

Evaluating Virtual Dissection Versus Traditional Learning for Enhancing Anatomical Understanding of the Endoscopic Endonasal Approach

Tatsuya Uchida¹; Yuanzhi Xu¹; Yuhei Sangatsuda¹; Erik Burgos-Sosa¹; Vera Vigo¹; Masaki Ikegami¹; Taichi Kin²; Nobuhito Saito²;

Aaron Cohen-Gadol³; Juan Fernandez-Miranda¹

¹Department of Neurosurgery, Stanford University

²Department of Neurosurgery, The University of Tokyo

³Department of Neurological Surgery, Keck School of Medicine of USC

Abstract

Background: Virtual dissection (VD) has recently gained attention as an innovative educational tool in skull base surgery, offering learners the ability to actively manipulate and explore anatomy in three dimensions. Traditional resources such as textbooks, lectures, and slide-based materials often fall short in conveying the depth and spatial complexity of critical neurovascular structures encountered during the endoscopic endonasal approach (EEA). Although VD has been introduced in various fields, rigorous evidence directly comparing its effectiveness with traditional learning (TL) methods remains limited. Addressing this gap is essential to establish the educational value of VD in neurosurgical training.

Objective: To evaluate the educational effectiveness of a newly developed VD environment for an EEA to anatomy by conducting a randomized comparison with TL.

Methods: Twenty-eight neurosurgical residents (postgraduate years 3–7) were randomly assigned to either a VD group (n = 14) or a TL group (n = 14). Both groups followed the same program structure; a pre-test consisting of 20 multiple-choice questions, a 20-min learning session, and a post-test of identical content. The test was designed to evaluate spatial anatomical knowledge and included four sections; bony landmarks of the sphenoid sinus, cavernous sinus (CS) anatomy, microvascular anatomy, and neural anatomy, with five questions each and an “I don’t know” option. Gain scores (post – pre) were compared between groups using the Mann–Whitney U test. Analysis of covariance was performed to adjust for pre-test scores and postgraduate year, and intragroup comparisons were conducted using the Wilcoxon signed-rank test.

Results: All participants completed the program. Median postgraduate years were 5.5 (interquartile range 4–6) in the VD group and 4.5 (interquartile range 4–6) in the TL group. The VD group achieved significantly greater overall improvement in total knowledge scores compared with the TL group. In particular, the gain score in “CS anatomy” was significantly higher in the VD group (p = 0.005). After adjustment with analysis of covariance, the VD group maintained significantly higher total scores (p = 0.036) and CS anatomy scores (p = 0.001). In intragroup analysis both groups improved across several sections, but the magnitude of improvement was consistently greater in the VD group, underscoring its educational impact.

Conclusion: This randomized comparison suggested that VD may provide educational benefits over TL, particularly in facilitating understanding of the complex anatomy of the CS. The interactive and immersive features of VD, such as dynamic visualization and procedural simulation, appeared to support enhanced three-dimensional (3D) comprehension. While these findings are preliminary due to the limited sample size, they suggest that VD has the potential to serve as a valuable complementary modality that could modernize anatomical education, expand accessibility, and contribute to the training of future neurosurgeons.

Introduction

– Current status and challenges in EEA anatomy education

- EEA requires precise understanding of deep, complex anatomy
- Traditional materials such as textbooks and lectures provide limited spatial understanding
- Cadaveric dissection = gold standard, but limited by cost and access
- Need for high-quality, accessible, and reproducible 3D anatomy learning tools

– Study Design (Core Components of the Study)

1. Development of interactive VD environment
2. Educational evaluation: a pilot comparative study vs. TL

Methods and Materials

1. Development of interactive VD environment

- Visualized using a virtual dissection system we developed
- Interactive functions: zooming, rotation, transparency/translucency adjustment, virtual drilling, retraction, and dural peeling
- Operated via laptop screen + mouse, also accessible remotely via Zoom
- Simulates the endonasal surgical procedure

2. Educational evaluation through a comparative pilot study

- **Participants:** 28 residents (PGY 3–7)
- **Randomized:** VD (n=14) vs TL (n=14)
- **Program:** Pre-test → 20-min session → Post-test

➤ VD Session

- Remote operation of the VD environment via Zoom screen sharing and remote control
- Interactive 3D observation of the spatial and layered structures of the sellar and parasellar regions



➤ TL Session

- Slide sequence matched the knowledge test structure



➤ Statistical analysis

1. **Between-group:** Gain scores (post–pre) compared using Mann–Whitney U test ANCOVA (analysis of covariance) : Adjusted for pre-test scores and PGY
2. **Within-group:** Pre–post comparisons analyzed using Wilcoxon signed-rank test

Results

1. Overview of the developed VD environment

Fig.1. Detailed anatomical representations.

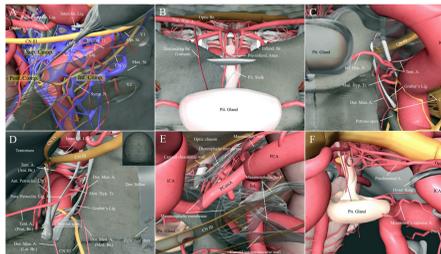
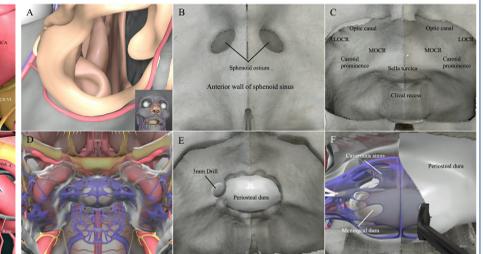


Fig.2. VD environment following the procedural steps of the EEA.



2. Results of comparative study

➤ Between-group

- VD > TL in total gain score

➤ ANCOVA

- Adjusted for pre-test scores and PGY
- VD > TL in total (p = 0.036)
- CS anatomy domain significantly higher (p = 0.001)

➤ Within-group

- Significant pre–post improvement in both groups

Fig.3. Between-group gain score comparison.

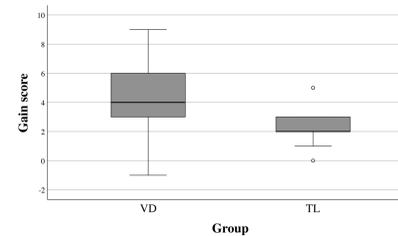


Fig.4. Within-group pre–post comparison.

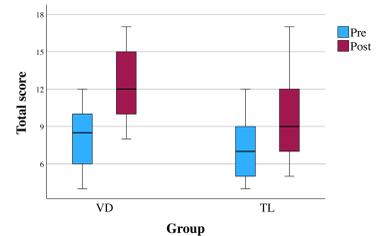


TABLE 1. Intergroup comparison of gain scores across each section and total of all four sections

Section	Gain score		p value
	VD (n=14)	TL (n=14)	
Bony landmarks of the sphenoid sinus	0.5 (0.0–1.0)	0.0 (0.0–1.0)	0.804
CS anatomy	3.0 (1.3–3.0)	1.0 (1.0–1.8)	0.005
Microvascular anatomy	0.0 (0.0–1.0)	0.5 (0.0–1.0)	0.769
Neural anatomy	1.0 (0.3–1.0)	0.0 (0.0–1.0)	0.104
Total of all four sections	4.0 (3.0–5.8)	2.0 (2.0–3.0)	0.027

TABLE 2. Intragroup comparison of pre- and post-test scores across each section and total of all four sections

Group	Section	Score		p value
		Pre-test score	Post-test score	
VD (n=14)	Bony landmarks of the sphenoid sinus	3.0 (2.0–3.0)	3.0 (3.0–4.0)	0.033
	CS anatomy	1.0 (0.0–2.0)	4.0 (3.0–4.0)	0.001
	Microvascular anatomy	3.0 (2.0–3.8)	3.5 (2.0–4.0)	0.433
	Neural anatomy	1.5 (1.0–2.0)	3.0 (2.0–3.0)	0.008
	Total	8.5 (6.0–10.0)	12.0 (10.3–14.8)	0.001
TL (n=14)	Bony landmarks of the sphenoid sinus	2.0 (1.3–2.8)	2.0 (2.0–3.0)	0.020
	CS anatomy	1.0 (0.3–2.0)	2.0 (2.0–3.0)	0.002
	Microvascular anatomy	2.0 (1.3–2.8)	2.0 (2.0–3.0)	0.034
	Neural anatomy	2.0 (1.3–3.0)	2.5 (2.0–3.0)	0.025
	Total of all four sections	7.0 (5.3–8.8)	9.0 (7.0–12.0)	0.001

Discussion

➤ Strengths:

- **Randomized controlled comparison**
Direct randomized comparison between VD and TL, enhancing methodological rigor in educational research.
- **Focus on complex EEA anatomy**
Targets anatomically challenging regions, particularly the CS, where VD demonstrated clear educational advantages.
- **Practical and scalable design**
Short, structured learning intervention suitable for integration into real-world neurosurgical training programs.

➤ Limitations:

- Small sample size, short-term evaluation, single-center study; results may not generalize
- No long-term follow-up or skill transfer assessment

Conclusions

- Developed a VD environment for anatomical learning in the EEA.
- VD may enhance 3D understanding and serve as a supportive tool for anatomy education.
- Demonstrated educational effectiveness with higher knowledge gain.

Contact

Tatsuya Uchida
Stanford University School of Medicine
453 Quarry Road, Palo Alto, CA 94304
uchidat@stanford.edu
669-667-9922

References

1. Bolzoni Villaret A, Battaglia P, Tschabitscher M, et al. A three-dimensional transnasal endoscopic journey through the paranasal sinuses and adjacent skull base: a practical and surgery-oriented perspective. *Neurosurgery*. 2014;10 Suppl 1:116–120, discussion 120.
2. Roh TH, Oh JW, Jang CK, et al. Virtual dissection of the real brain: integration of photographic 3D models into virtual reality and its effect on neurosurgical resident education. *Neurosurg Focus*. 2021;51(2):E16.
3. Qi F, Gan Y, Wang S, et al. Efficacy of a virtual reality-based basic and clinical fused curriculum for clinical education on the lumbar intervertebral disc. *Neurosurg Focus*. 2021;51(2):E17.
4. Uchida T, Kin T, Xu Y, et al. Development of a virtual dissection environment integrated into cadaveric dissection for skull base anatomy education. *J Neurosurg*. 2025;1–12.
5. Santona G, Madoglio A, Mattavelli D, et al. Training models and simulators for endoscopic transphenoidal surgery: a systematic review. *Neurosurg Rev*. 2023;46(1):248.
6. Xu Y, Mohyeldin A, Lee CK, et al. Endoscopic endonasal approach to the ventral petroclival fissure: anatomical findings and surgical techniques. *J Neurol Surg B Skull Base*. 2024;85(4):420–430.
7. Gonzalez-Romo NI, Mignucci-Jiménez G, Hanalioglu S, et al. Virtual neurosurgery anatomy laboratory: a collaborative and remote education experience in the metaverse. *Surg Neurol Int*. 2023;14:90.
8. Darras KE, Spouge R, Hatala R, et al. Integrated virtual and cadaveric dissection laboratories enhance first-year medical students' anatomy experience: a pilot study. *BMC Med Educ*. 2019;19(1):366.
9. Gonzalez-Romo NI, Hanalioglu S, Mignucci-Jiménez G, et al. Anatomic depth estimation and three-dimensional reconstruction of microsurgical anatomy using monoscopic high-definition photogrammetry and machine learning. *Oper Neurosurg (Hagerstown)*. 2023;24(4):432–444.
10. Aydin SO, Barut O, Yilmaz MO, et al. Use of three-dimensional modeling and augmented/virtual reality applications in microsurgical neuroanatomy training. *Oper Neurosurg (Hagerstown)*. 2023;24(3):318–323.