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Endoscopic Training—Is the Future Three-Dimensional?

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Background/Objectives: Endoscopic surgery has a distinct disadvantage compared to direct vision: loss of binocular vision. Three-dimensional endoscopy has been welcomed due to the promise of improving stereopsis.

Methods: Prospective randomized study of junior doctors with minimal endoscopic experience, using both two-dimensional and three-dimensional, zero-degree, 4-mm Storz endoscopes. Data was collected using validated, standardized training models, both objectively and subjectively. Paired comparisons between variables relating to the endoscopes were performed using Wilcoxon's tests. Operators were then split into groups based on their endoscope preference, with comparisons made using Mann-Whitney tests for Likert scale responses, Kendall's tau for ordinal variables, and Fisher's exact tests for nominal variables.

Results: Reduction of field of vision of three-dimensional endoscopy by 2%. Significant findings included decreased past-pointing, improved depth and perception and image quality.

Conclusion: The use of an endoscopic endonasal approach with three-dimensional technology has measurable advantages for novice users, and highlights potential tailoring of future surgical training

Key Words: Endoscope, pituitary, surgery, three-dimensional, transsphenoidal, endoscopic surgical procedure, skull base.

Level of Evidence: 1b

INTRODUCTION

Having initially been introduced in the late nineteenth and early twentieth centuries, it was not until the amalgamation of Karl Storz and Harold Hopkins' work on endoscopy where the field of otolaryngology flourished.[1] The introduction of the two-dimensional endoscope set a milestone in visualization of the surgical field, in addition to providing more direct access, a reduction in retraction injury, and a minimization of damage to neurovascular structures.[1,2] Similarly, patients also encountered decreased postoperative morbidity and shorter recovery periods.[3–5]

Despite multiple advances in surgical technology, surgeons using 4-mm endoscopes are required to operate within a two-dimensional (2D) environment, with lack of stereopsis creating its own drawbacks. Experienced surgeons mitigate this difficulty through the use of visual and tactile feedback, dynamic movements of the scope, light, and shadows, and detailed anatomical knowledge.[1,6,7] In essence, surgeons are capable of creating three-dimensionality through experience, commonly through years of training in otolaryngology. Other specialities, however, including neurosurgery and ophthalmology, as well as junior doctors with little to no endoscopic experience, are required to acquire a new skill set using an unfamiliar tool while operating in delicate surgical fields.[8,9]

In 2012, a new 4-mm three-dimensional (3D) endoscope was introduced primarily to overcome the lack of stereopsis. 3D endoscopes have encountered an evolution of their own through improvements in image clarity and endoscopic quality. Recently, multiple studies have shown subjective improvements in precision of anatomy identification, stereoscopic depth perception, and surgical comfort.[2,10–12] Despite this, there has been minimal objective data collection with small studies highlighting postoperative outcomes, length of hospital stay, quantity of blood loss, and complication rates comparable to standard 2D techniques.[10,13] Additionally, Van Gompell et al.[14] documented a 52% field of view restriction with a different 3D endoscope in 2014.

There is understandable interest in the potential of 3D endoscopy. However, the limitations of some previous publications on this subject have been in the selection of experienced surgeons with small numbers. We conducted a study aimed at junior doctors and medical students with little to no endoscopic experience using both objective and subjective measures.[2,6,7,9,11–14]

MATERIALS AND METHODS

Study Design

Prospective randomized trial incorporating both quantitative measures of endoscopic handling using a box-trainer and a

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Full informed consent was obtained from all patients prior to data collection. All patient data was anonymized prior to data analysis.

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TABLE I.
Comparisons Between 2DHD and 3DHD Endoscopes

Variable	2DHD	3DHD	*P* Value
Time to complete task (seconds)	107 (75–141)	86 (56–126)	.153
Adjustment Time (seconds)	9 (5–13)	10 (5–19)	.067
Past Pointing (VAS)	2 (0–5)	0 (0–2)	**.025**
Number of drops (VAS)	2 (1–2)	1 (0–2)	.501
Subjective depth perception (VAS)	4 (3–5)	8 (7–8)	**<.001**
Field of view (VAS)	6 (5–7)	7 (5–8)	.072
Image quality (VAS)	6 (5–8)	8 (7–9)	**.002**
Maneuvrability (VAS)	7 (6–8)	7 (6–8)	.247

Data reported as median (IQR), with *P* values from Wilcoxon's tests. Bold *P* values are significant at $P < .05$.
2DHD = two-dimensional high definition; 3DHD = three-dimensional high definition; VAS = visual analogue score.

validated qualitative questionnaire, in addition to calculating field of vision restrictions between the two different endoscopes. The study was conducted at the University Hospital Birmingham (UHB) NHS Foundation Trust in November 2016.

The study used Karl Storz 4-mm, 0-degree, 2D and 3D endoscopes. Participants were randomized into one of the following two groups: completing task with 2D endoscope followed by 3D endoscope or completing task with 3D endoscope followed by 2D endoscope.

Participants

Our sample population consisted of medical students and junior doctors with little to no experience of endoscopic surgery—measured as fewer than 10 endoscopic operative exposures (either 10 witnessed and/or less than four performed/assisted), working at the UHB NHS Foundation Trust.

Participants were excluded if they had observed greater than 10 endoscopic operations or performed/assisted in more than four.

A unique study identification number was assigned to each participant and baseline demographic data was collected.

Modified Box-Trainer Task

Participants performed one fundamental task—peg transfer (and transfer back to original peg).[15,16] Modifications were made to adapt box trainer task:

1. Use of singular port for both endoscope and instrument (straight Blakesley forceps) to simulate endoscopic surgery through the nose.
2. Task confined to distance between 30 mm and 50 mm (numerous anatomical studies have found the distance between nasal vestibule to anterior attachment of middle turbinate and superior turbinate within this range).[17–20]

At the beginning of the study, prior to beginning peg transfer, all participants were shown the box trainer opened and given a detailed explanation of the expected task.

Methods

All study participants were consented and randomized to begin the study using either the standard high definition two-dimensional (2DHD) endoscope or high definition three-dimensional (3DHD) endoscope. Participants were randomized using simple randomization—(flipping of a coin).

An explanation of the task was provided verbally and in written format. Participants were then required to perform the "modified box trainer task" with each endoscope according to their randomization. Quantitative measures including: task completion time (in seconds), adjustment time (time taken to touch first bead), past pointing and number of drops were recorded by two independent assessors. The task was repeated for the second endoscope, with identical measures recorded.

Following completion of second cycle, participants were asked to fill out a qualitative questionnaire using a validated visual analogue scale, including demographic data and subjective measures of depth perception, field of vision, image clarity and maneuverability (Appendix 1).

Finally, we objectively calculated field of vision using standard measurements of 6 cm and 2 cm working distance. This was performed by two independent assessors using standardized 2-mm squared paper and calculating the percentage difference between the 2DHD and 3DHD endoscopes.

Statistical Methods

Paired comparisons between variables relating to the 2D and 3D endoscopes were undertaken using Wilcoxon's tests, with data summarized as medians and interquartile ranges (IQRs). Operators were then split into groups based on their stated preference, with comparisons made using Mann-Whitney tests for the Likert scale responses, Kendall's tau for ordinal variables, and Fisher's exact tests for nominal variables.

All analyses were performed using IBM SPSS 22 (IBM Corp., Armonk, NY), with $P < .05$ deemed to be indicative of statistical significance throughout.

RESULTS

A total of 35 operators took part in the study, with median age of 28 years (IQR: 27–32). Most operators had previously observed at least one endoscopy (N = 27, 77%), and only 42% (N = 15) had previous operative experience.

Comparisons between the two endoscopes (Table I) found no evidence of significant differences between the time ($P = .153$) or the adjustment time ($P = .067$), although the trend was for the latter to be longer in the 3D endoscopes irrespective of whether using this endoscope first or second. However, past pointing was found to be significantly lower when using 3D endoscopes (median 0 vs. 2, $P = .025$), and depth perception (8 vs. 4, $P < .001$)

TABLE II.
Comparisons Between Operators With Different Endoscope Preferences

Endoscope (N = number of participants preferring specific endoscope irrespective of starting endoscope)	Operator Preference		
	2D (N = 8)	3D (N = 27)	*P* Value
Strength of preference (0–10 visual analogue scale)	5 (3–7)	8 (7–8)	**<.001**

Data reported as median (IQR), with *P* values from Mann-Whitney tests. Bold *P* values are significant at $P < .05$.

and image quality (8 vs. 6, $P = .002$) were also found to be significantly improved with the 3D endoscopes.

The majority of operators said that they preferred the 3D endoscope over the 2D endoscope (77%, N = 27). The magnitude of this preference was found to be stronger in those that were randomized to use the 3D endoscope first, with a median score of 8 out of 10, compared to 5 out of 10 for those that preferred the 2D endoscope ($P < .001$, Table II). Comparisons were then made between the ages of those operators that preferred the 2D versus 3D endoscopes, but were not found to be statistically significant.

Comparisons were made between field of vision (Table III) and found a reduction of 2.38% and 10.51%, respectively, at 2 cm and 6 cm working distance.

DISCUSSION

With the continuing expansion of endoscopic surgery including the endonasal approach to the skull base and brain, as well as transorbital neuro-endoscopic surgery, there are numerous specialities having to adapt to an unfamiliar tool through necessity. The main concern is the loss of stereoscopic vision.[9] With appropriate visualization vital for tissue and anatomical identification, previous research has highlighted the subjective preference for 3D endoscopy, as can be confirmed by our study, with the strength of preference statistically significant ($P = < .001$).[2,7,10,18] 3D endoscopy has shown comfort when opening the dura, improved visualization of complex airway anatomy with higher rates of precision when removing tissue, and increased sinus anatomy understanding in cadaveric dissection. [2,10–12]

Issues relating to previous publications on 3D endoscopy have included difficult tissue maneuvrability due to increased scope size, especially in narrow nasal spaces, increased susceptibility to losing focus secondary to blood spoiling, and an adjustment period of surgeons adaptability.[9] Other potential limits have been a reduction in field of vision and the lack of angled scopes.[9,14] While we have demonstrated that the newer versions of the 3DHD endoscope have a reduction in field of view, this is only modest (2% reduction with endoscope at 2 cm from target and 10.5% with endoscope held at 6 cm from target) (Table III). This compares very favorably to the previous study by Van Gompel et al.,[14] which showed a 52% reduction in field of view with a different 3DHD endoscope.

TABLE III.
Measuring Field of Vision.

Distance between endoscope tip and target (cm)	Percentage difference from 3DHD to 2DHD endoscope (%)
2	**-2.38**
6	**-10.51**

2DHD = two-dimensional high definition; 3DHD = three-dimensional high definition.

CONCLUSION

We believe further research using the Storz 0-degree, 4-mm, 3D endoscope would introduce further information into an exciting new field.

Our study design using novice users of endoscope technology is the first study to give objective data confirming the subjective preference for this technology by end users. We have shown a significant objective reduction in past pointing in novice users, while subjective improvements in depth and image clarity when comparing 2DHD endoscopy and 3DHD endoscopy. We believe through the current evolution of endoscopy we will see this technology become commonplace in simulation training and in our surgical theaters replacing existing 2DHD endoscopes.

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