



## Establishing the First Neurosurgical Skill Laboratory in West Africa: An Initiative for an Affordable Regional Education Center

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■ **BACKGROUND:** The benefits of a neurosurgical skill laboratory (NSL) are unquestionable. Despite the increasing number of sub-Saharan African neurosurgeons, few cadaveric laboratories are available for neurosurgical education. The first of its kind in West Africa, a NSL opened in 2019 in Abidjan, Cote d'Ivoire to promote neurosurgeons' education and technical skills. We have described our experience in creating and running this facility.

■ **METHODS:** NSL is a private academic center in Abidjan, Cote d'Ivoire. It includes 2 rooms dedicated to cadaveric hands-on training and microscopic neurosurgery and multipurpose rooms, which contain 7 table-mounted microscopes and 3 endoscopes. The designed layout replicates an operating room. The curriculum was designed to meet the needs for training for complex brain and spine surgeries.

■ **RESULTS:** The training covers skull base (conventional and extended) approaches, microsuturing, and antero-lateral and posterior approaches for spine surgeries. The training was open to residents and consultants. The faculty members included anatomists, neurosurgeons, otolaryngologists, and orthopedists. Additionally, the NSL welcomes fellows from foreign countries. Fellows from 4 countries have been trained, and 14 educational activities have been organized.

■ **CONCLUSIONS:** In the present report, we have provided insight into a sub-Saharan African neurosurgical

laboratory striving toward an affordable and self-sustainable center. The short-term goal of the NSL is to be a center for developing technical skills for African neurosurgeons for better patient outcomes.

### INTRODUCTION

One cannot emphasize enough the importance of neuro-anatomical knowledge and psychomotor skills for patient safety during surgery.<sup>1,2</sup> During neurosurgical procedures, misinterpreting the millimetric relationship between neurovascular and osseous structures can lead to serious complications and, even, death. Thus, regarding regulations and patient safety, permitting residents to operate as seniors is a privilege that should wait until their last year of residency. Among educational activities, cadaveric hands-on training is one of the most effective platforms to reduce the learning curve and decrease peroperative adverse events.<sup>3,4</sup> By spending considerable time performing dissections in a cadaveric laboratory, trainees can refine their microsurgical skills and familiarize themselves with modern surgical equipment such as microscopes and endoscopes.

However, access to neurosurgical training laboratories is limited in low- and middle-income countries (LMICs), especially in sub-Saharan Africa. Recently, Robertson et al<sup>5</sup> evaluated the obstacles to professional development among 953 young neurosurgeons worldwide and reported that 14.46% of their requests were focused on access to skills courses and cadaveric dissection. Until the advent of the COVID-19 (coronavirus disease 2019) pandemic, neither neurosurgeons nor residents could

### Key words

- Africa
- Cadaveric laboratory
- Education
- Neurosurgery
- Simulation

### Abbreviations and Acronyms

**LMIC:** Low- and middle-income country

**NSL:** Neurosurgical skill laboratory

**OR:** Operating room

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**Figure 1.** The main rooms dedicated to neurosurgical education. (A, B) The microneurosurgery room includes 3 workstations, with each station connected to a

wall-mounted television screen. (C, D) The versatile room serves as a lecture room and houses 7 workstations available on-demand.

afford to attend cadaveric workshops organized overseas. To the best of our knowledge, 2 cadaveric laboratories are dedicated to neurosurgical education in sub-Saharan Africa: one in South Africa and the other in Abidjan, Cote d'Ivoire. The first of its kind, the neurosurgical skills laboratory (NSL) of Abidjan opened in 2019 with the aim of training and promoting a networking center for regional neurosurgeons.

In the present report, we have described our experience in designing a NSL and a training curriculum and its activities in a resource-limited setting. Furthermore, we have discussed our perspective toward collaborative educational activities between African residency programs.

## METHODS

### Laboratory Layout

The NSL is located within the human anatomy department of the Université Felix Houphouët-Boigny School of Medicine in Abidjan, Cote d'Ivoire, which is remote from the neurosurgery department. The facility has 4 main rooms, including a cold room, a room for microneurosurgery, a versatile room, and a storage room. The cold room contains a locally manufactured container with a storage capacity for 6 adult human bodies maintained at  $-4^{\circ}\text{C}$  and a station dedicated to on-site specimen preparation. The microneurosurgery room is a  $24\text{-m}^2$  area with 3 computers and

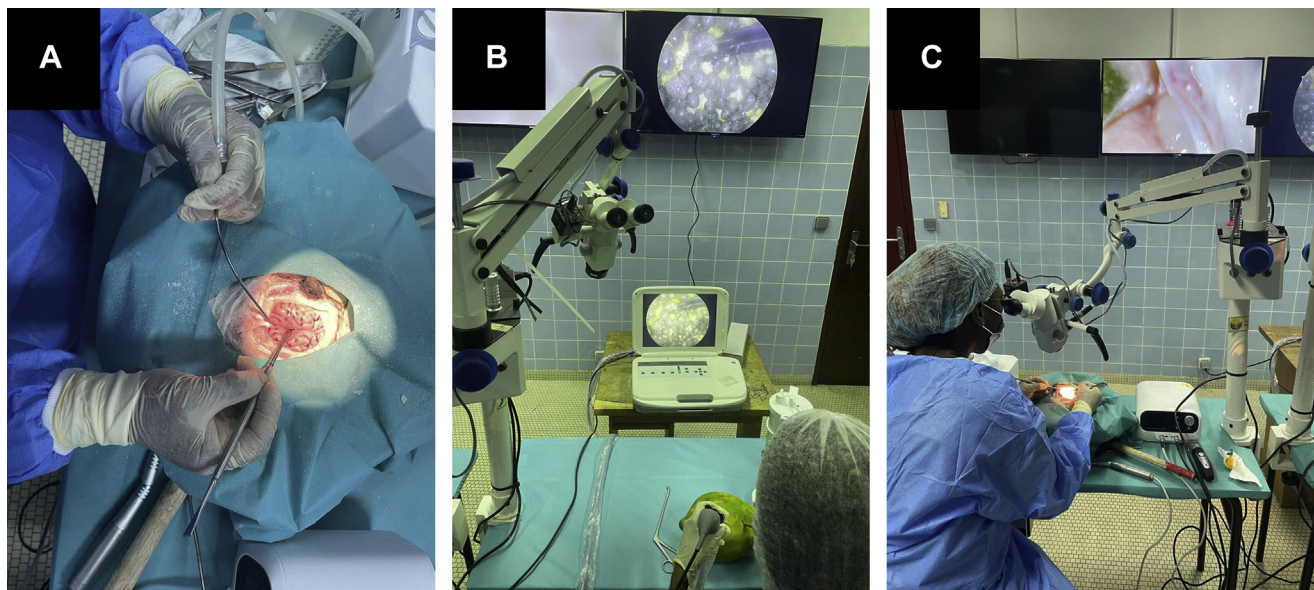
3 workstations designed to replicate an operating room (OR). Each workstation includes the following (Figure 1A and B):

- A table-mounted microscope with magnification  $\leq 20\times$ , with an integrated high-definition camera connected to a computer and a wall-mounted large light-emitting diode screen
- A high-speed electric drill
- A surgical chair
- An electric suction device
- A set of microsurgical tools

In addition, each workstation can accommodate an endoscopic device on-demand. The versatile room is a  $60\text{-m}^2$  chamber that allows for spine workshops, larger microsurgical dissection events, lectures, and conferences. It can hold 60 individuals during educational events (Figure 1C and D). The storage room contains spared equipment and personal protective material.

### Specimen Acquisition and Nonhuman Training Models

The NSL receives human specimens regularly through a partnership between the School of Medicine and the national funeral service company. The specimens are selected from the pool of



**Figure 2.** Residents in training using nonhuman models. (A) The trainee is mimicking brain tumor dissections in a sheep brain. (B) The resident is

practicing eye—hand coordination using an endoscope and a papaya. (C) Simulation of an arachnoid dissection using a chicken thigh.

bodies that remain unclaimed for >3 months. The selection process was organized under approval of the University Scientific Ethics Board and is regulated by the National Ministry of Justice. Specimen preparation and injection are performed on-site by a fully trained embalmer. In addition, nonhuman models such as fresh sheep heads, chicken, swine feet, and peppers are used (Figure 2).<sup>3,6</sup>

### Equipment

The NSL sought to replicate an OR environment for cranial and spinal procedures. The equipment for cranial procedures includes 7 low-cost table-mounted microscopes (Ecleris [Villa Martelli, Argentina]; Medirer Surgical [Ambala, India]), 7 high-speed drills (Meditech Equipment Co. [Shandong, China]; Bien-Air Surgery [Le Noirmont, Switzerland]), 7 microsurgical instrument sets, 7 vacuum devices, and 3 endoscopic stations with 0°, 30°, and 45° telescopes. For the spinal procedures, the NSL acquired an instrumentation set for laminectomy and posterior and anterolateral spinal fixation.

### RESULTS

The NSL opened with a few pieces of equipment. The NSL started with the cold container for body storage and 3 workstations equipped with table-mounted microscopes. Progressively, the educational activities provided funding to acquire more equipment (Table 1) with the help of local, private nonmedical companies. Whenever possible, the NSL purchased locally manufactured equipment (e.g., head holders, light sources, cold container) and bought additional affordable equipment from India and

China to minimize the costs. This combined effort allowed for the introduction of more components in the training curriculum.

### Training Curriculum

We designed a curriculum with various modules to allow for training of residents, young neurosurgeons, and attending neurosurgeons. Ivorian neurosurgical residents have allocated training time for laboratory work. The first-year residents are required to spend 1 month in the NSL during their rotation curriculum, during which they learn neuroanatomy and basic suture techniques and familiarize themselves with the surgical instruments. Additionally, 3 cadaveric workshops are organized annually for all residents as a part of their training curriculum (Figure 3). The NSL also organizes so-called master classes on specific dates during which a senior neurosurgeon demonstrates a surgical approach and discusses the tips and pearls learned with their peers (Figure 4). These activities cover cranial and spinal procedures (Table 2). To date, the NSL has organized 8 workshops on skull base, 2 on endoscopy endonasal, and 4 on spinal approaches.

### Fellowship

The NSL offers local and sub-Saharan neurosurgeons the opportunity to complete a fellowship. According to their needs, fellows spend 2 weeks to 3 months in the NSL. Curricula are available for skull base, neuroendoscopy (i.e., endonasal, pineal gland, retro-sigmoid approaches), and spinal techniques. However, a tailored program can also be designed according to the specific needs of the fellow. Fellows perform dissections independently but a faculty person is available once a week for supervision and guidance. Whenever possible, fellows are welcomed into the OR to observe



**Table 1.** Cost of Major Equipment

Item	Quantity	Unit Price (USD)	Total Cost* (USD)
Microscope†	7	2500	17,500
Endoscope	3	1500	4500
Telescope†	3	300	900
Television screen†	4	400	1600
Cold container†‡	1	6000	6000
High-speed drill	7	1200	8400
Vacuum device	3	300	900
Spinal fixation instrument set	1	1000	1000
Laminectomy set	2	300	600
General instrument set	1	350	350
Microscopic instrument set	7	200	200
Head holders‡	7	50	350
Mobile light source†‡	2	200	400

\*The total cost for all equipment listed: \$42,700.  
†Equipment donated.  
‡Equipment locally manufactured.

cases relative to their dissection area. This loop from the laboratory to the OR back to the laboratory is considered to foster the fellow's learning. On completion of the training, the fellows are invited to present on the lessons they learned and they receive a certificate. To date, the laboratory has hosted fellows from countries such as Burkina Faso, Congo-Brazzaville, Guinea, and Niger.

### Human Resources

Running a neurosurgical laboratory requires an organization with management, maintenance, and technical skills.<sup>7</sup> The NSL is directed by one of us (M.K., professor of anatomy and neurosurgery), who initiated the project of building a facility dedicated to neurosurgical education. A secretary and an embalmer were hired as full-time employees. Moreover, the laboratory has faculty members with dual appointments as anatomists and surgeons. The faculty include 3 neurosurgeons, 1 otolaryngologist, and 1 plastic surgeon, all of whom supervise the training curricula. Adjunct specialties such as otolaryngology, maxillofacial surgery, and orthopedic surgery are occasionally included during the courses. Additionally, medical students work part-time as instructors and are paid by the medical school (Figure 3).

### DISCUSSION

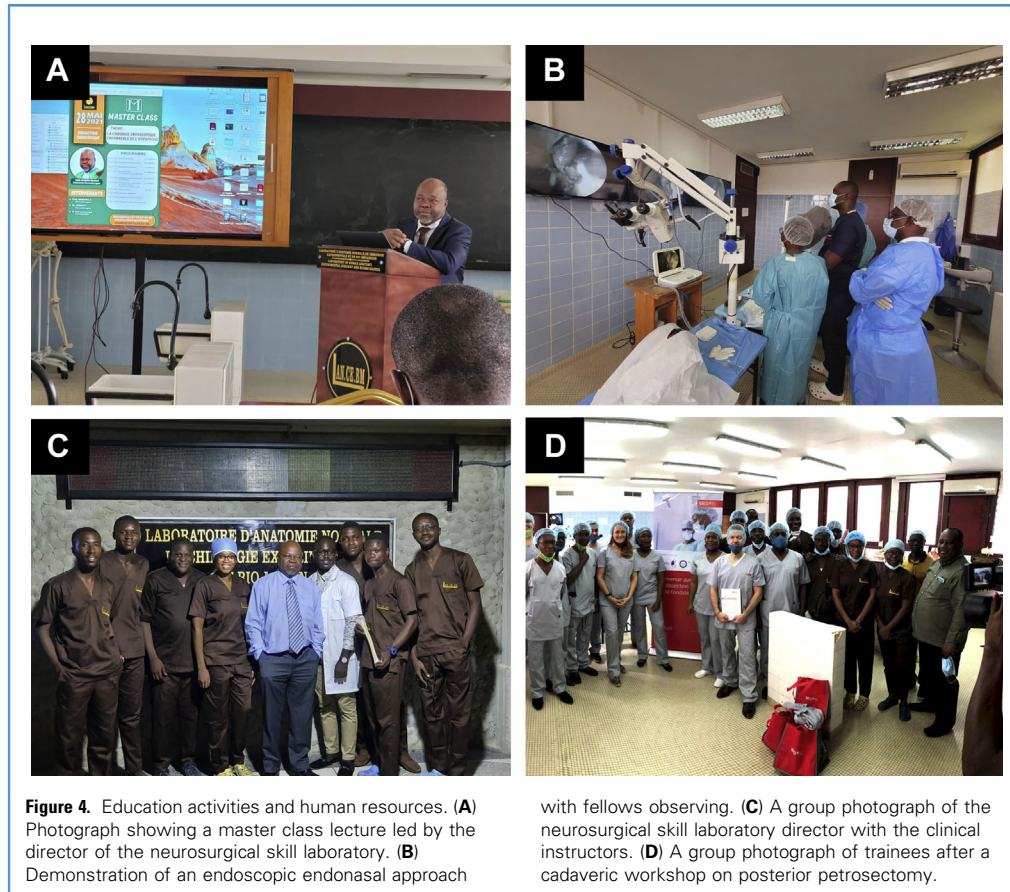
#### Neurosurgical Education in Sub-Saharan Africa

The landscape of neurosurgical education in sub-Saharan Africa is changing. The increased awareness of neurosurgical diseases among Africans, the financial burden of transferring neurosurgical

patients overseas for care, and the return of foreign-trained neurosurgeons are among the factors helping efforts toward increasing the capacities and skills of African neurosurgeons. Moreover, initiatives such as Africaroo, the Foundation for International Education in Neurological Surgery, CURE Hydrocephalus and Spina Bifida, and the World Federation of Neurosurgical Societies Rabat Training Center have provided substantial support to increase the neurosurgical workforce in the continent.<sup>8</sup> Recently, Burkina Faso, Cameroon, and Niger started their neurosurgery residency program, increasing the number to 40 training programs in sub-Saharan Africa.<sup>9</sup> With these training centers, more local neurosurgeons will become available, reducing the access gap to neurosurgical care. However, this rapid expansion of training centers contrasts with the low number of dedicated cadaveric laboratories in the continent. After investigation, we identified neurosurgical laboratories in 4 countries: Egypt, Morocco, South Africa, and Cote d'Ivoire. Our country is part of the West African region, which has ~202 consultant neurosurgeons and >200 trainees spread throughout 16 local programs.<sup>9,10</sup> Therefore, having a neurosurgical cadaveric laboratory in this region is an undeniable asset for educational purposes.



**Figure 3.** Resident training in brain and spine approaches. (A) The resident is performing a craniotomy. (B) Demonstration of an interhemispheric approach. (C) Training in posterior lumbar interbody and fusion. (D) Demonstration of an anterolateral approach to the thoracic spine.



### Challenges in Establishing a NSL in Africa

Opening a cadaveric laboratory is challenging for cultural, administrative, and financial reasons. In many countries, cultural and religious beliefs make it arduous or even impossible to obtain bodies for dissection. In countries where cadaveric dissections are allowed, body donation remains taboo, making people reluctant to donate. In 2006, Broalet et al<sup>11</sup> examined the knowledge and perception of 360 Ivoirians regarding body donation. They found that 68% of the interviewees knew about the ability to body gift, mainly from the media, and that 35.8% of them were inclined toward body donation. Although body donation of willing individuals has not yet been enacted in our legislation, Cote d'Ivoire is fortunate to have a law framing body donation via a partnership between the medical school and the national funeral service. This partnership allows our human anatomy department to receive bodies from the pool of cadavers unclaimed 3 months after their documented death. Such might not be in place in other countries. Funding is the major obstacle in building a cadaveric laboratory. In addition to the fees associated with the preparation and conservation of cadaver specimens, a neurosurgical laboratory requires expensive equipment, including microscopes and high-speed drills. In LMICs, the medical industry is often nonexistent, and funding is solely dependent on the government. However, government funding for such facilities has not been prioritized. To circumvent this financial limitation, we led a fundraising project, targeting

nonmedical private companies by raising their awareness of the potential benefits of such facilities for patient outcomes. Our motto was “Never train surgery on a living patient.” This winning strategy has permitted us to raise ~\$50,000 to purchase equipment. The NSL operates using a private academic model, in which the benefits generated from the educational activities are used to maintain and acquire more equipment. This model has allowed the NSL to be self-sustainable and to acquire additional endoscopic devices and microsurgical and spinal instrumentation.

**Table 2.** Dissection Activities (Training Curriculum)

Courses offered
3-Day cadaveric workshops
1-Day cadaveric workshop (master class)
Laboratory fellowship
Training curriculum
Basic suture technique
Use of high-speed drills
Skull base: neuroanatomy and approaches
Neuroendoscopy: endonasal, retrosigmoid, pineal region
Spine: neuroanatomy and anterior, posterior, and anterolateral approaches

### Core Components of the Training Curriculum and Its Expected Effects

The expansion of training centers in Africa has resulted in the need for subspecialized neurosurgical competencies according to local need. At present, neurosurgical patients are transferred outside their countries for conditions such as skull base tumors, cerebrovascular disease, and complex tumor, degenerative, and deformity conditions of the spine.

We, therefore, designed our training syllabus to meet such needs. Microneurosurgery and endoscopic training sessions were conceived with applications for cranial neuroanatomy. We believe that endoscopy should be in the armamentarium of all modern neurosurgeons.<sup>12</sup> Training neurosurgeons using pepper and papaya models was a cost-effective method to familiarize trainees with the use of endoscopic devices. Also, the otolaryngology department provides its perspective concerning skull base approaches for lesions involving the paranasal sinuses or petrous bone. A specific module was designed for the use of high-speed drills, a skill also necessary for skull base surgeons. For training in the spine, anatomists, neurosurgeons, and orthopedists provide their expertise in teaching posterior and anterolateral approaches. Altogether, the training modules have been designed to equip surgeons with a comprehensive tour of cranial and spinal approaches.

As stated, one of the reasons for medical evacuations of complex neurosurgical cases could be insufficient exposure to such cases during the surgeons' training. Given that iatrogenic perioperative complications can occur even during surgery performed by experienced surgeons, it is less likely for residents to achieve adequate proficiency with such complex cases during their training. Subsequently, these technical deficiencies can continue throughout their entire career as senior surgeons. This is especially true in LMICs, where neurosurgeons often lack basic neurosurgical instruments. To fill the gap, the cadaveric laboratory stands as a suitable place to acquire, develop, and refine technical skills.<sup>13,14</sup> Working in such a stress-free environment is ideal for refining eye–hand coordination, sensory feedback, depth perception, and knowledge of neurovascular relationships. Also, such a facility sets the stage for innovative techniques and encourages scholarly publications.

### Study Limitations and Perspectives

One recurrent issue we have faced has been the decay of intracranial structures when the body has not been initially well conserved before we have received it in the laboratory. This situation has limited dissection of the brain parenchyma and the identification of the cerebral vasculature. One solution might reside in the acquisition of simulation models of brain vasculature

recently made available on the market. The other alternative could be the use of animal (e.g., sheep) brain parenchyma to simulate the dissection of brain tumors.<sup>3,6</sup>

We foresee establishing the NSL as a training center in West Africa and beyond by offering affordable training courses continentally and, thus, nurturing a collaborative platform in which neurosurgeons from Africa and beyond will come and share their technical expertise with peers and younger generations. Academically, we envision engaging trainees and fellows in scholarly activities and publications. This will foster surgical proficiency and innovation and indirectly contribute to better outcomes for local neurosurgical patients.

### CONCLUSIONS

In the present report we have recounted the gradual and daunting process of establishing an affordable training NSL in Abidjan to improve the neurosurgical workforce in Africa. The study of neuroanatomy remains necessary and compulsory for increasing operating skills, although this has long been scarce in our setting owing to sociocultural barriers. Since NSL's opening in 2019, these continuous efforts have proved successful, with improvements observed in the surgical and psychomotor skills of the neurosurgical trainees in the OR. We look forward to improving the grade of tools acquired for the NSL, nurturing subregional neurosurgical partnerships, and objectively determining the effects of this training on patient quality of care in Africa. Our next steps in the NSL will be to objectively assess the aptitudes acquired after fellow and resident training, increase surgical innovations, and monitor the effects on neurosurgical patient outcomes.

### CRedit AUTHORSHIP CONTRIBUTION STATEMENT

**Meleine Landry Konan:** Conceptualization, Methodology, Data curation, Formal analysis, Writing – review & editing. **Raïssa Diaby:** Data Acquisition, Image editing. **Nathalie Christelle Ghomsi:** Writing – original draft, Writing – review & editing, Methodology, Proofreading. **Wilfried M. Meuga:** Data acquisition, Writing – original draft. **Grace Djondé:** Data acquisition, Data curation. **Joel Brou:** Data acquisition, Data curation, Image editing. **Yvan Zunon-Kipré:** Writing – review & editing, Approval of final version before submission. **Medard Kakou:** Formal analysis, Approval of final version before submission.

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