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# A study of the visual symptoms in two-dimensional versus three-dimensional laparoscopy

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## Introduction:

There is a strong evidence to suggest that 3 dimensional (3D) imaging improves the surgical task performance during laparoscopic surgery (1, 2). A previous study has explained the underlying scientific reasons for the apparent improvement in 3D surgical task performance (3). However, this improved performance comes at a price of increased eye strain for a subgroup of surgeons, as several studies has proven that 3D imaging is associated with visual symptoms (4, 5). There is no study to date that explains the causes for the eye strain during the use of 3D laparoscopy and any possible ways to minimize this squeal.

We aimed to study the extent of visual symptoms seen in 3D versus conventional 2D imaging in volunteers performing laparoscopic tasks and study the effect of eye exercises on 3D laparoscopy. We studied the visual symptoms while factorizing the imaging into separate components by laparoscopic tasks developed in a previous study (3). In addition, we looked at eye divergence as a possible cause for eye strain and studied the eye deviation in the participants.

## Methods:

Consented medical students who were laparoscopic novices were included in this study. The participants performed a battery of specific isolated laparoscopic tasks. Each task took approximately 20 to 25 seconds. Each participant had to complete 70 tasks in both 2D and 3D. This amounted to about 30 minutes. The laparoscopic tasks were conducted in a laparoscopic Endo Trainer (Body Torso Simulator box, Pharmabotics Ltd, Hampshire) using a laparoscope (26003BA, Hopkins ®, 30 degree, 10mm diameter, 31 cm length, Karl Storz) with HD 2D and HD 3D systems (19 inch, resolution 1920x 1080 pixels, Karl Storz GmBh & Co, Tuttlingen, Germany). Participants had to wear 3D polarized glasses with the use of 3D monitor.

The laparoscopic tasks were developed in a previous study to test the surgeons' ability to detect changes in 2D and 3D environments (3). Generic components of the laparoscopic image of an object were previously identified as the distance, area, angle, curvature and volume. Each task was performed independently in both 2D and 3D laparoscopic environments. The tasks included the assessment by the method of measuring, comparing and creating. The measurement task tested the ability of the participants to estimate a given measurement in any of the components (distance, angle and volume). The comparison task assessed how the participants could compare the given components of varying measurements. The creation task involved the ability of the participant to create a given measurement in selected components (table 1).

Before and after the 2D and 3D laparoscopic tasks, subjects were asked to complete a standardised questionnaire designed to scale (from 0 to 10) their visual symptoms (blurred vision, difficulty in refocusing from one distance to another, irritated or burning eyes, dry eyes, eyestrain, headache and dizziness).

Participants were asked before conducting the experiments if any of them had eye disease such as myopia, diplopia or astigmatism. All the participants went through the visual acuity test, eye deviation test and visual analogue scale. Visual acuity test was done using Snellen chart (3 meters) (6). Eye deviation was measured with Maddox Wing device (7). The visual analogue scale used to assess the presence of eye strain or other symptoms on a scale from 0 to 10 (0- none, 2- annoying, 4- uncomfortable, 6- dreadful, 8- horrible, 10-agonising). The participants were crossed-over to begin with 2D or 3D experiments randomly.

Participants who underwent 3D laparoscopic tasks were randomized into two groups, those who received two minutes eye exercises before performing the tasks and those who didn't. There were three exercises performed by the participants. 1) Palming eye relaxation technique: participants would sit on a chair and make themselves comfortable. They would rub their hands until they warm up. They would close their eyes and cover them with the palm of their hands without pressing hard on their eyes. Participants would then breathe deeply.

2) The two dots vision exercise: a chair was placed at 10 feet away from a wall. Each participant would sit comfortably and take a deep breath and relax. Medium sized circles were cut and pinned to the wall approximately one and half meter apart. The participant needed to focus at one of the dots for a few seconds, and then slowly move his eyes to the other dot. He/she had to repeat this exercise for a minute. Then, after one minute, participants had to close their eyes and relax.

3) The eye blinking test: the participants would close their eyes and relax. They would blink 15 times rapidly. Each participant would be asked to blink lightly without compressing the eye lids tightly. Then, they had to close their eyes and relax. Participants had to repeat this exercise twice.

The visual acuity test, visual analogue symptom questionnaire and the simple eye deviation test (Maddox Wing) were performed by all the participants (figure 1). The visual symptoms were scored for the 3D group with and without eye exercises.

The results were analysed with IBM SPSS version 22. Paired t-test was used to detect any significant difference. A p-value less than 0.05 was accepted as statistically significant.

**Results:**

Twenty four students completed this study. None of the participants had any known eye disease. There was no difference in the eye deviation between the 2D and 3D imaging mean (s.e.m.): 5.21 (0.92) vs 6.33 (1.53), p values 0.235 vs 0.411 respectively (table 2).

For eye symptoms in 2D imaging, visual analogue scale revealed that eye strain was statistically significant in 2D imaging mean (s.e.m.): 0.42 (0.17) when compared to 3D with 1.38 (0.98), p values 0.022 vs 0.061 respectively (Figure 2) (table 2). In 3D imaging, the difficulty in refocusing from one distance to another was statistically significant 1.5 (1.05), p=0.035 vs 0 when compared to 2D (Figure 3) (table 2).

The effect of the simple eye exercises on relieving the visual symptoms in the 3D group was not statistically significant (p >0.05) (table 2).

**Discussion:**

This study showed that visual symptoms were present in both 2D and 3D imaging laparoscopy. Eye strain was prominent in 2D imaging and difficulty in refocusing from one distance to another was prominent in 3D.

In a previous study, it has been proven that 3D imaging enhances the task performance in detecting changes in the volume of an object and the spatial coordinates of that object (3). There remains a contradicted evidence that visual symptoms are more prominent in 3D. Some papers have shown that visual strain, dizziness, headache, and facial discomfort are more problematic with the use of 3D systems (4, 5).

In order to see 3D images, each eye must see a slightly different picture. This is done by the help of polarized glasses in 3D technology systems, oppositely polarized lenses ensure eyes being spaced apart, so each eye gets only its designated frame. The brain combines then the two pictures together in order to form the perception of depth (8). Because eyes diverge in order to perceive a 3D image, Maddox Wing device was used to measure and compare any persistent eye divergence following 2D and 3D imaging. We noted no difference in eye deviation in both surgical imaging.

The task performance, surgical errors and visual symptoms have previously been assessed by using composite tasks called the Fundamentals of Laparoscopic Modules (peg transfer, precision cutting, ligating loop, extra-corporeal knotting and intra-corporeal knotting) (9). These tasks consist of interplay of various dimensions and are not testing any aspect in isolation, unlike the tasks used in our study that were developed based on the fact of the presence of basic physical characteristics of any shape of image. Area, angle, curvature and volume are consists of any image. While the distance and curvature are 1 dimensional, the area and angle are 2 dimensional, and volume is in form of 3 dimensional in character. This is the first study to look at the visual symptoms in 2D and 3D images using the visual component tasks.

A previous study proved that there was no objective findings of visual fatigue in 3D imaging but revealed subjective visual findings that were significant in 3D from the scored symptoms (10). Our study revealed that difficulty in refocusing from one distance to another was significant with a marginally significance in eye strain and headache in 3D imaging. While, eye strain was noted to be statistically significant in 2D. The eye strain found following the 2D imaging was unexpected, however, this may be explained partly by cognitive overload experienced by the novice surgeons when they encountered the component tasks. It might be the case that the cognitive load in the 3D imaging is less than 2D. The proof of this because the tasks were performed better in 3D systems. However, these results of the prominence of visual symptoms in 3D were not replicated in other studies (11, 12), while another study reported less eye strain in 3D when compared to 2D (13). This can be explained by the variability of the difficulty of the tasks used in each study.

This study was also designed to analyse the effect of eye exercises in 3D imaging and to assess any significant benefit in exercising eye muscles. Eye exercise is believed to be one of the therapies for many visual problems including myopia and ocular motility disorders (14). Apart from that, regular twice daily eye exercises are commonly prescribed to school pupils of certain populations to relieve ocular fatigue and myopia that maybe caused following prolonged periods of intense concentration and studying (15). Our study is the first study that investigated the benefit of such eye exercises in 3D imaging in relieving symptoms commonly experienced following 3D imaging. However, the results showed that there was no effect of eye exercises on visual symptoms seen in the 3D group. The eye exercises were short and simple, and were intended to relax extra-ocular muscles.

One future direction is to perform a well-designed randomized controlled study to explore the effect and the application of eye exercises at different durations on 3D visual symptoms in clinical laparoscopic settings.

**Conclusion:**

The visual symptoms were present in both 2D and 3D imaging laparoscopy. Eye strain was prominent in 2D imaging and difficulty in refocusing from one distance to another was prominent in 3D. Eye exercises before the 3D laparoscopic tasks as a possible solution for 3D visual symptoms did not bring any significant benefit.

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The authors declare no conflict of interests.

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**Ethical approval:**

Approval was granted by local research ethics committee prior to the commencement of this study.

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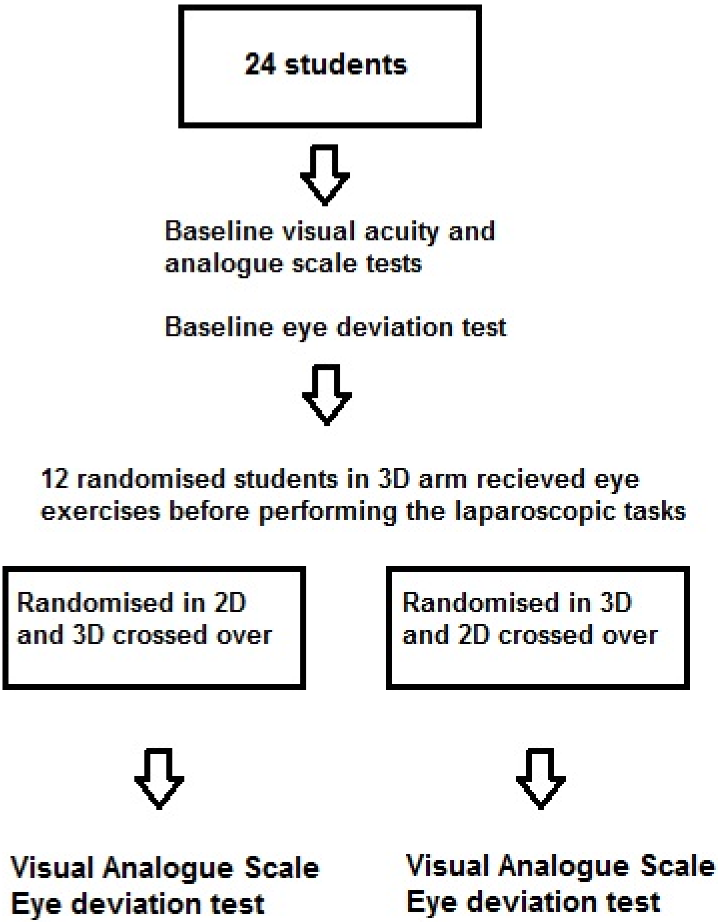
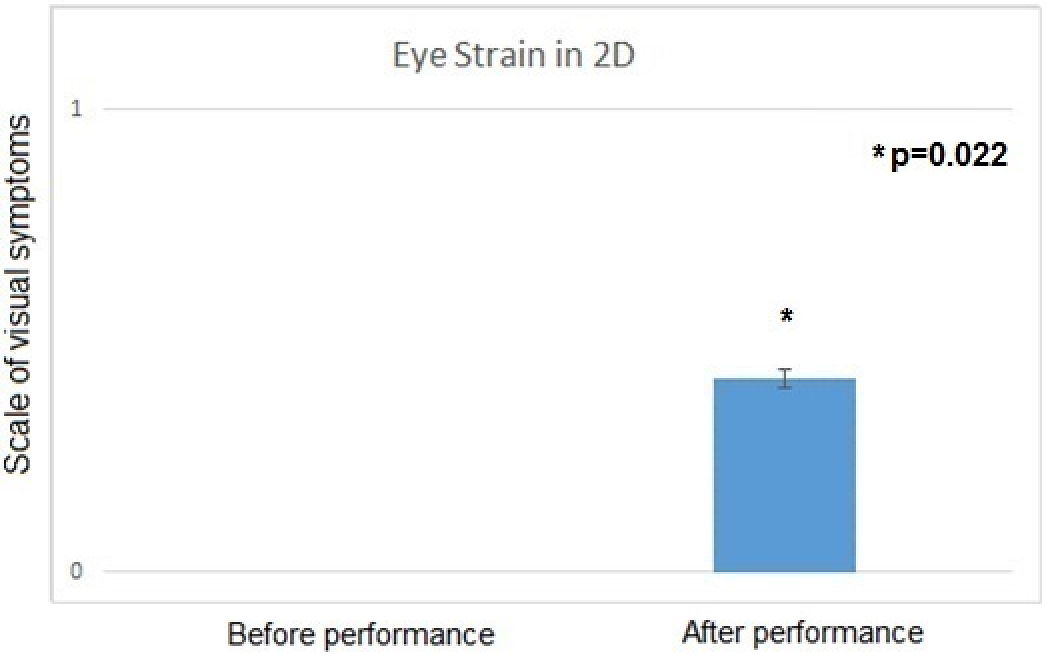
**Table 1**: The laparoscopic tasks in 2D and 3D

| **Component** | **Creation** | **Comparison** | **Measurement** |
|---|---|---|---|
| Area | Omitted due to task complexity | To compare areas of different squares and circles in a laparoscopic Endo Trainer | To estimate areas of specific squares and circles in a laparoscopic Endo Trainer |
| Distance | To create specific distances by using a laparoscopic grasper to move a referenced peg along a string | To compare different distances | To estimate specific given distances |
| Curvature | Omitted due to task complexity | To compare different curvatures | Omitted due to task complexity |
| Angle | To create specific angles using a laparoscopic grasper by moving an adjustable arm attached to a fixed horizontal arm with a hinged vertex | To compare different angles | To estimate specific angles |
| Volume | To create specific volumes by injecting Foley's catheter balloons | To compare volumes of different balloons | To estimate specific volumes presented with inflated Foley's catheter balloons |

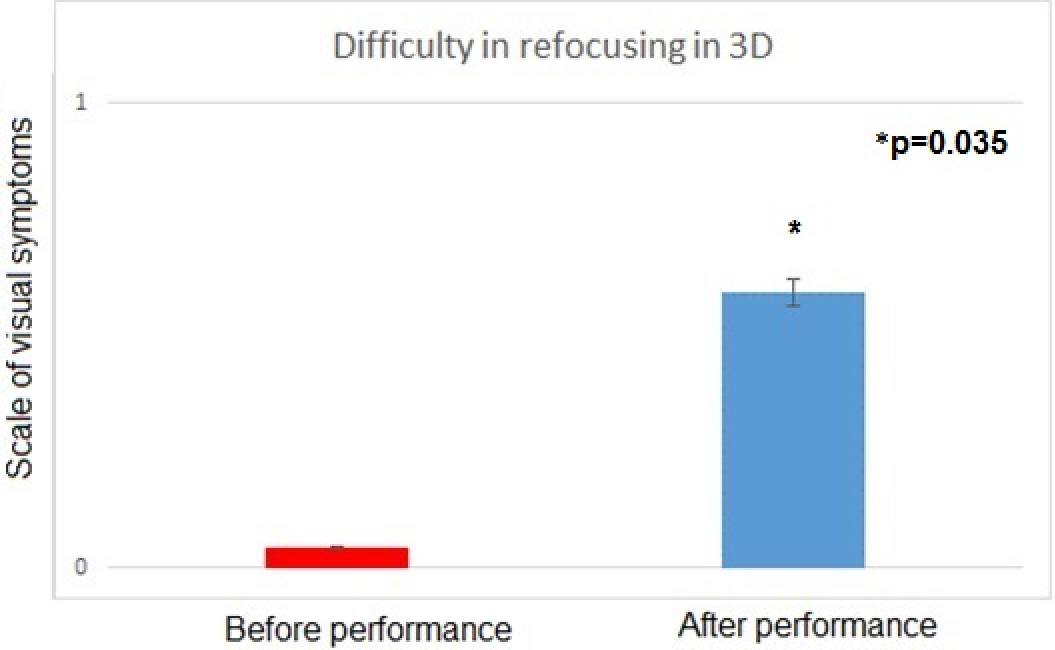
**Table 2:** Mean (s.e.m.) and p values of visual parameters in 2D and 3D laparoscopy

| Visual parameters | Mean (s.e.m.) value in 2D | p value in 2D | Mean (s.e.m.) in 3D without eye exercises | p value in 3D without eye exercises | Mean (s.e.m.) in 3D with eye exercises | p value in 3D with eye exercises |
|---|---|---|---|---|---|---|
| Blurry vision | 0.04 (0.04) | 0.328 | 0.63 (0.50) | 0.119 | 0.5 (0.5) | 0.862 |
| Dry eye | 0.17 (0.12) | 0.162 | 0.5 (0.33) | 0.162 | 0.5 (0.33) | 1 |
| Difficulty in refocusing from one distance to another | 0/0 | - | **1.5 (1.05)** | **0.035** | 1.75 (1.03) | 1 |
| Eye strain | **0.42 (0.17)** | **0.022** | 1.38 (0.98) | 0.061 | 1.5 (0.98) | 0.552 |
| Headache | 0/0 | - | 0.5 (0.33) | 0.057 | 0.5 (0.5) | 0.698 |
| Eye deviation | 5.21 (0.92) | 0.235 | 6.33 (1.53) | 0.411 | 4.33 (0.86) | 0.068 |


24 students
Baseline visual acuity and analogue scale tests
Baseline eye deviation test
12 randomised students in 3D arm recieved eye exercises before performing the laparoscopic tasks
Randomised in 2D and 3D crossed over
Randomised in 3D and 2D crossed over
Visual Analogue Scale
Eye deviation test
Visual Analogue Scale
Eye deviation test



Eye Strain in 2D
Scale of visual symptoms
1
0
* p=0.022
*
Before performance
After performance


Difficulty in refocusing in 3D
Scale of visual symptoms
1
0
*p=0.035
*
Before performance
After performance