Three-Dimensional Versus Two-Dimensional Neuroendoscopy: A Preclinical Laboratory Study

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■ BACKGROUND: **Use of traditional two-dimensional (2-D) neuroendoscopy is limited by lack of depth perception. The advent of next-generation three-dimensional (3-D) endoscopes potentially compensates for this limitation. The aim of this study was to objectively compare the 2 modalities in a controlled laboratory environment.**

■ METHODS: **Using 2-D and 3-D endoscopes, 8 participants performed simple and complex motor tasks. Participants were divided into 3 groups: novice ($n = 3$), beginner ($n = 4$), and expert ($n = 1$), based on prior neuroendoscopy training. Efficiency of completing simple motor tasks in an allocated time and time to complete complex motor tasks were recorded for both visualization methods with demerits for inaccuracy.**

■ RESULTS: **Inaccuracy was reduced with increasing experience in the use of the 3-D endoscope for simple motor tasks such as spiral drawing ($P = 0.04$), but there was no statistical difference in completion time for complex motor tasks pertaining to depth perception among the groups ($P > 0.05$) or within groups for simple or complex tasks. To assess the impact on the learning curve, we analyzed the performance improvement in use of the other endoscope based on which endoscope each participant used first. There was marked improvement in accuracy and efficiency of 2-D scope use in the "3-D first" group for performing simple motor tasks such as dotted-line drawing ($P = 0.002$), but no benefit was observed for complex motor tasks.**

■ CONCLUSIONS: **Our data do not support the superiority of the 3-D endoscope over its conventional 2-D congener, although its use may shorten the learning curve associated with neuroendoscopy, regardless of subjects' prior experience with neuroendoscopy.**

INTRODUCTION

Phillip Bozzini introduced the endoscope in medical practice in 1806,[1,2] and Walter Dandy[1,3] pioneered the use of endoscopy and endoscopic-assisted approaches in neurosurgery nearly a century ago. The continuing efforts of influential individuals such as Harold Hopkins and Karl Storz subsequently paved the way for the current success and acceptance of neuroendoscopy in skull base neurosurgery.[1,2] Despite their many advantages, traditional endoscopes remain inferior to microscopes in the area of depth perception.[4] Microscopes offer three-dimensional (3-D) visualization, whereas two-dimensional (2-D) endoscopes rely on motion parallax; perspective size cueing; and other monocular cues such as object interposition, shadow, and expectation to assess depths.[4-6] Because a period of adaptation is required to master these skills, the learning curve associated with the use of the 2-D endoscope is considerably longer than the learning curve for the use of the microscope.[4-6] It is thought that the 3-D visualization improves hand—eye coordination, provides a better understanding of surrounding structures including depth perception, aids in optimal dissection of neurovascular structures, and shortens the associated learning curve for operating with these devices.[7-9]

Although 3-D endoscopes have been used in laparoscopic surgery since the early 1990s,[10] they were not introduced for use in neurologic surgery until 1998.[11] Even after that date, early 3-D systems, with active shutter glass and hand-mounted display, did not gain wide acceptance among neurosurgeons because of their larger diameter; poor resolution; and high incidence of

Key words
- 2-D endoscope
- 3-D endoscope
- Controlled laboratory study
- Learning curve
- Neuroendoscopy
- Superiority study

Abbreviations and Acronyms
2-D: Two-dimensional
3-D: Three-dimensional
LB: Long bayonetted
SS: Short straight

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headache, nausea, ocular fatigue, and dizziness in the operating surgeon.[1,2,12,13] With the advent of the high-definition 3-D camera using polarized glasses, many of these limitations have been overcome, but the use of 3-D endoscopy is still not widespread, and its benefits have not been conclusively demonstrated.[1,2,12,13] To date, very few studies have objectively compared the 2-D and 3-D visualization systems in neuroendoscopy in a preclinical laboratory setting.[5,12-15] There is conflicting evidence to confirm the superiority of the 3-D endoscope over its traditional 2-D congener. Therefore, the aim of this study was to objectively compare the 2 modalities in a controlled preclinical laboratory environment, across subjects having different prior experiences of neuroendoscopy training.

MATERIALS AND METHODS

Study Design

The study enrolled 8 participants, who each performed simple and complex motor tasks using both 2-D and 3-D endoscopes in the same laboratory setting. No compensation was provided to subjects for participating in this study. Participants were divided into 3 groups: novice ($n = 3$), beginner ($n = 4$), and expert ($n = 1$), based on their prior experience of neuroendoscopy training and practice. The novice group included first-year and second-year neurosurgical residents without any prior experience with neuroendoscopy. The beginner group included senior neurosurgical residents (4th year onward) with some prior experience of assisting with cranial or spinal endoscopy. The expert group included 1 experienced neurosurgeon well versed in neuroendoscopy. We used a standardized protocol for assessing the superiority of a visualizing technology in a controlled laboratory setting as described in our prior publication comparing surgical fidelity between the microscope and the 2-D endoscope.[4] For further subgroup analysis, we also divided the study cohort into 2 groups (2-D first, $n = 4$, and 3-D first, $n = 4$), based on the order of use of the visualization methods (2-D and 3-D), regardless of prior experience in neuroendoscopy.

Objective of Study

The primary objective of this study was to assess the accuracy and efficiency of completing simple motor tasks in an allocated time and the time taken to complete complex motor tasks for both visualization methods (2-D and 3-D). Participants also performed simple motor tasks using 2 different sets of instruments (short straight [SS] and long bayonetted [LB]) with both 2-D and 3-D endoscopes to assess any potential impact of design of operating instruments on primary outcome. A secondary objective of the study was to assess the impact of either technology (2-D or 3-D) on learning curve in neuroendoscopy. We also evaluated for any possible subjective clinical complications, such as dizziness or nausea, pertaining to the use of the 3-D endoscope in study subjects.

Study Protocol

The motor tasks were designed not to resemble an endonasal endoscopic approach for skull base lesions to avoid any potential learning associated with prior experience in the beginner and expert groups. In our study protocol, the participants who did the 2-D visualization first used the SS instrument (Penfield No. 4 dissector) first, whereas the participants who did the 3-D visualization first used the LB instrument (pituitary ring curette) first. To prevent any bias arising from refinement of surgical skills with practice, the type of endoscope (and the instrument type) used first was alternated among subjects. To prevent any bias that might arise from a difference in manufacturers, we used the new-generation VisionSense III neuroendoscope (VisionSense; Petach Tikva, Israel) for both the 2-D and the 3-D modes in high definition. The tasks were performed on an adjustable Mayo table to prevent any discrepancy arising from the relative height of the subject and the laboratory table. All the performances were filmed in real time.

Simple Motor Tasks

Assessment of Accuracy. The first simple motor task was to draw a spiral (from inside out) within another spiral, avoiding any contact to the dark area (**Figure 1A**). A demerit (for inaccuracy)

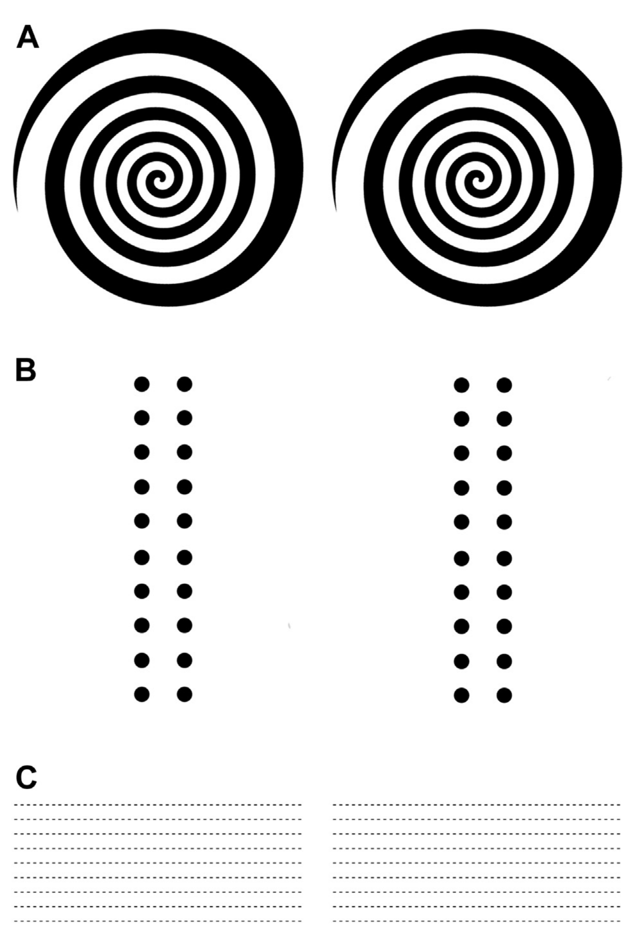

Figure 1. (**A**) The first simple motor task was to draw a spiral within another spiral, avoiding any contact to dark area. (**B**) The second simple motor task was to connect 20 dots in alternate left-to-right and vice versa fashion. (**C**) The third simple motor task was to draw over a series of dotted lines. All the tasks were performed using both visualization systems (two-dimensional and three-dimensional endoscope) and both types of operative instruments (short, straight and long, bayonetted).