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Educating Future Generations of Surgeons across Borders: Novel Global Linked Hybrid Live Cadaveric Peripheral Nerve Surgical Training Course

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Background: This study aimed to evaluate a novel, multi-site, technology-facilitated education and training course in peripheral nerve surgery. The program was developed to address the training gaps in this specialized field by integrating a structured curriculum, high-fidelity cadaveric dissection, and surgical simulation with real-time expert guidance.
Methods: A collaboration between the Global Nerve Foundation and Esser Masterclass facilitated the program, which was conducted across three international sites. The curriculum was developed by a panel of experienced peripheral nerve surgeons and included both text-based and multimedia resources. Participants' knowledge and skills were assessed using pre- and postcourse questionnaires.
Results: A total of 73 participants from 26 countries enrolled and consented for data usage for research purposes. The professional background was diverse, including hand surgeons, plastic surgeons, orthopedic surgeons, and neurosurgeons. Participants reported significant improvements in knowledge and skills across all covered topics ($p < 0.001$). The course received a 100% recommendation rate, and 88% confirmed that it met their educational objectives.
Conclusions: This study underscores the potential of technology-enabled, collaborative expert-led training programs in overcoming geographical and logistical barriers, setting a new standard for globally accessible, high-quality surgical training. It highlights the practical and logistical challenges of multi-site training, such as time zone differences and participant fatigue. It also provides practical insights for future medical educational endeavors, particularly those that aim to be comprehensive, international, and technologically facilitated. *(Plast Reconstr Surg Glob Open 2024; 12:e5559; doi: 10.1097/GOX.0000000000005559; Published online 23 January 2024.)*

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INTRODUCTION

The landscape of surgical training has undergone significant shifts due to increasing demands for clinical efficiency and heightened concerns regarding reduced surgical time in the operating theater. These changes have led to fewer opportunities for hands-on surgical training, posing challenges for the development of proficient future surgeons.[1] Studies have demonstrated that a structured curriculum, supplemented by high-fidelity simulation such as cadaveric training, can effectively bridge this educational gap.[2]

Cadaveric simulation offers an unparalleled, realistic platform for skills acquisition and refinement, providing a risk-free environment to practice complex procedures. This is particularly vital for specialized fields such as peripheral nerve surgery, where the stakes are high, and the margin for error is low.[3]

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The role of expert involvement in surgical training and posttraining continued education cannot be overstated, and it aligns well with Bandura's theory of expert modeling and observational learning.[4] According to this social learning framework, skill acquisition is not merely a result of direct instruction but also occurs through observing, imitating, and modeling behaviors, attitudes, and emotional reactions of experts.[5] Recent advancements in technology have provided a unique solution to the limitations imposed by geographical distances, enabling the involvement of remote experts in real-time, synchronous training.[6]

In light of these considerations, we hypothesized that a comprehensive, globally accessible training program for peripheral nerve surgery is both timely and necessary. This initiative, facilitated through a collaboration between the Global Nerve Foundation and Esser Masterclass, was designed to leverage technology for synchronous, multisite training, engaging experts from remote locations to augment the learning process. The aim of this study was to evaluate the effectiveness of a comprehensive, globally accessible, and technology-facilitated training program in peripheral nerve surgery that integrated structured curricula with high-fidelity cadaveric simulation and real-time expert guidance.

METHODS

Study Design

The study used a design and development framework,[7] incorporating a multi-method approach to investigate the effectiveness of a comprehensive, technology-facilitated, and globally accessible training program in peripheral nerve surgery.

Curriculum Development

The curriculum was meticulously designed by a panel of five expert peripheral nerve surgeons. (**See appendix, Supplemental Digital Content 1**, which displays: A, Curriculum content, illustrating lecture-based topics and surgical techniques explored. B, The pre- and postcourse self-reported confidence of participants in knowledge. C, The pre- and postcourse self-reported confidence of participants in performing surgical skills. **http://links.lww.com/PRSGO/D38**.) It covered a range of topics, from the assessment and operative management of various nerve pathologies to specific surgical techniques. Instructional materials, including text-based documents, illustrated course manual, and multimedia video resources were made openly accessible online to enhance the learning experience and provide participants with precourse preparation opportunities.[8]

The choice of cadaveric workshops was driven by their high-fidelity nature, offering anatomical realism essential for peripheral nerve surgery training. These workshops provide a risk-free, ethically sound environment for mastering complex surgical skills. The realism of cadaveric models bridges the gap between theoretical learning and clinical application, making them an invaluable asset for the program.[9,10] Adhering to a consensus protocol approach, procedural segmentation was implemented to allow for a step-by-step approach to learning new techniques by the participants as well as fidelity assessment by the faculty. This is essential for complex multistep procedure learning and supported progression.[11]

> **Takeaways**
>
> **Question:** We aimed to evaluate the effectiveness of a comprehensive, globally accessible, and technology-facilitated training program in peripheral nerve surgery that integrates structured curricula with high-fidelity cadaveric simulation and real-time expert guidance.
>
> **Findings:** A total of 73 participants from 26 countries enrolled. Participants reported significant improvements in knowledge and skills across all covered topics ($P < 0.001$). The course received a 100% recommendation rate.
>
> **Meaning:** Technology-enabled, expert-led training programs can overcome geographical and logistical barriers, setting new standards for globally accessible, high-quality surgical training.

Program Delivery

The program was conducted as a live, synchronous multisite event across three distinct locations: the anatomy laboratory at Erasmus Medical Center Rotterdam, the Netherlands; the Canselor Tuanku Muhriz UKM Hospital, Kuala Lumpur, Malaysia; and the Vesalius Clinical Training Center, Bristol, United Kingdom. Site selection was done in accordance with local guidelines and permissions related to the use of cadavers for training. Fresh frozen cadaveric arms were sourced from local body donation programs at each site, ensuring no previous history of surgery or trauma. All participants traveled to one of the three locations, based on personal preference. There were no restrictions on attendance placed, and the course was open to the international community. Cadaveric teaching was delivered as both faculty led dissections and paired-participants practice on their assigned limbs (Fig. 1).

Technology Integration

For synchronous training, video links were established across the three sites, running in tandem across different time zones. This setup allowed for real-time interaction and session moderation by remote experts, thus adhering to Bandura's theory of expert modeling and observational learning.

Data Collection

Participants were required to complete an online precourse survey using the Vevox app, a real-time audience engagement tool featuring live polling and Q&A functionalities. This survey aimed to gauge participants' baseline practices, understanding of peripheral nerve pathologies, and confidence in performing a set of defined surgical procedures. At the end of each day, participants filled

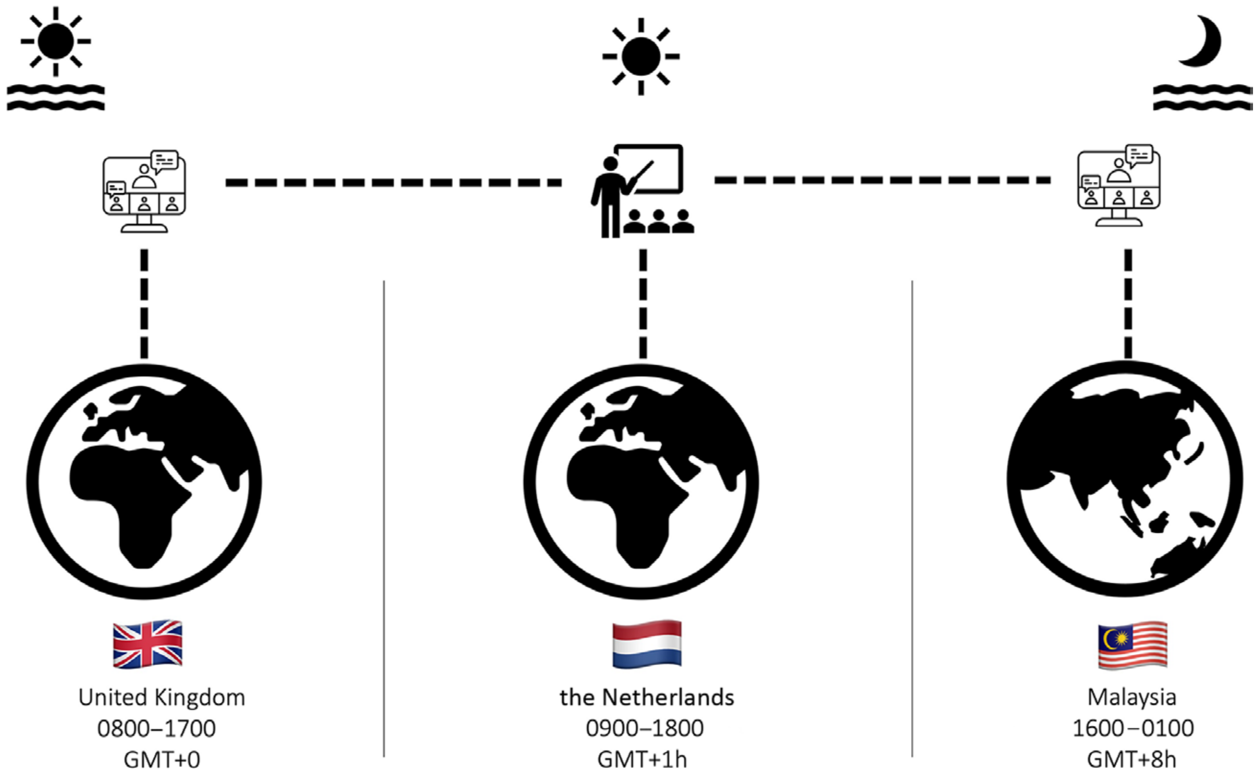

Fig. 1. Live, synchronous multisite event across three distinct locations, with video links running in tandem across different time zones.

out a postcourse questionnaire to assess their learning outcomes.

Statistical Analysis

Completed questionnaires received over the three days were subjected to statistical analysis. A paired *t* test was performed to compare pre- and postcourse responses, as the data followed a normal distribution. Sub-group analyses were carried out, and a Bonferroni correction was applied to adjust for multiple testing. This methodology outlines the study's structured and evidence-based approach to assessing the effectiveness of this novel approach to surgical training.

RESULTS

A total of 88 participants from 26 different countries enrolled in the multisite training course (Fig. 2). Of these, 73 participants consented to have their data used for research and educational purposes. Participant distribution was as follows: 29 in the United Kingdom, 31 in the Netherlands, and 13 in Malaysia. The professional background included specialist hand surgeons (24.66%), plastic surgeons (41.10%), general orthopedic surgeons (24.66%), neurosurgeons (8.22%), and one trauma surgeon (1.37%). The average length of participants' professional practice was 9.47 years, with an SD of ±6.8 (Fig. 2).

Regarding the nerve-related workload, 35 participants (47.9%) reported that it constituted 0%–25% of their practice, 26 (35.65%) reported 26%–50%, and 11 (15.1%) reported 51%–75%. Table 1 provides detailed statistics on the participants' surgical experience in various nerve procedures.

Participants overwhelmingly reported improvements in knowledge and skills across all covered topics and procedures ($P < 0.001$) (**Supplemental Digital Content 1, http://links.lww.com/PRSGO/D38**). The course received a 100% recommendation rate, and 88% (n = 57) of participants confirmed that it met their educational objectives and expected learning outcomes.

DISCUSSION

Given the need for ongoing surgical education in nerve surgery, a comprehensive, globally accessible training course was developed. This curriculum was meticulously designed to offer select coverage of critical/key topics within the given time constraints, considering local logistics such as faculty-to-candidate ratios and the quality of cadavers available. A priority was placed on maximizing hands-on cadaveric practice for the participants and was a step away from classical online video teaching options currently available.[12] The pedagogical approach adopted was one of shared learning, enabling open discussions between faculty and participants across all sites. Through pre- and postcourse surveys we found that the interactive format was highly valued by attendees, and it fostered in-depth conversations about various surgical techniques and management strategies from different global perspectives.

Technology played a pivotal role in the program's success. A robust video conferencing platform, tested in advance, facilitated live streaming and real-time

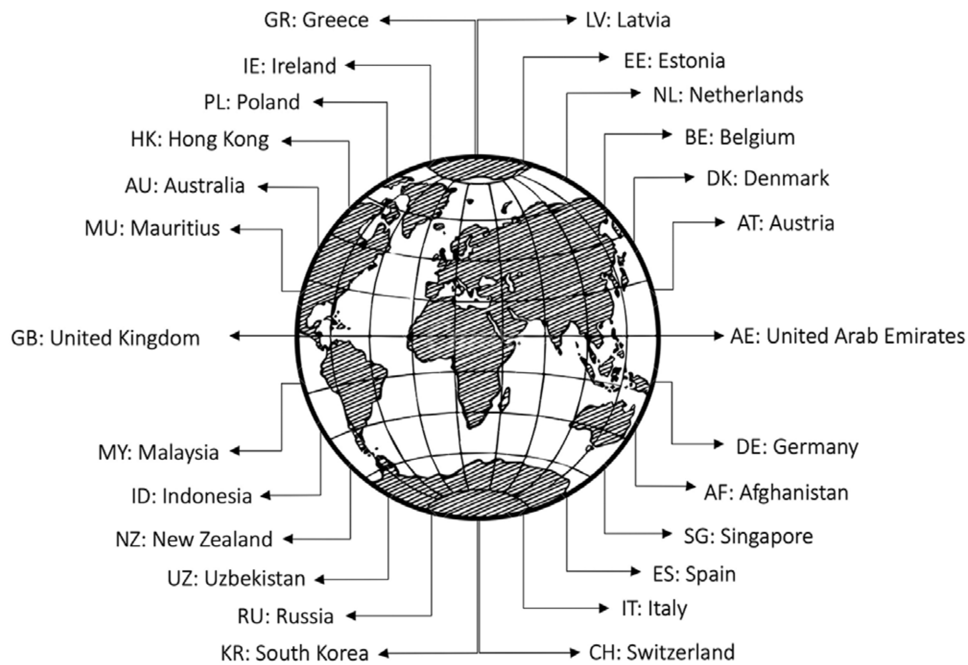

Fig. 2. Global provenance of participants at the multisite training course.

Table 1. Surgical Experience of Participants in Performing Nerve Decompression, Repair, and Transfer

	Frequency of Technique Performed Yearly		
Procedure	**0–25 Times**	**25–50 Times**	**>50 Times**
Nerve decompression surgery, n (%)	19 (26.0)	25 (34.2)	29 (39.7)
Nerve repair surgery, n (%)	48 (65.8)	18 (24.7)	7 (9.6)
Nerve transfer surgery, n (%)	67 (91.8)	5 (6.8)	1 (1.4)

interactivity across sites. This technology also supported various interactive elements like Q&A sessions, live polls, and breakout groups, encouraging active engagement amongst participants, many of whom accessed these features via mobile devices either via Wi-Fi or 4G/5G internet. The anonymity offered through this platform allowed participants to ask questions and express ideas without fear of being judged. The live polling was instrumental in identifying when participants were struggling to assimilate a particular concept and allowed the moderator to steer the session accordingly.

Collaboration among global peripheral nerve experts was crucial for maintaining participant engagement and interaction over the three-day course. These experts were instrumental in creating an immersive learning environment that sustained the program's momentum.

However, logistical challenges were inevitable in planning an intercontinental hybrid course. Time zone differences posed a significant hurdle, particularly an 8-hour lag between the UK and Malaysia, requiring compromises in scheduling. The timing led to reported participant fatigue, especially during postdinner and postdissection lectures, which may have affected concentration levels. Close attention was also required in choosing the venues, ensuring adequate access to high-speed internet via Wi-Fi or Ethernet connection along with suitable video conferencing hardware to enable the cross-site interactions. Focusing the delivery of such teaching courses to one location also minimizes any impact of potential geographic or horizontal inequalities, or digital divide.

One limitation of the study was the challenges in data capture. Despite the voluntary nature of precourse self-evaluations, multiple prompts were necessary to encourage completion of evaluations after the course. Additionally, potential feedback fatigue was observed over the three-day period, which may have influenced the completeness and quality of responses.

Future iterations of this course will benefit from the development of standard operating procedures, incorporating lessons learned from this initial offering. These guidelines will address the planning, content, and delivery aspects of the course, providing a structured framework for both teaching and nonteaching faculty involved.

PRACTICAL IMPLICATIONS OF THE STUDY

The study has several learning points that extend beyond the realm of academic research into the actionable aspects of surgical training.

1. Curriculum design: The study demonstrates the feasibility and effectiveness of designing a structured, comprehensive curriculum that can be delivered across multiple international sites. This could serve as a blueprint for other specialized surgical training programs and is not limited to peripheral nerve surgery teaching. However, specific adaptation to meet the intended outcome will be required depending on the curriculum objectives and time factor.

2. Technological scalability: The successful implementation of robust video conferencing technology indicates that high-quality surgical training can be scaled across different geographic locations. This opens the door for greater inclusivity in specialized training programs, potentially leveling the field for professionals from regions with fewer resources.
3. Interdisciplinary collaboration: The study underscores the value of collaborative efforts among global experts in enhancing the quality of surgical education. Such collaborations could become a standard feature in medical training, enriching the educational experience and possibly improving patient outcomes.
4. Participant engagement: The interactive elements like Q&A sessions, live polls, and breakout groups were well-received. This offers a practical lesson in how to maintain high levels of engagement in an intensive, multi-day training program.
5. Time management: The study highlights the need for careful planning around time zones and local constraints, a practical consideration for any future international, synchronous training programs.
6. Feedback mechanisms: The study identifies challenges related to data capture and participant feedback fatigue, providing insights into the need for more streamlined and user-friendly methods for capturing real-time feedback in future programs.
7. Standard operating procedures: The lessons learned from this initial offering can be used to develop a structured framework for both teaching and nonteaching faculty, streamlining the planning and delivery of future courses.
8. Patient safety and quality of care: Ultimately, the high-fidelity, hands-on training in cadaveric workshops, supplemented by real-time expert guidance, aims to translate into enhanced clinical skills, potentially leading to improved patient outcomes.
9. Cost-efficiency: By utilizing technology and multisite collaboration, the program may offer a more cost-efficient model of high-quality surgical training compared with traditional methods.

CONCLUSIONS

This study successfully demonstrates the viability and effectiveness of a multisite, technology-facilitated training program in peripheral nerve surgery. Leveraging a meticulously designed curriculum, robust video conferencing technology, and interdisciplinary collaboration among global experts, the program achieved significant improvements in participant knowledge and skills. Practical challenges related to time zones, participant fatigue, and data capture were identified, providing valuable insights for future iterations of this or similar training programs.

The key takeaway is that well-designed, technology-enabled, and expert-led training programs can overcome geographical and logistical constraints, setting a new standard for surgical training that is both globally accessible and of high quality. This has significant implications for improving surgical practice and patient outcomes worldwide.

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DISCLOSURES

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A founding member of GNF is Axogen. DMP is a board member of GNF and an advisory member of EM. Authors AM, LSD and JMZ are members of the Education Committee of GNF. JMZ and LD are Board Directors of EM. All the other authors have no financial interest to declare in relation to the content of this article.

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REFERENCES

1. Evans CH, Schenarts KD. Evolving educational techniques in surgical training. *Surg Clin North Am*. 2016;96:71–88.
2. Javid P, Aydın A, Mohanna PN, et al. Current status of simulation and training models in microsurgery: a systematic review. *Microsurgery*. 2019;39:655–668.
3. Holland JP, Waugh L, Horgan A, et al. Cadaveric hands-on training for surgical specialties: is this back to the future for surgical skills development? *J Surg Educ*. 2011;68:110–116.
4. Bandura, A. *Social Learning Theory*. Englewood Cliffs, N.J.: Prentice Hall; 1977.
5. Rajaratnam V, Rahman NA, Dong C. Integrating instructional design principles into surgical skills training models: an innovative approach. *Ann R Coll Surg Engl*. 2021;103:718–724.
6. Sadideen H, Kneebone R. Practical skills teaching in contemporary surgical education: how can educational theory be applied to promote effective learning? *Am J Surg*. 2012;204:396–401.
7. Richey R, Klein JD. *Design and Development Research: Methods, Strategies, and Issues*. L. Erlbaum Associates; 2007.
8. Mayer RE. Applying the science of learning: evidence-based principles for the design of multimedia instruction. *Am Psychol*. 2008;63:760–769.
9. Rajaratnam V, Gan G, Ahmad AA, et al. Design, development, and validation of a high-fidelity "ganglion cyst" model for cadaveric hand surgery training. *J Hand Microsurg*. 2022;14:58–63.
10. Yiasemidou M, Gkaragkani E, Glassman D, et al. Cadaveric simulation: a review of reviews. *Ir J Med Sci*. 2018;187:827–833.
11. Dewey J. *Experience and Education*. New York, N.Y.: Macmillan; 1938.
12. WashU Surgical Education. WUSTL Learn Surgery. Available at https://www.youtube.com/@wustllearnsurgery7726. Retrieved Oct 28, 2023.