE CAPACITY.
International evidence confirms that short-term interventions, without educational integration or institutional strengthening, perpetuate dependency. Only longitudinal models combining equipment, treatment, and education achieve true autonomy.

4. THE ETE MODEL SHOWS IT IS POSSIBLE TO PROGRESS FROM ZERO NEUROSURGICAL CAPACITY TO REGIONAL CENTERS OF EXCELLENCE.
Zanzibar has evolved from having no neurosurgeons to performing over 3,000 surgeries, training local residents, and becoming an accredited reference center—proving the feasibility of stepwise transformation.

5. EACH LEVEL OF NEUROSURGICAL DEVELOPMENT LAYS THE FOUNDATION FOR THE NEXT.
Stepwise progress—from basic treatments (Level 1) to high complexity (Level 3)—ensures sustainability and safety. Attempting complex procedures without consolidating the basics increases risk and prevents real autonomy.

6. SAVING LIVES AND BUILDING AUTONOMY ARE INSEPARABLE PROCESSES.
Every surgery performed is not just immediate care: It also represents training for the local team and system building. This duality multiplies the impact of each intervention beyond the individual patient.

7. STRUCTURED TRAINING AND SUSTAINED MENTORSHIP ARE FUNDAMENTAL FOR TALENT RETENTION.
Long-term success depends on establishing accredited residency and fellowship programs that enable the training of local neurosurgeons, preventing the brain drain that perpetuates shortages.

8. MULTIDISCIPLINARY COLLABORATION IS ESSENTIAL FOR NEUROSURGICAL SUCCESS.
A solid service requires teamwork among neurosurgeons, anesthetists, nurses, imaging technicians, intensivists, and physiotherapists. Without this integrated network, isolated surgery loses both efficacy and sustainability.

9. FINANCIAL SUSTAINABILITY REQUIRES GOVERNMENT COMMITMENT.
While international cooperation is vital for takeoff, achievements only consolidate when national health systems gradually assume the financing of personnel, equipment, and maintenance.

10. THE ETE MODEL IS REPLICABLE AND ADAPTABLE TO OTHER LOW-RESOURCE CONTEXTS.
Zanzibar's documented experience offers a clear roadmap that can inspire similar transformations elsewhere, adapting to local realities while maintaining the fundamental principles of stepwise progression.

1 Introduction: The Challenge of Neurosurgery in Low-Resource Settings

1. Introduction: The Challenge of Neurosurgery in Low-Resource Setting

Neurosurgery represents one of the greatest equity challenges in global health. In low- and middle-income countries, access to neurosurgical services remains extremely limited, leading to millions of lives lost or marked by preventable disabilities. The scale of the problem translates into stark realities. In 2008, no newborn with hydrocephalus in Zanzibar could be treated locally, and only four patients with severe TBI were admitted to intensive care—none survived beyond five days..

A GAP THAT COSTS LIVES

Over the past decade, global surgery literature has established that access to essential surgical services—including neurosurgery—is a core component of universal health coverage and a key factor for economic development. The Global Surgery 2030 reports estimate that the lack of access to safe, affordable surgery causes substantial GDP losses in low-income countries, identifying neurosurgery as a critical area due to its high DALY burden and its impact on children and the working population (Meara et al., 2015).

THE STRUCTURAL DEFICIT

Global capacity analyses show that the shortage of specialists is the main bottleneck—but the problem extends beyond the absence of neurosurgeons. The deficit is compounded by challenges in anesthesia and intensive care, lack of diagnostic neuroimaging, and basic issues such as sterilization. This combination leaves millions without access to procedures that, elsewhere, would be routine. The result is avoidable delays and high indirect costs in disability and lost productivity (Dewan et al., 2019; Ukachukwu et al., 2022).

In these settings, neurosurgical pathologies have a particular profile. Road-traffic-related TBI, infant hydrocephalus, CNS infections, spina bifida, and treatable tumors represent a disease burden that—paradoxically—could be addressed with appropriate resources. Yet the combination of high incidence and limited services creates a vicious cycle where avoidable delays translate into devastating human and economic consequences.

CHALLENGES IN TRAINING AND TALENT RETENTION

The shortage of neurosurgeons is linked to lengthy training pathways concentrated in few centers, along with poor retention due to inadequate pay, deficient infrastructure, and limited academic opportunities. Many trained professionals emigrate, perpetuating scarcity.

Although initiatives such as COSECSA (College of Surgeons of East, Central and Southern Africa) have expanded regional training, critical bottlenecks persist: Lack of specialist supervision, limited exposure to complex cases, and restricted access to technology. Recent studies highlight the importance of early mentorship and the value of university–hospital partnerships to fill key skill gaps (Bekele et al., 2024; Kuol et al., 2024).

APPROPRIATE INFRASTRUCTURE AND TECHNOLOGY

Neurosurgery depends on more than the operating room; it requires a complex ecosystem that includes imaging, anesthesia and critical care, sterilization systems, instrument banks, and biomedical logistics for maintenance. Pioneering experiences such as mobile endoscopy have demonstrated that complex procedures can be introduced and stabilized in peripheral settings, keeping costs under control and ensuring continuity of care (Almeida et al., 2018; Piquer et al., 2010). The key lies in selecting robust, sustainable equipment, accompanied by proper maintenance protocols and specialized training for technical staff.

CONTEXT-ADAPTED CLINICAL STRATEGIES

Evidence has identified specific strategies that make a difference in low-resource settings. In selected cases of infant hydrocephalus, endoscopic third ventriculostomy (ETV ± CPC) can be a viable alternative when shunt management is problematic. Scoring systems help select suitable candidates, including data for posthemorrhagic hydrocephalus in preterm infants.

For myelomeningocele, early surgery and infection-prevention protocols have markedly improved survival and function. In TBI management, standardized triage, pragmatic use of basic neuroimaging, and context-adapted intracranial pressure control—when monitors are unavailable—combined with context-specific critical care protocols have reduced complications and intervention times (Leidinger et al., 2019).

MODELS OF COOPERATION AND SUSTAINABILITY

International experience strongly confirms that episodic surgical missions, without educational integration or institutional strengthening, do not generate sustainable capacity. In contrast, longitudinal models combining equipment, joint treatment, and continuous education—both onsite and remote—allow real transfer of competencies, progressive autonomy, and local talent retention.

Deliberate practice and mentorship with residents and local specialists translate into measurable improvements in outcomes and safety. Supervised task delegation in well-defined procedures can expand access without compromising quality, provided there are clear supervision circuits and graded complexity criteria (Rodríguez-Mena et al., 2023).

ETHICAL FRAMEWORK AND GLOBAL AGENDA

Initiatives such as the Boston Declaration 2025 emphasize reciprocity, co-development, and transparent evaluation using clinical, training, and system indicators. These principles seek to avoid traditional asymmetries and ensure that cooperation strengthens, rather than replaces, the host system (Veerappan et al., 2022).

TOWARD A REPLICABLE MODEL: FROM DEPENDENCE TO AUTONOMY

The case of Zanzibar illustrates how a well-designed cooperation model can progressively transform diagnostic and therapeutic capacity in low-resource environments. Through the ETE model (Equip, Treat, Educate), the NED Foundation has shown that combining appropriate infrastructure and equipment, context-adapted treatment programs, and longitudinal training can move a system from external dependence to sustainable local capacity (Piquer et al., 2024).

The results are tangible: Zanzibar has evolved from almost no neurosurgical capacity to a functional program with over 2,800 surgeries and 40,000 consultations. In 2018, the NED Institute obtained COSECSA accreditation to train neurosurgery residents—admitting the first neurosurgery resident in Zanzibar's history. By 2025, many routine surgeries are performed by local doctors, including 24-hour neurotrauma care.

This experience aligns with international literature and provides a framework to inspire other regions facing similar constraints (Fuller et al., 2016).

A STEPWISE ROADMAP

This trajectory can be understood as a stepwise roadmap in three progressive levels, each laying the groundwork for the next. The NED Foundation model demonstrates how, starting from minimal clinical capacity, it is possible to progressively reach greater local autonomy.

FIGURE 1. *Equip, Treat and Educate (ETE) Model*

NED MODEL	1	2	3
Equip	**Basic infrastructure** • Operating room • Surgical instruments (skull and spine) • Consultation rooms • Meeting room	**Specialised infrastructure** • Hospitalization Unit • General ICU • Microscope • Neuroendoscope • Ultrasound scanner	**Advanced infrastructure** • Neurocritical ICU • Gas analyzer • X-ray arch • Vascular box • Skull base box • Incubators
Treat	**Level I Pathologies** • Traumatic brain injury • Hydrocephalus • Myelomeningocele • Encephalocele • Central Nervous system infections	**Level II Pathologies** • Ventricular endoscopy • Spinal cord injury • Spinal cord tumors • Hemispheric brain tumors • Degenerative spine	**Level III Pathologies** • Pituitary tumors • Pediatric tumors • Skull base surgery • Vascular pathology • Complex spinal surgery
Educate	**Mentoring** • Local talent recruitment • Motivation and • empowerment of staff • Basic training (eg.surgical instrumentation course) • Daily meetings	**Resideney Program Official accreditation** • Residency Program • Specialized training (e.g. Neuro-oncology) • Fellowships • Weekly sessions (offline/online)	**Lifelong training Super-specialization** • Local specialists train new residents • Continuous training (advanced skills and new techniques)

Note. Schematic representation of the NED Foundation's ETE health cooperation model showing three levels of development across the domains of Equipment, Treatment, and Education. Adapted from Piquer et al., 2023, *Global Neuroscience and Social Change: A Model of Health Cooperation.*

Level 1 focuses on basic treatments and initial autonomy, prioritizing high-impact, life-saving pathologies manageable with relatively simple procedures: Infant hydrocephalus (VPS), mild–moderate TBI with hematoma evacuation, and CNS infections requiring basic drainage.

Level 2 incorporates intermediate procedures and capacity consolidation, addressing complex trauma, compressive spinal disease, intricate congenital malformations, and selected brain tumors—marking the transition to an intermediate service with growing autonomy and structured training capacity.

Level 3 represents full specialty maturity, with autonomous management of highly complex pathologies such as skull base tumors, selected vascular lesions, complex spinal deformities, and procedures requiring advanced microsurgery and neurophysiological monitoring.

This progressive dynamic reflects not only technical advancement but also parallel development in infrastructure, training, and clinical governance, culminating in a self-sustaining neurosurgical ecosystem.

“THE LACK OF ACCESS TO SAFE AND AFFORDABLE SURGERY CAUSES SUBSTANTIAL GDP LOSSES IN LOW-INCOME COUNTRIES”.

2 A Tiered Model: From Dependence to Autonomy

2.1. First level: Basic treatments and initial autonomy

2.2. Second level: Expansion of capabilities and structured training

2.3. Third level: High-complexity procedures and full autonomy

2. A Tiered Model: From Dependence to Autonomy

Sustainable neurosurgical development in low-resource settings requires a structured and gradual progression that balances ambition with realism. The experience of Zanzibar demonstrates that such transformation can be organized into three consecutive levels—from the management of basic emergencies to the autonomous resolution of complex pathologies. Each level consolidates specific capacities before moving to the next, ensuring that growth is safe, sustainable, and oriented toward autonomy rather than prolonged dependence. In this section, each stage of the model is analyzed through four interconnected dimensions.

In this section, each stage of the model is analyzed through four interconnected dimensions. For every level of development, we identify the priority pathologies guiding clinical practice, examine the specific neurosurgical techniques to be mastered, outline the infrastructure and training needs, and assess the expected clinical and systemic impacts. This structure helps to understand not only what is done at each phase, but why it is prioritized in that order and how each element contributes to the ultimate goal of building sustainable local capacity.

2.1. Level One – Basic Treatments and Initial Autonomy

Level 1 focuses on establishing the most fundamental neurosurgical capabilities in environments starting from zero or with severely limited resources.

Its goal is to address the most common and life-threatening neurosurgical emergencies with minimal but reliable equipment. This initial stage is critical, as it responds to previously unmet needs that often determine survival.

In low-income countries, certain conditions—such as infant hydrocephalus or severe head trauma—frequently amount to a death sentence or lifelong disability due to the absence of surgical care. For example, in 2008, no newborn with hydrocephalus in Zanzibar could be treated at Mnazi Mmoja Hospital. Only wealthier families could afford transfer to the mainland for a ventriculoperitoneal shunt (VPS), while most infants either died or suffered irreversible neurological injury due to lack of access.

Similarly, severe traumatic brain injury (TBI) had a grim prognosis: That same year, only four patients with severe TBI were admitted to the local Intensive Care Unit (ICU), and none survived beyond five days—there was no neurosurgeon and no possibility of surgery.

These sobering data underline the urgency of introducing basic neurosurgical capacity. Level 1, therefore, is about saving lives by responding to critical emergencies while simultaneously laying the foundations of a local neurosurgical service (Rodríguez-Mena et al., 2023).

ILLUSTRATIVE PATHOLOGIES

At this first level, the focus is on high-prevalence, high-impact conditions that can be resolved through low- or moderate-complexity techniques, where timely intervention prevents severe complications and reduces mortality. Key examples include:

Mild to moderate TBI with accessible epidural or subdural hematomas, particularly among young patients (Meara et al., 2015; Piquer et al., 2023).

- **Spina bifida – myelomeningocele**, an exposed congenital malformation with a high risk of infection and neurological deterioration. Early closure (ideally within 72 hours) using a simple layered repair, antibiotic prophylaxis, appropriate nursing care (sterile moist dressing, prone positioning, temperature control), and pediatric anesthesia is prioritized. Associated hydrocephalus must also be assessed and treated. Standardized management of these steps in Zanzibar significantly reduced infections and improved functional survival (Warf, 2011; Leidinger et al., 2019).
- **Infant hydrocephalus** suitable for VPS or, in selected cases, endoscopic third ventriculostomy (ETV ± CPC) depending on the team's experience and equipment availability (Dewan et al., 2019). Early treatment is crucial: A single shunt procedure may determine life or death—or the difference between normal development and lifelong disability.
- **Central nervous system (CNS) infections**, such as bacterial meningitis. While antibiotic therapy is the mainstay of treatment, the neurosurgeon's role arises in preventable or surgically treatable complications: For example, infectious hydrocephalus requiring shunt placement or brain abscesses and epidural/subdural collections that require drainage (Barichello et al., 2023).

These conditions are prioritized because they are common, highly responsive to simple interventions, and serve as training milestones for local teams.

TECHNIQUES

Procedures at Level 1 are essential, reproducible, and low-tech, forming the core of basic neurosurgery. They can be performed safely with standard surgical instruments and general surgical skills:

- **Ventriculoperitoneal shunt (VPS)** placement using standardized techniques and affordable valves to divert excess cerebrospinal fluid into the peritoneal cavity.
- **Simple endoscopic procedures**—when equipment allows—such as ETV ± CPC, which has proven effective in appropriately selected cases of infant hydrocephalus, reducing shunt dependence and hardware-related failures (Warf, Mugamba & Kulkarni, 2010).
- **Emergency burr holes** or **simple craniotomy/craniectomy** for evacuation of small epidural or subdural hematomas. In early phases, many surgical decisions in trauma rely primarily on **clinical assessment** rather than imaging, due to lack of computed tomography (CT). For instance, during Zanzibar's early years, emergency surgery for TBI was often indicated based on clinical signs—low Glasgow Coma Scale, dilated pupils, or obvious depressed skull fracture—proceeding with an exploratory burr hole or decompressive craniectomy without prior imaging (Rodríguez-Mena et al., 2023).

For CNS infections, techniques include diagnostic lumbar puncture, external ventricular drainage (EVD) for acute infectious hydrocephalus, and surgical drainage of accessible brain abscesses via small craniotomy.

Although technically simple, these interventions require a functioning operating room, safe general anesthesia, and a team trained in airway management, bleeding control, and immediate postoperative care (Fuller et al., 2016).

REQUIREMENTS

Implementing Level 1 requires addressing several critical prerequisites:

- **Infrastructure:** A functional operating room with proper lighting, reliable sterilization, and a post-anesthesia recovery area.
- **Equipment:** A basic neurosurgical set (manual or electric drill, standard instruments, suction system, magnifying loupes), VPS materials (valves, catheters), and essential medical supplies (intravenous antibiotics, anesthetics, sutures).
- **Human resources:** At least one surgeon trained in basic procedures, an anesthetist familiar with neurosurgical cases, and trained perioperative nursing staff.
- **Clinical protocols:** Context-adapted guidelines for trauma, hydrocephalus, and CNS infections, with clear referral criteria for complex cases.
- **Logistics:** A secure supply chain for valves, drains, and essential antibiotics, with inventory control and scheduled restocking.

These needs align with Global Surgery 2030 recommendations and mirror successful experiences in Uganda, Tanzania, and Malawi (Meara et al., 2015). In Zanzibar, when the first NED team arrived in 2008, the only neurosurgical instrument they found was a shunt tunneler—used to pass catheters under the skin. Such conditions are common in under-resourced hospitals: Teams often start literally from zero.

For this reason, international cooperation plays a crucial role from the outset.

Level 1 services are typically launched with external support providing basic equipment (shunt kits, manual drills, simple monitoring devices) and deploying short-term surgical missions. These volunteer teams visit hospitals for a few weeks, treating as many urgent patients as possible while simultaneously training local staff. This model has been used throughout sub-Saharan Africa to initiate neurosurgical services and was the only viable option at the start of the Zanzibar program (Leidinger et al., 2018).

Regarding training needs, Level 1 focuses on building basic skills and stimulating local interest in neurosurgery. Because there are usually no local neurosurgeons at this stage, early training targets young general practitioners or surgeons, teaching them how to identify and manage neurosurgical emergencies. Nursing teams receive instruction in perioperative care, sterile technique, and instrument handling.

During Zanzibar's first years, NED organized introductory courses covering basic image interpretation (when CT was occasionally available), patient preparation, surgical positioning, asepsis, and use of instruments (Rodríguez-Mena et al., 2023). Particular emphasis was placed on teaching simple, life-saving procedures—for instance, performing a lumbar puncture or an emergency burr hole—to grant local teams early autonomy in critical cases.

At this stage, close supervision by visiting experts is indispensable. Virtually every procedure is performed under the guidance or direct assistance of visiting neurosurgeons, whose mission is not only to treat patients but to "teach by doing." This intensive mentoring creates the foundation for local surgeons to gain confidence and skill through repetition and observation.

IMPACT

Achieving Level 1 results in tangible, measurable benefits:

- Reduced mortality from severe TBI through timely evacuation of epidural or subdural hematomas.
- Fewer complications and deaths from hydrocephalus treated early.
- Improved functional recovery and fewer neurological sequelae in surgically managed CNS infections.
- Growing confidence and experience within the local team, paving the way for more complex interventions.

This initial autonomy sets the stage for future system growth, fosters professional commitment, and strengthens community trust in local healthcare capacity.

In Zanzibar, implementation of this level between 2018 and 2020 increased annual neurosurgical procedures from fewer than ten to over 150. Although complication rates were initially high, they declined steadily thanks to continuous training and protocol standardization (Piquer et al., 2024).

2.2. Level Two: Capacity Expansion and Structured Training

At this stage, the service begins to manage more complex pathologies than in Level 1, while still focusing on conditions that are common and high-impact in low-resource settings. These are cases in which timely surgery can dramatically improve survival and quality of life, provided there is a team with growing experience and a minimum consolidated infrastructure.

Level 2 is typically reached after several years of Level 1 work, once key milestones are in place: a modest upgrade of hospital infrastructure, local staff trained in foundational skills, and often one or more locally based physicians dedicated to neurosurgery (even if still in training). In this sense, Level 2 marks the transition from the basics to an intermediate neurosurgical service, where the facility expands its technical capabilities and the local team begins to play a leading role in surgery (Ellegala et al., 2014; Uche et al., 2022).

In broad terms, Level 2 widens the case mix (covering moderately complex conditions previously referred out or left untreated) and gradually reduces dependence on external support as local professionals gain experience (Rodríguez-Mena et al., 2023). It is a period of accelerated autonomy: The hospital invests in mid-range equipment, formalizes training programs (residencies, fellowships), and a substantial share of the clinical workload is carried by local physicians. In Zanzibar, the shift to Level 2 became possible only after 2014 with the construction and opening of the NED Institute of Neurosurgery within Mnazi Mmoja Hospital.

ILLUSTRATIVE PATHOLOGIES

Priority conditions include:

- **Complex traumatic brain injury (TBI):** Large epidural or subdural hematomas, hemorrhagic contusions, and extensive depressed or compound skull fractures—lesions with significant mass effect requiring wider craniotomies and intensive postoperative care.
- **Non-complex compressive spine disease**, mainly degenerative (e.g., lumbar or cervical canal stenosis; disc herniation causing sciatica or myelopathy). In many African countries, these cases historically went untreated due to the lack of specialists, leaving patients with chronic pain and disability. Today, decompressive surgery—often with microsurgical support—can address many of them.
- **More complex congenital conditions (e.g., hydrocephalus with Chiari II malformation,** multiloculated hydrocephalus) that demand advanced endoscopy or combined techniques. These pathologies form a bridge between basic surgery and highly specialized procedures, and progressively increase local autonomy (Haglund et al., 2017; Warf, 2011).
- **CNS infections:** Larger brain abscesses requiring craniotomy for drainage when antibiotics alone are insufficient; and spinal tuberculosis (Pott disease) with bone destruction and deformity, optimally managed with combined antituberculous therapy, decompression, and spinal instrumentation—which already presupposes availability of implants and surgical experience.
- Initial management of **selected supratentorial brain tumors** in symptomatic patients with progressive deficits where resection can be achieved safely via conventional approaches—for example, favorably located intracranial meningiomas (superficial, convexity), which tend to grow slowly and have good functional and survival outcomes when appropriately treated.

TECHNIQUES

Level 2 requires a technical step-up compared with Level 1. In Zanzibar, the acquisition of a modern surgical microscope (high magnification and illumination) was pivotal—a true inflection point that opened sustained opportunities to train local staff in microsurgical techniques, coupled with a gradual expansion of cranial and spinal microinstrumentation and strong external mentorship.

On the diagnostic side, 24/7 in-hospital CT access at no cost to patients was a game changer, revolutionizing diagnostic capacity and surgical planning: Local neurosurgeons no longer relied exclusively on clinical signs but could confirm intracranial lesions, localize abscesses or tumors, and evaluate trauma accurately, improving the efficiency and timeliness of urgent decision-making. The introduction of intraoperative ultrasound further strengthened outcomes in brain tumor surgery.

Representative Level-2 techniques include:

- **Wide craniotomies/craniectomies** to evacuate intraparenchymal hematomas with more demanding hemostasis and drainage, and cranial reconstruction for complex fractures.
- **Resection of accessible intracranial tumors, i**ncreasingly employing microsurgical methods.
- **Spinal decompressions** for severe stenosis or cord compression and spinal fixation—anterior (mainly cervical) or posterior (thoracolumbar)—for vertebral fractures or degenerative disease, achieving mechanical stability with metallic osteosynthesis. Here, a mobile C-arm fluoroscopy unit is crucial to provide intraoperative imaging for safer instrumentation.
- **Advanced neuroendoscopy** for multiloculated hydrocephalus or cases associated with **cranioencephalic malformations**, requiring greater technical mastery and reliable, routinely available endoscopic systems.

Although complex cases may still require visiting specialists, the proportion of surgeries performed by the local team rises steadily. Clinicians who were apprentices in Level 1 now conduct, under targeted supervision, a growing volume of routine procedures, consolidating skills and intraoperative judgment. In Zanzibar, an illustrative milestone came in 2017, when ~90% of TBI surgeries were performed by locally trained doctors at the NED Institute with minimal external assistance—a clear sign of Level-2 autonomy.

REQUIREMENTS

Progress to Level 2 is impossible without parallel strengthening of infrastructure, system organization, and team training. Key needs include:

- **Infrastructure:** Operating rooms equipped with an adaptable surgical table, high-power suction and reliable electrocautery, adequate surgical lighting, and uninterrupted oxygen and power supply (backup generators); surgical microscopes, second-generation endoscopes, and advanced sterilization systems. A larger stock of neurosurgical instruments (electric drill systems, craniotomy and laminectomy sets, microsurgical forceps kits, etc.) is essential. Many of these resources are expensive and often require external funding or targeted donations. In Zanzibar, building the NED Institute was accompanied by the provision of anesthesia ventilators, multiparameter monitors, the microscope, and other supplies that transformed the OR into a theater suitable for more complex cases—illustrating that Level 2 demands substantial investment in mid-range equipment, typically achieved through NGO–government partnerships (Rodríguez-Mena et al., 2023).
- **Critical care:** Availability of ICU with hemodynamic and respiratory monitoring, access to broad-spectrum antibiotics, mechanical ventilation, and follow-up neuroimaging.
- **Human resources**: Neurosurgeons with advanced training, anesthetists experienced in complex cases, and nursing staff specialized in critical care and rehabilitation.
- **Continuous training:** International mentorship, structured residency programs, access to surgical simulation, and rotations at reference centers.
- **Diagnostic support:** Reliable CT and MRI, plus the ability to perform basic pathology studies to guide decision-making in oncological disease.

In education and human resources, Level-2 needs are even more critical. Consolidating a sustainable neurosurgical service requires moving from ad-hoc training to an official specialist training program. There are two complementary paths:

1. Sponsored mobility for local physicians to complete residency at accredited regional/international centers, with a commitment to return; and/or
2. Establishing an accredited in-house neurosurgery residency, capable of training professionals continuously.

Across sub-Saharan Africa, COSECSA has played a central role by accrediting hospitals that meet neurosurgical training standards. In 2018, the NED Institute in Zanzibar achieved COSECSA accreditation to train neurosurgery residents, enabling admission of the first neurosurgery resident in the archipelago's history. This milestone marked the transition from short courses to structured, long-term training with multi-year programs, internal rotations, and placements at regional and international hospitals.

Education at this level extends beyond residents: It includes scrub nurses dedicated to neurosurgery, anesthesiologists trained in neurological procedures, radiology technicians for CT/MRI services, and progressively ICU staff with competencies in neurological monitoring. In parallel, on-site international courses—such as ATLS for trauma and surgical neuroanatomy—help update knowledge and consolidate safety standards in daily practice.

Investment in training at Level 2 ensures that surgical autonomy no longer depends on an external expert's presence but on a critical mass of local professionals able to sustain and expand the service (Henderson et al., 2020; Kelechi, 2021).

Institutionally, Level 2 requires embedding neurosurgery within local systems via clear protocols and workflows: Referral and counter-referral criteria from peripheral hospitals; clinical pathways for polytrauma, severe TBI, and spinal trauma (from Emergency to ICU with defined checkpoints); and waiting-list management for elective surgery (degenerative spine, accessible intracranial tumors). Standardization reduces clinical variability, improves safety, and enables performance monitoring with process and outcome indicators (e.g., time to CT, time to OR, complication and readmission rates) (Ahmed et al., 2024; Meara et al., 2015; Uche et al., 2022; Cheyuo & Hodaie, 2023).

Financial sustainability must also evolve: Whereas Level 1 relied heavily on volunteers and donations, Level 2 seeks increasing budgetary commitment from government to cover trainee salaries, equipment maintenance, and critical consumables (valves, drains, antibiotics, sterilization). Centralized procurement, biomedical maintenance contracts, and predictable spare-parts logistics reduce external dependence and protect service continuity.

External support remains valuable but its role shifts—from filling daily service gaps to targeted mentorship and tele-mentoring for complex cases (e.g., weekly virtual case conferences), plus advanced training (simulation, technique workshops, case reviews). Expert visits are scheduled with clear clinical and educational goals, co-led with local leadership, and documented with competency transfer metrics. The relationship becomes a peer collaboration, with co-directed programs and joint quality and safety evaluation. In this framework, the center consolidates a core local faculty able to sustain the service and train the next cohort.

In summary, Level 2 demands specialized teams, structured training (accredited residencies and high-yield rotations), and stronger local governance and financing. By the end of this phase, results are typically striking: The center treats more patients with better outcomes, the first locally trained neurosurgeons emerge as clinical and teaching leaders, and the hospital consolidates its status as a regional referral hub with growing autonomy—setting the stage for Level 3.

IMPACT

Consolidating Level 2 has a transformative impact on neurosurgical care in low-resource environments. First, there is a marked reduction in avoidable mortality among severely ill patients—those with TBI, intracranial hematomas, CNS and spinal infections, and hydrocephalus—thanks to the capacity to perform urgent surgery coupled with more intensive postoperative care. Patients who previously died within days now survive and often return to family and productive life.

Second, introducing intermediate procedures expands the service toward chronic and/or progressive conditions—such as benign brain tumors, degenerative spinal disease, or CNS infections. The impact goes beyond survival: It directly improves quality of life by restoring neurological function and reducing disability. Hospitals that reach Level 2 are increasingly perceived by communities as reliable referral centers capable of offering solutions beyond life-threatening emergencies, thereby strengthening trust in the health system (Veerappan et al., 2022).

A further critical effect is the reinforcement of local autonomy. As more surgeries are performed by locally trained physicians, the need for costly, distant referrals decreases. In Zanzibar, for example, this has led to a sharp reduction in transfers to Dar es Salaam, producing substantial savings for families and more equitable access. Level 2 also creates a multiplier effect in human capital: Accredited residency programs and a robust general neurosurgical activity attract and retain young doctors, anesthetists, and nurses. The hospital becomes a regional training hub.

Level 2 upskills local teams through mentorship, rotations in specialized centers, and the implementation of context-adapted surgical protocols (Piquer et al., 2024). This consolidates multidisciplinary teamwork, improving coordination across surgery, anesthesia, and postoperative care—an essential factor in reducing professional emigration, a chronic challenge in sub-Saharan Africa (Henderson et al., 2020; Kelechi, 2021).

Finally, Level 2's impact extends beyond health: With more patients treated locally and fewer families forced into debt to seek care off-island, there are tangible economic and social gains. The ability to manage more complex conditions locally strengthens community cohesion and legitimizes public investment in neurosurgery as a driver of health-system and social development.

2.3. Level Three: High-Complexity Procedures and Full Autonomy

Level 3 represents the maturity of neurosurgery as a specialty within the local context. The objective at this stage is for the hospital to acquire the capacity to manage high-complexity neurosurgical pathologies autonomously, with only minimal or selective external support. At this point, the institution already has fully trained local specialists, supported by advanced infrastructure and well-established clinical protocols. The degree of autonomy is high: Most neurosurgical cases in the population can be managed internally, with only rare, highly specialized situations referred to external centers. Reaching this level usually requires over a decade of gradual development, sustained investment, and well-structured international cooperation. In Zanzibar, this stage has not yet been fully achieved, although solid foundations have been laid toward it (Rodríguez-Mena et al., 2023; Piquer et al., 2024).

The transition to Level 3 coincides not only with the completion of training by the first generation of local neurosurgeons—the "fruits" of the residency program initiated in Level 2—but also with the accumulation of years of professional experience, which strengthens surgical and clinical competencies and enables them to lead and organize the service. In parallel, the installation and use of state-of-the-art equipment—advanced microscopes, neuronavigation, neurophysiological monitoring, and high-end endoscopic technology—mark the consolidation of a self-sufficient surgical ecosystem (Bekele et al., 2024; Uche et al., 2022).

Importantly, Level 3 does not signify the end of international collaboration. While structural dependency decreases significantly, strategic partnerships remain essential for ultra-specialized cases, continued training, and participation in global research networks. Cooperation at this level becomes selective and excellence-oriented, reflecting the service's maturity and integration into the international neurosurgical community.

ILLUSTRATIVE PATHOLOGIES

Level 3 involves managing **high-complexity pathologies** that demand mature teams, advanced technology, and consolidated clinical systems.

- Intracranial: **Skull base tumors** (e.g., middle and posterior fossa meningiomas), intrinsic brain tumors such as low- and high-grade gliomas in eloquent areas, posterior fossa tumors in children (ependymomas, medulloblastomas), and **selected pituitary** lesions suitable for micro-/endoscopic endonasal approaches in collaboration with ENT specialists.

- **Vascular pathology:** Depending on local resources, selected aneurysms of the **circle of Willis** and **arteriovenous malformations** (AVMs) can be addressed when microsurgical capacity and critical care support are available.

- Spinal and spinal cord pathology: **Complex deformities, multilevel canal stenosis** requiring instrumentation and neurophysiological monitoring, and craniovertebral junction abnormalities (e.g., C1–C2 instability) needing combined decompression and fixation, as well as **intradural–intramedullary tumors**. These conditions mark the shift from "essential resolution" to specialized surgery, emphasizing functional preservation and quality of life (Meara et al., 2015).

Hydrocephalus remains relevant at this level, especially in recurrent or refractory cases after multiple surgeries or infections—typically in fragile pediatric patients—where accumulated experience is critical for complex decision-making and management (Dewan et al., 2019; Warf, Mugamba, & Kulkarni, 2010).

TECHNIQUES

Level 3's technical repertoire is defined by:

- **Advanced microsurgery and skull base/spinal endoscopy**, supported by intraoperative imaging and monitoring. Cranial microsurgery requires an advanced operating microscope, high-speed drills with various burrs, reliable bipolar coagulation, and, when available, ultrasonic aspirators for controlled tumor resection. Neuronavigation enhances preoperative planning and orientation in deep or eloquent areas, while intraoperative ultrasound remains a valuable, cost-effective tool for guiding resections and identifying cavities (Veerappan et al., 2022; Uche et al., 2022).

- Endoscopy: **Endonasal approaches to the pituitary and anterior skull base**, as well as **advanced ventricular neuroendoscopy** for multiloculated hydrocephalus requiring complex fenestrations, demand robust endoscopic towers, optics at different angles, irrigation systems, and backup sets (a second tower or contingency kit) to minimize risks. Complex spinal and spinal tumor cases with neurological involvement benefit from neurophysiological monitoring (MEP/SEP), C-arm fluoroscopy, and, when possible, navigation for accurate pedicle screw placement (Cheyuo & Hodaie, 2023).

- Vascular surgery: Indications should be selected under strict safety and benefit criteria. **Aneurysm clipping or AVM resection** is reserved for centers with neurocritical ICUs, diagnostic angiography, and trained multidisciplinary teams. Where endovascular resources are lacking, interinstitutional coordination enables planned referral circuits. Intracranial pressure (ICP) monitoring, external ventricular drainage (EVD), and blood management protocols form part of the perioperative standard (Meara et al., 2015; Veerappan et al., 2022).

REQUIREMENTS

Level 3 needs can be grouped into four pillars: Infrastructure, technology, human capital, and academic-clinical governance.

- **Infrastructure:** Dedicated neurosurgical operating rooms with laminar airflow where feasible; microscopes, endoscopic towers, C-arm fluoroscopy, neuronavigation, and access to CT/MRI for timely postoperative control. A well-equipped ICU with mechanical ventilation, invasive monitoring, and tailored sedation/analgesia protocols is essential. Additionally, pathology services (including intraoperative biopsy where possible), specialized radiology interpretation, and early rehabilitation are required (Fuller et al., 2016; Uche et al., 2022).

- **Technology and maintenance:** Adequate inventory of critical microsurgical instruments, optics, burrs, and ultrasonic aspirators (if available); stock of consumables (valves, clips, hemostatic agents); and a supply chain management system to prevent interruptions—supported by biomedical maintenance contracts. Intraoperative ultrasound and navigation based on preoperative CT/MRI provide a cost-effective bridge for systems transitioning toward high complexity (Ahmed et al., 2024; Punchak et al., 2018).

- **Human capital:** Consolidation of accredited residencies, creation of fellowships or advanced rotations (skull base, vascular, pediatric, complex spine), and establishment of stable multidisciplinary teams (neuroanesthesia, neurosurgical nursing, physiotherapy/rehabilitation). Regular clinical meetings, tumor boards, and morbidity–mortality reviews are institutionalized, while telemedicine and international mentorship focus on complex cases with specific learning goals (Veerappan et al., 2022; Henderson et al., 2020). Training aims at subspecialization and continuous updating—for instance, sending a local neurosurgeon to a 6–12-month vascular or neuro-oncology fellowship to bring back advanced expertise, a successful strategy in countries such as Nigeria and South Africa (Dada et al., 2021). Ongoing participation in international congresses, advanced courses, and collaborative research ensures the team stays current. A key milestone at Level 3 is for the center itself to become a training hub, with senior local neurosurgeons teaching new national residents.

- **Academic-clinical governance and research:** Level 3 requires structured quality and safety programs with periodic audits, standardized registries (tumors, TBI, spine), applied research, and publication of results with local authorship. Recent consensus statements (e.g., Boston Declaration 2025) highlight the importance of reciprocity and co-development, with transparent metrics and traceable cooperation (Gupta et al., 2025; Uche et al., 2022). Organizationally, the neurosurgical service should be fully integrated into the national health system, with assigned budgets, expansion plans to other provinces (e.g., satellite units or rotations of trained neurosurgeons to other hospitals), and national referral protocols**.**

REQUIREMENTS

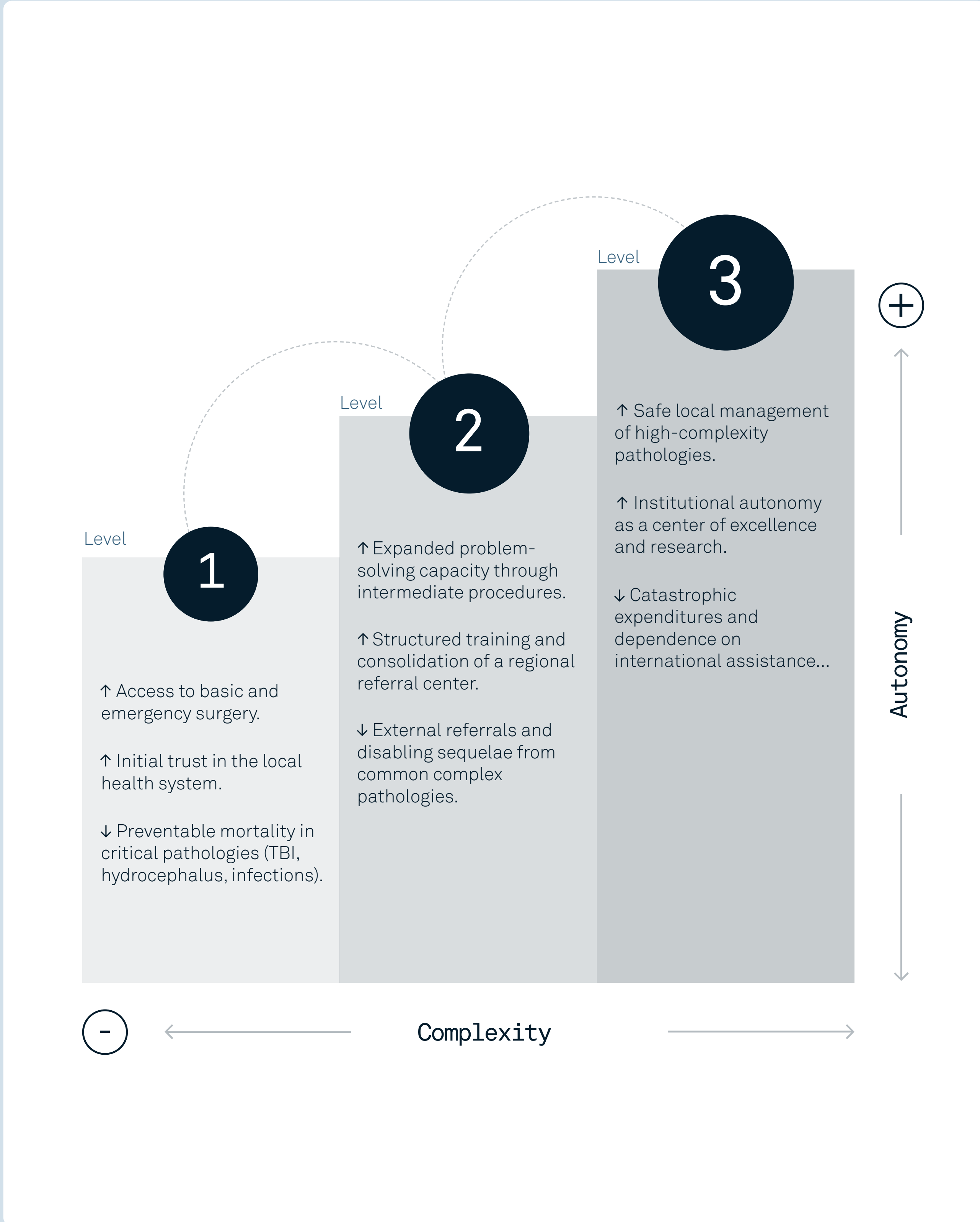
Level 3 needs can be grouped into four pillars: Infrastructure, technology, human capital, and academic-clinical governance.

- **Clinical:** Improved survival and functional preservation in patients with tumors, complex hydrocephalus, and spinal disorders; reduced need for out-of-country referrals; and stabilization of therapeutic pathways with more predictable timelines.
- **Institutional:** The hospital achieves advanced autonomy, becomes a regional referral center, and consolidates talent retention through attractive training and career pathways.
- **Social and economic:** Catastrophic household expenditures decrease, productivity among working-age patients improves, and public investment in neurosurgery is legitimized as a high-return health policy.

Tiered Implementation of the Intervention in Zanzibar

2008	First Missions at Mnazi Mmoja Hospital	**Program launch:** Introduction of basic neurosurgery and initial provision of donated equipment. **Clinical–training start-up:** First operated cases (hydrocephalus, trauma) and beginning of local staff training.
2014	Opening of the NED Institute	**Dedicated infrastructure:** Creation of specialized spaces and resources for neurosurgery. **Clinical scaling and autonomy:** Expansion of surgical activity and services, progressing toward minimal local autonomy in basic procedures.
2018	COSECSA Accreditation	**International recognition:** Accreditation and visibility as a regional training center. **Advanced training:** Launch of the local neurosurgery residency program, consolidating structured education.
2022	Project Consolidation	**Impact and training:** Over 2,800 surgeries and 30,000 consultations completed; first local resident in training. **Reference and autonomy:** The service becomes a regional referral center; the local team gains autonomy (Level 2 consolidated, still progressing toward the next stage).
2025	First locally trained specialist; Introduction of Microsurgery with external support; Management of more complex cases	**Continued progress:** Locally trained residents become specialists; the service begins performing complex cases and prepares for the next qualitative leap.

Model Impact: Main Outcomes by Level of Development



3 Key Lessons

Key Lessons

More than a decade of implementing the ETE model in Zanzibar has produced insights that transcend the specific context of the archipelago. These lessons—supported by over 3,000 surgeries performed and the training of the first generation of local neurosurgeons—offer a practical roadmap for future neurosurgical cooperation initiatives.

1 STRATEGY AND PLANNING

Strategic prioritization of pathologies maximizes impact. In resource-limited settings, focusing early efforts on hydrocephalus, traumatic brain injury (TBI), and central nervous system (CNS) infections saves the greatest number of lives with the least investment, building community trust and local team experience.

Stepwise progress is safer and more sustainable than abrupt leaps. Attempting complex procedures before consolidating basic skills increases risks and does not generate real autonomy. Each level must first master its competencies before moving to the next.

2 MODEL COMPONENTS

A proper balance among equipment, training, and clinical care is critical. Initiatives that emphasize only one pillar tend to fail; synchronization of all three creates a virtuous cycle where each reinforces the others.

Multidisciplinary teamwork determines the success or failure of the service. A single neurosurgeon cannot sustain a program alone. Structured collaboration across specialties—from anesthesia to rehabilitation—is as essential as individual surgical skill.

3 HUMAN CAPITAL DEVELOPMENT

Sustained mentorship has a greater impact than one-off training. The transition toward local autonomy requires years of accompaniment, not isolated courses. The quality of mentorship influences both technical competence and talent retention.

Social and cultural factors are as important as technical ones. Gender, socioeconomic status, and cultural beliefs affect access, training opportunities, and community acceptance. Ignoring these dimensions compromises program sustainability.

4 INSTITUTIONAL SUSTAINABILITY

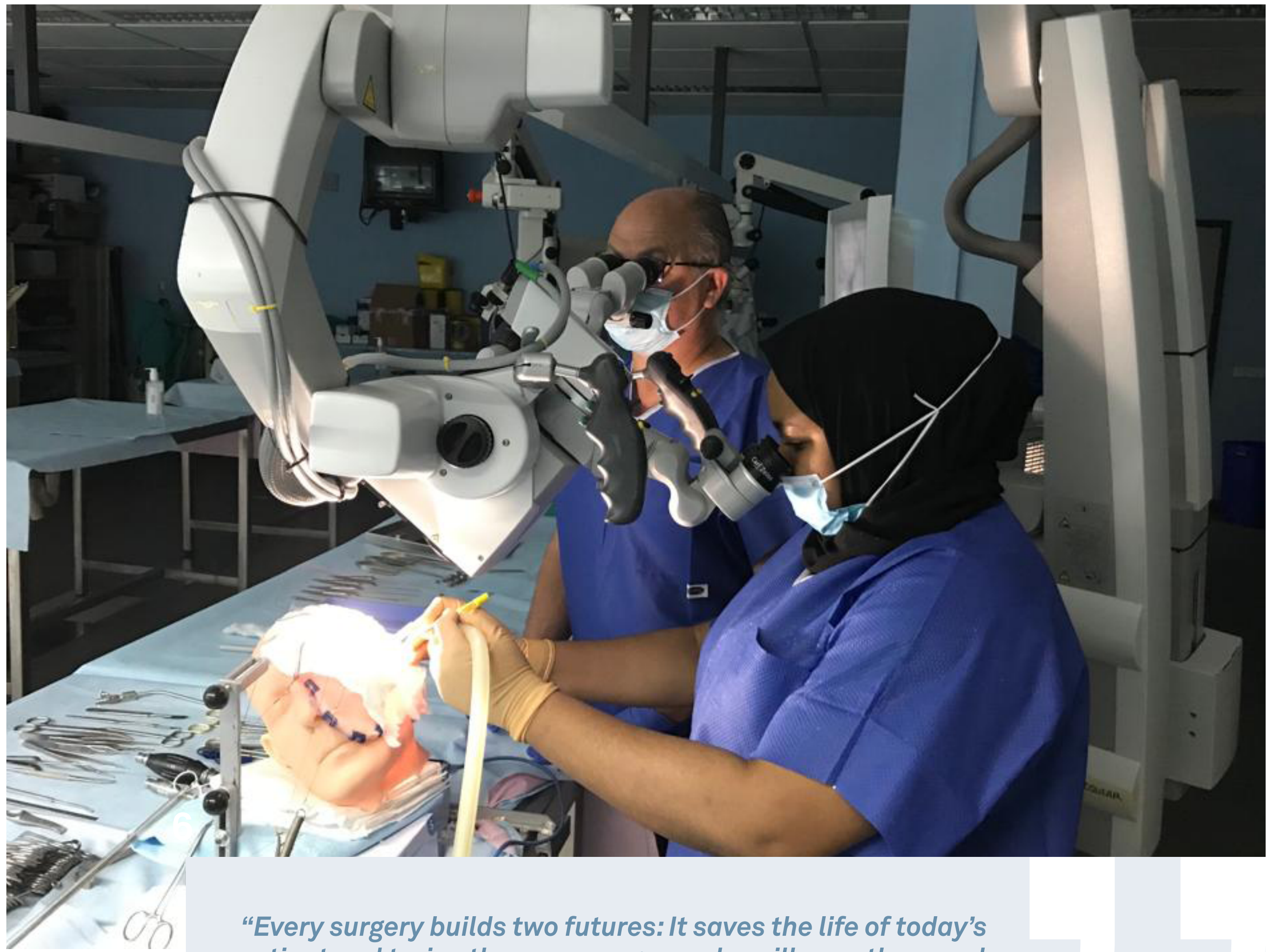
Local financial commitment is indispensable for continuity. While international cooperation can initiate programs, only progressive budgetary ownership by local governments ensures long-term sustainability.

Context-adapted innovation can transform practice. Solutions such as telemedicine, portable technologies, or training general surgeons in basic neurosurgical techniques have proven to expand coverage cost-effectively during critical development phases.

Conclusions

This report demonstrates that the tiered implementation of the ETE model has proven to be an effective approach for bringing neurosurgery to low-resource settings, transforming realities where previously no service existed. The experience gathered—from Zanzibar to other African countries—shows that, with the right combination of commitment, knowledge, and resources, it is possible to create and consolidate a sustainable neurosurgical service where none existed before.

Each level achieved opens the door to the next, in a process that progresses from saving the first lives with basic means to establishing local centers of excellence. The data and lessons compiled here provide a roadmap for future global health and surgical cooperation initiatives. The recommendation is clear: Adopt a similar approach, adapted to local conditions, with the ultimate goal of ensuring that populations in low-income countries have timely and equitable access to safe, affordable, and high-quality medical and surgical care. Only then can the ideal of Global Neurosurgery be fulfilled—as a tool for social change and health equity.



"Every surgery builds two futures: It saves the life of today's patient and trains the neurosurgeon who will save thousands tomorrow."

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