

# Optimization of Surgeon Ergonomics With Three-dimensional Heads Up Display for Ophthalmic Surgeries

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## Research Article

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# Abstract

**Purpose:** To describe the variables that may be utilized in the optimization of three dimensional heads up surgeries (3D-HUS) for achieving better ergonomics among ophthalmic surgeons.

**Methods:** A cross-sectional study conducted at the operating room of a tertiary eye care centre, equipped with ARTEVO 800 3D surgical microscope and display monitor. The parameters noted were: monitor height (MH), surgeon eye to floor distance (ETFD) surgeon eye to monitor distance (ETMD) (Fig. 1a) and viewing tilt (VT) angle. The neck and eye strain of the surgeon and assistant were scored as per Borg's CR-10 scale, before and after surgeries.

**Results:** 15 surgeries were analysed. The minimum ETMD was 51 inches and eye strain reduced with shorter ETMD. VT and ETFD was higher for right eye surgeries. The optimum MH was between 50 to 55 inches. Overall, neck strain and eye strain were in the range of 0-3 and 0-1, respectively.

**Conclusion:** The various parameters affecting 3D image quality, neck and eye strain are: chair height, viewing tilt angle, eye centration, monitor distance, laterality of the eye and room illumination.

## 1. Introduction

Three-dimensional heads-up surgery (3D-HUS) has revolutionized ophthalmic surgeries. They have improved surgical performance and deliver a better surgeon's experience, with reduced back and neck strain to the surgeon for various anterior and posterior segment surgeries.[1–3] The conventional microscopes have reported to cause neck and back pain and eye strain among the surgeons due to a constant need to look into the microscope during ophthalmic microsurgeries.

The main advantages of 3D HUS are: improved ergonomics, lower endoillumination intensity and thus reduced phototoxicity, better visualization, better peripheral visualization, magnification, less asthenopia for vitreoretinal surgeries.[1, 3] Various available 3D-HUS systems include: ARTEVO 800 (Carl Zeiss Meditec) and NGENUITY 3D Visualization System (Alcon Laboratories). 3D-HUS microscopes and operating systems have improved surgeon ergonomics and help avoid the deleterious delayed effects on musculoskeletal system observed in surgeons operating on conventional microscopes.

In 3D-HUS visualization systems, crosstalk refers to an incomplete isolation of the left and right images. Crosstalk impairs 3D image quality, often leading to ghost images. Tsuboi et al studied relationship between display position and crosstalk for HUS systems in ophthalmology and reported that crosstalk decreased with increasing display distance when viewing screen with polaroid glasses.[4] A viewing distance of 1.2 metres (47.2 inches) is suggested for NGENUITY 3D-HUS system[5], and 3–4 feet (36–48 inches) for ARTEVO system.[6] No studies have yet been performed to study the optimum monitor distance that balances the amount of crosstalk and provides adequate magnification and comfort to the surgeon as well.

However, the authors believe there can be a further refinement and optimization of performance of these 3D-HUS systems. The factors helping in the optimization of these systems have not been studied in detail. The current study was undertaken to study the modifiable factors, which help in the optimization of 3D-HUS visualization system for improving surgeon ergonomics while performing ophthalmic surgeries.

## 2. Methods

This cross-sectional study was conducted at ophthalmology operating room (OR) of our tertiary care centre, which is equipped with 3D-HUS monitor and a 3-D compatible viewing microscope (Fig. 1). No patients were involved in the study. This study was assessed as minimal risk and, as such, was exempt from institutional review board review.

2.1 Technical specifications of 3D-HUS: ARTEVO 800 (Carl Zeiss Meditec) surgical microscope and visualization systems were used. Zeiss intraoperative OCT (Rescan 700, Carl Zeiss Meditec) was, wherever intraoperative scanning was required. A 3D video monitor measuring 55" mounted on a movable cart, allowing adjustments in the total height of the monitor (floor to topmost point of the display) in the range of 67–72 inches, was used.

2.2 Measurements taken in OR: A single surgeon was observed for surgical position (adjusted as per the convenient ergonomics) during consecutive cataract surgeries performed on ARTEVO system under peribulbar anesthesia. Surgeon position was superior (90 degrees) in all cases. The measurements taken were: monitor height (MH, i.e. the vertical distance of the center of the monitor from the floor), surgeon eye to floor distance (ETFD, i.e. the vertical distance of surgeon eye level from the floor) surgeon eye to monitor distance (ETMD, i.e. the horizontal distance between the surgeon's eyes and the monitor) (Fig. 1a), viewing tilt (VT, i.e. the angle subtended between the ETMD and an imaginary line connecting the eyepiece of the microscope and the surgeon's back of the head) (Fig. 1b) and surgeon gaze height (Fig. 1c). The laterality of the operated eye was also recorded.

2.3 Eye and neck strain: Before and after each surgery, the surgeon and assistant rated their eye and neck strain as per Borg's CR-10 scale.[7, 8] Three questions that were asked were: "To what extent do your eye ache or feel strained?", "To what extent do you have a burning or smarting sensation in your eyes?" and "To what extent do you feel pain or discomfort in your neck and/or shoulders" to rate the internal symptoms (related to accommodation or vergence stress), external symptoms (related to dry eye disorders) and neck strain, respectively.[9] The surgeon ensured a zero screen time (mobile devices, television screen, etc) at least two hours prior to surgeries, to reduce digital eye strain due to device use.

2.4 Eye Centration: Different ophthalmology residents observed the eye centration on the 3D screen during the surgery, using 3D goggles. They judged the quality of 3D display during the entire surgery, while viewing the monitor sitting in the viewing plane of the surgeon.

2.5 Data Analysis: All data was managed in a Microsoft Excel spreadsheet. Statistical analysis was performed using Statistical Package for the Social Sciences software (SPSS) version 17.0 (SPSS Inc.

Chicago, IL, USA). Descriptive statistics were obtained for all parameters and data was expressed as mean  $\pm$  standard deviation (SD). Mean values for ETFD, ETMD and VT were evaluated for all surgeries by one-way repeated measures analysis of variance (ANOVA). Post hoc analysis was done to compare between different groups of data. A p-value  $< 0.05$  was considered to be statistically significant. All categorical data was analyzed using Pearson X<sup>2</sup> or Fisher's exact test.

### **3. Results**

We conducted measurements for 30 surgeries (13 right, 17 left). The results are summarized in Table 1. The mean monitor distance after ergonomic adjustment for various surgeries was  $67.4 \pm 10.21$  inches.

#### **3.1 Impact of Monitor distance**

We observed that the internal eye strain was more for surgeries done at a higher distance (ETMD) of monitor from the surgeon ( $r = 0.76$ ,  $p < 0.0001$ ). The external eye strain and the neck strain did not vary significantly, when ETMD varied ( $r = -0.12$ ,  $p = 0.51$  and  $r = 0.13$ ,  $p = 0.48$ , respectively). ETMD did not depend on the laterality of the operated eye.

#### **3.2 Viewing tilt or angle**

VT was higher for right eye surgeries than left eye surgeries ( $29.69 \pm 2.56$  vs  $17.82 \pm 4.54$  degrees, respectively;  $p < 0.0001$ ). A higher neck strain score was associated with a higher VT ( $r = 0.77$ ,  $p < 0.0001$ ). The internal and external eye strain did not vary significantly with change in VT.

#### **3.3 Centration**

The resident observing the surgeries noted better quality 3D visualization and a good quality 3D image when eye was well centered on the 3D screen compared to the events when eye was in peripheral corners of the screen (Fig. 2).

#### **3.4 Chair height**

The mean chair height or ETFD was  $52 \pm 2.04$  inches. A higher neck strain was noted for lower ETFD ( $r = 0.7$ ,  $p < 0.001$ ) i.e. at lower chair heights surgeon experienced more neck strain (Fig. 3a). MH observed were in the range of 50–55 inches. There was no significant effect on the eye strain scores with the adjustment of ETFD. Also, ETFD was higher for the right eye surgeries than the left eye surgeries.

#### **3.5 Ergonomics of the assistant in surgeries**

Assistant had less neck strain when left eye surgery was performed. The neck strain was reported to be more when the assistant same on the same side as the monitor screen (Fig. 3b).

#### **3.6 Use of Hybrid mode of 3D-HUS**

There was seamless transition when switching from seeing 3D screen to seeing into binoculars of the microscope for the assistant and the surgeon both (Fig. 3c).

## 3.7 Effect of laterality

It was observed that the tilt while viewing and neck strain were significantly more for right eye surgeries than for left eye surgeries. The mean VA for right eye and left eye were  $29.69 \pm 2.56$  and  $17.82 \pm 4.54$ , respectively ( $p < 0.0001$ ). The mean neck strain scores for right eye and left eye were  $1.92 \pm 0.64$  and  $0.47 \pm 0.21$ , respectively ( $p < 0.0001$ ).

## 3.8 Effect of room illumination

The room had to be only dim lit to provide better contrast on the 3D monitor (Fig. 3c). Dim illumination provided better 3D image quality. However, the neck strain and eye strain scores were the same with variation in room illumination.

## 4. Discussion

3D-HUS systems have expanded frontiers, have simplified ophthalmic surgeries and are increasingly popular due to better ergonomics than conventional microscopes.[10] They provide a better experience to the surgeon, assistant and the residents in training, who can watch the surgical steps from a distance. They also enable social distancing in the OR, especially useful in this coronavirus (COVID-19) era.[6] However, there is a need to define the variable parameters that can help optimize the surgical experience with 3D-HUS systems.

Monitor display position strongly affects image quality in 3D systems. [4] In the current study, we report that surgeon neck and eye strain were found to reduce with the adjustment of the surgeon chair height and monitor distance, respectively. A closer kept monitor i.e. a lesser monitor distance (~ 50–55 inches) was found to cause less eye strain to the surgeon. Similar to our finding, Tsuboi and coworkers report an optimum distance of 1.26 m (~ 49 inches) with NGENUITY 3D-HUS system to minimize the crosstalk (a phenomenon occurring with stereoscopic images on 3D displays) and improve the 3D image quality. Tsuboi and coworkers also reported that the amount of crosstalk decreased with increasing display distance from the observer and increased when the eye level of the observer was too high or too low.[4]

Usually, because the microscope swivel arm is kept towards the right hand side of the surgeon, surgeon has to maintain a head tilt while operating with the 3D-HUS systems to look out of the eyepiece of the surgical microscope during the right eye surgeries. This is relatively easier for the left eye surgeries. In our study, we confirmed this hypothesis as the viewing tilt angle was observed to be more for the right eye surgeries. This also causes slightly more neck strain to the surgeon in the right eye surgeries.

The various parameters affecting 3D image quality, neck and eye strain are: chair height, viewing tilt angle, eye centration, monitor distance, laterality of the eye and room illumination. But the impact of these parameters on depth perception were not analyzed and this is one limitation of our study. Nevertheless, to the best of our knowledge, our study is the first reporting the methods to optimize 3D-HUS surgical experience.

# Declarations

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Conflicts of interest/Competing interests

The authors have no conflicts of interest and no financial interest.

## Availability of data and material

Data is available and will be provided on request

## Code availability

Not applicable

## Authors' contributions

YG and RT conceptualized the research. YG compiled manuscript, RT critically analyzed it and reviewed the manuscript. YG and RT did data collection, data analysis and statistics. YG and RT did final approval of the manuscript to be published.

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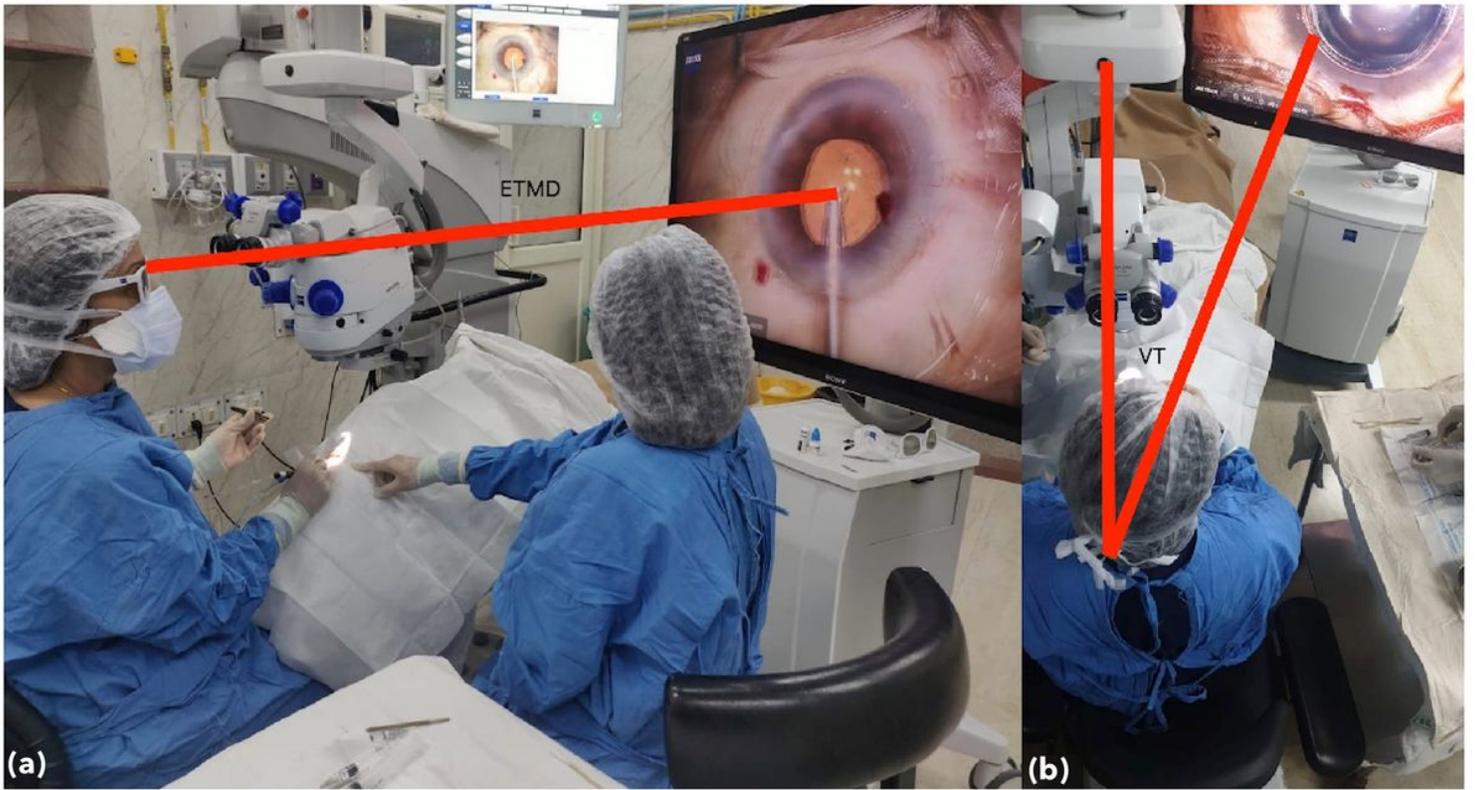
## Table

Table 1.

The various parameters noted during the surgeries performed using ARTVEO 800 3-D HUS system.

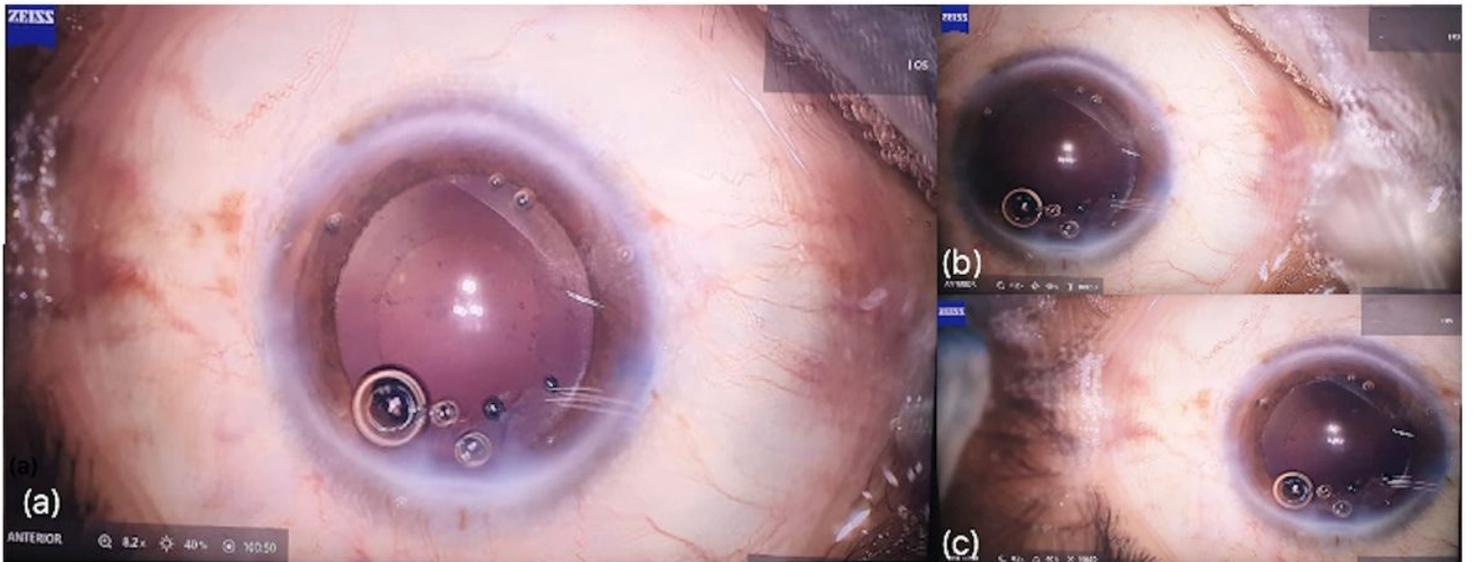
Parameter	Mean ± SD	Range	Right Eye (n = 13)	Left Eye (n = 17)	P val
Eye-to-monitor distance (inches)	67.4 ± 10.21	51–83	66.38 ± 11.94	68.17 ± 8.98	0.6
Eye-to-floor distance (inches)	52 ± 2.04	50–55	53.15 ± 2.15	51.35 ± 1.54	0.01
Viewing tilt (degrees)	29.69 ± 7.06	10–34	29.69 ± 2.56	17.82 ± 4.54	< 0.0001*
Neck strain	1.1 ± 0.92	0–3	1.92 ± 0.64	0.47 ± 0.21	< 0.0001*
Internal eye strain	0.46 ± 0.51	0–1	0.46 ± 0.51	0.47 ± 0.51	0.9
External eye strain	0.23 ± 0.43	0–1	0.38 ± 0.51	0.11 ± 0.33	0.06
*Significant p value if < 0.5; SD = standard deviation					

## Figures



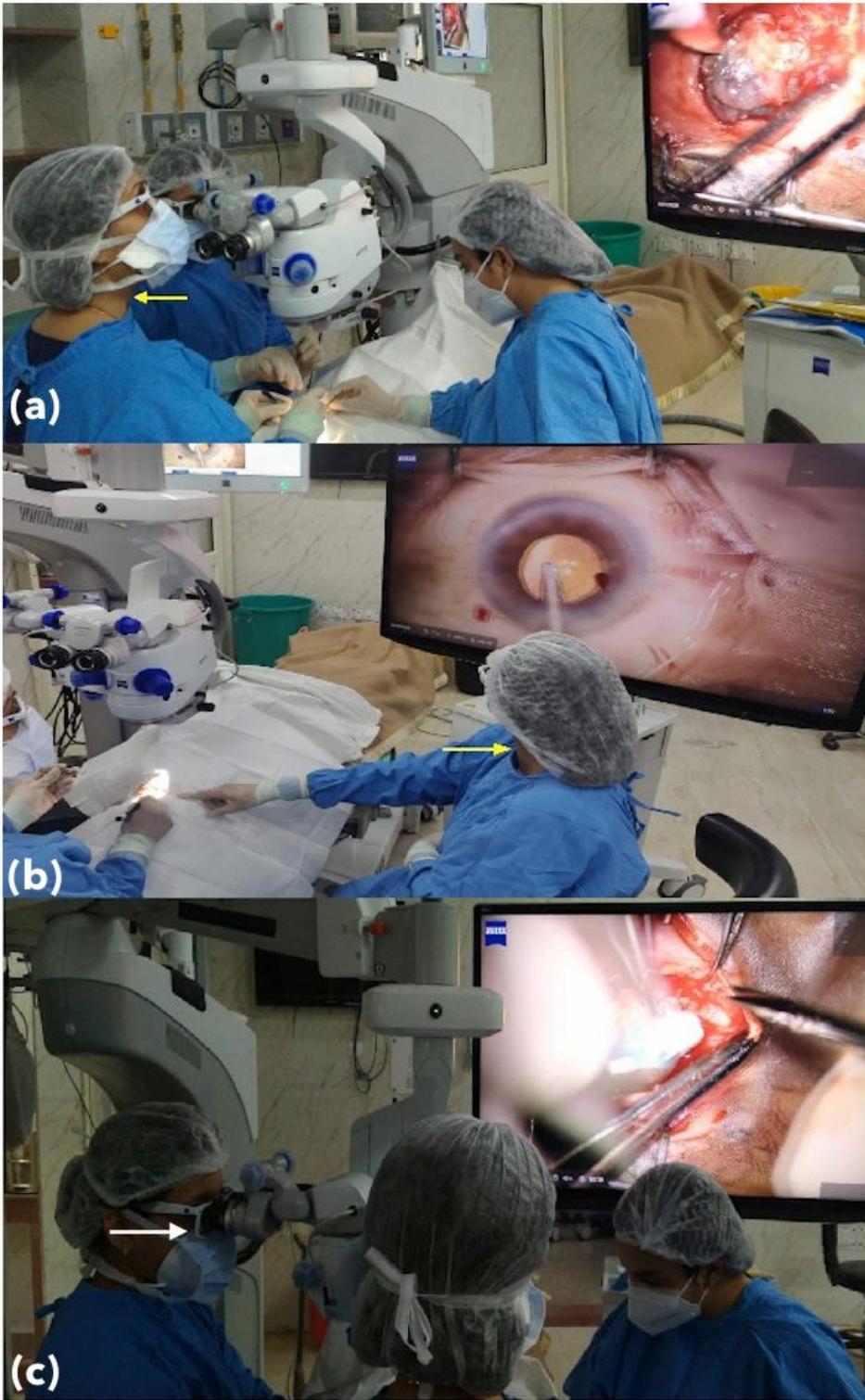
**Figure 1**

Measurement of (a) eye-to-monitor distance (ETMD) (b) viewing tilt (VT) angle measured from picture taken with bird eye view



**Figure 2**

Images showing (a) better 3D visualization when eye was well centred on the 3D monitor display screen and (b) impaired quality when eye was at the corner of the monitor



**Figure 3**

Image showing (a) greater neck strain (yellow arrow) with lower eye to floor height of the surgeon (b) greater neck strain (yellow arrow) for assistant when sitting on the same side as the screen (c) seem less transition (white arrow) for the assistant between the 3D screen and the binoculars of the microscope in the hybrid mode of ARTEVO 800 system. Also note the dim illumination of the operating room for a better 3D image quality