



The Scope Of Three-Dimensional Digital Visualization Systems In Vitreoretinal Surgery

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Introduction: Significant advances in three-dimensional (3D) imaging technology have allowed for the incorporation of 3D digital displays into medical and surgical devices. Despite initial adoption of the NGENUITY[®] 3D Visualization System in vitreoretinal surgery, there are limited publications regarding its use. The generally accepted main benefits include improved ergonomics, enhanced surgical team communication and education, reduced retinal phototoxicity, increased depth of field, and display image manipulation. Despite these potential benefits, many retina specialists have questioned its universal applicability to a wide variety of vitreoretinal surgeries.

Objective: To report on the variety of indications and surgical efficacy of the NGENUITY[®] 3D Visualization System in vitreoretinal surgery via a review of surgical experience at two vitreoretinal practices in both the academic and community settings.

Methods: A retrospective review was conducted of consecutive surgical cases performed on the NGENUITY[®] 3D Visualization System at Massachusetts Eye and Ear Infirmary and Florida Retina Institute from June 1st, 2017 to November 1st, 2018. Age, presenting diagnosis, surgical procedure, and intraoperative details were recorded.

Results: 272 vitreoretinal surgeries on the Alcon NGENUITY[®] 3D Visualization System were identified between June 1st, 2017 and November 1st, 2018 at the participating institutions. A detailed breakdown of the indications for surgery and related procedures is reported. During all 272 cases on the 3D digital system, there were no complications attributed to the visualization system.

Conclusion: This series illustrates the diversity of vitreoretinal surgeries that can be performed on this system without compromising surgical viewing or increasing surgical complications. The Alcon NGENUITY[®] 3D Visualization System possesses favorable ergonomics, illumination levels, depth of field, display filters, and trainee experience.

Keywords: heads-up display, 3-D Visualization, NGENUITY, retina, surgery

Introduction

Intraoperative visualization during vitreoretinal surgery has relied on the optical microscope since the first open sky vitrectomy was performed.¹ While incremental improvements to the optical microscope have successfully been implemented over the past 50 years, such as wide-angle viewing systems, the basic components and operational experience of the surgical microscope remain unchanged.

Modernization of the surgical microscope via digital augmentation has only recently been attempted. The exponential increase in digital video quality parameters such as pixel count, resolution, frame rate, dynamic range, and latency has allowed for surgical display systems to rely on digital video as the primary source of intraoperative visualization. Further, the advent of three-dimensional (3D) surgical display systems

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provides the necessary stereopsis for all vitreoretinal surgeries. The first report of visual performance equivalency for vitreoretinal surgery between the optical microscope and a 3D digital display was presented in 2010.²

The generally accepted main benefits of 3D display systems include improved ergonomics, illumination, enhanced surgical team communication and education, reduced retinal phototoxicity, increased depth of field, and display image manipulation. Despite the initial proof-of-concept and potential benefits, adoption of these systems has been limited and there are few publications regarding the utility of 3D display systems in vitreoretinal surgery. While practical matters such as cost, space constraints, and unfamiliarity are partially responsible for the slow implementation of 3D surgical displays, many retina specialists have questioned if this technology can universally be relied on for a wide variety of vitreoretinal surgeries.

The purpose of the following manuscript is to report on the variety of indications and surgical efficacy of the NGENUITY[®] 3D Visualization System in vitreoretinal surgery. The NGENUITY[®] 3D Visualization System uses a high dynamic range camera attachment to the surgical microscope which transmits overlapping images to a 3D screen. The surgeons wear polarized glasses to provide a stereoscopic view of the monitor. Herein, we review our surgical experiences using the NGENUITY[®] 3D Visualization System at two vitreoretinal practices in both academic and community settings.

Methods

A retrospective review was conducted of consecutive surgical cases performed on the NGENUITY[®] 3D Visualization System by one primary surgeon at Massachusetts Eye and Ear Infirmary and one primary surgeon at Florida Retina Institute from June 1st, 2017 to November 1st, 2018. Age, presenting diagnosis, surgical procedure, and intraoperative details were recorded. This study was approved separately by the Massachusetts Eye and Ear Human Studies Committee and the Advarra Institutional Review Board. Patient consent was waived by both IRBs due to a lack of identifying information inclusion in data collection. We protected patient data confidentiality and conducted the study in compliance with the Declaration of Helsinki.

Results

272 vitreoretinal surgeries on the Alcon NGENUITY[®] 3D Visualization System were identified between June 1st, 2017 and November 1st, 2018 at the participating institutions. The

indications for surgery and related procedures can be found in Table 1 and include macular membrane peels for epiretinal membrane, macular hole and vitreomacular traction (MP), repair of rhegmatogenous retinal detachment, vitrectomy for non-clearing vitreous hemorrhage/proliferative diabetic retinopathy/tractional retinal detachments, intraocular lens procedures, removal of silicone oil, vitrectomy for vitreous floaters, subretinal tissue plasminogen activator injection (TPA) for neovascular age-related macular degeneration-related subretinal hemorrhage, intraocular foreign body removals, retained lens fragments removals, choroidal drainage, scleral buckle removal, endophthalmitis, and acute retinal necrosis (ARN). During all 272 cases on the 3D digital system, there were no complications attributed to the visualization system and there were no cases that needed to be aborted or converted to the optical microscope.

Discussion

The current report is the largest case series using a “heads-up” 3D digital visualization system in vitreoretinal surgery. All 272 cases were completed without complications attributed to the visualization system and no cases were converted to traditional microscope use. Despite a wide array of vitreoretinal surgical cases, we found no limitations in the type of cases that could be completed with the system.

Our experience reported here is similar to previous publications on the efficacy of 3D visualization systems. A study by Kumar et al in 2018 randomized 50 eyes with macular holes to surgery using either a 3D system or optical microscope. They found that visual acuity, surgical time, total ILM peel time, number of flap initiations, and macular hole closure rates were equivalent between the groups and that illumination intensity was significantly lower in the 3D display group.³ Additional studies on 3D digital surgery are more targeted and 3D systems have been reported in individual procedures including implantation of the Argus II Retinal Prosthesis⁴ and IOL extraction, among others.⁵

3D digital visualization systems are not only an equivalent replacement to the optical microscope, but they also have particular benefits. These benefits include improved ergonomics,⁶ lower illumination levels,⁷ improved depth of field,⁸ display filters and digital layout for intraoperative OCT,⁹ and excellent trainee and nursing experience/viewing.¹⁰ Additionally, Adams et al showed that these systems may reduce the risk of retinal phototoxicity during surgery as all surgeons reported comfort operating at an

Table 1 Indications And Total Number Of Surgeries Completed Using Three-Dimensional Visualization Systems

Procedure/Indication For Surgery	Number Of Cases	Percentage Of Total Cases (%)	Complications Related To Visualization
Membrane peel for ERM/MH/VMT	77	28.3	0
RRD repair	71	26.1	0
VH/PDR/TRDs	43	15.8	0
IOL procedures	24	8.8	0
Silicone oil removal	23	8.5	0
Floaterectomy	22	8.1	0
tPA injection for AMD-related subretinal hemorrhage	3	1.1	0
IOFB removal	2	0.7	0
Retained lens fragment	2	0.7	0
Choroidal drainage	2	0.7	0
Scleral buckle removal	1	0.4	0
Endophthalmitis	1	0.4	0
Acute retinal necrosis	1	0.4	0

Abbreviations: ERM, epiretinal membrane, MH, macular hole, VMT, vitreomacular traction, RRD, rhegmatogenous retinal detachments, VH, vitreous hemorrhage, PDR, proliferative diabetic retinopathy, TRD, tractional retinal detachment, IOL, intraocular lens, tPA, tissue plasminogen activator, AMD, age-related macular degeneration, IOFB, intraocular foreign body.

endoillumination level of 3–10% of maximum output,¹¹ a level significantly lower than what most surgeons utilize on a standard operating microscope. Of note, the enhanced depth of field was one aspect of the 3D digital system that stood out to the primary surgeons. With more than a quarter of surgeries in this study being macular cases, the 3D digital system excelled. Macular viewing with the platform was crisp and focused, and the enhanced depth of field remained in focus with less need to adjust fine focus during peeling. The enhanced depth of focus was also routinely utilized in diabetic tractional detachments. With the 3D digital system, fine focus remains despite increasing magnification. As a result, tractional membranes extending past the arcades are easily segmented and delaminated solely with the primary non-contact wide angle lens without the need for a macular contact lens. Finally, the 3D digital system allows for “surgeon’s viewing” to everyone in the room from the surgeon and fellows, to the scrub tech/nurse and anesthesiologist. As a result, the platform should be an integral component in fellow and resident education. Additionally, it allows all the staff to be in sync, so that the scrub tech/nurse and surgeon can anticipate the next steps in a procedure.

Reasonable concerns and drawbacks in using the 3D digital system exist. There have been anecdotes and rumors of substandard peripheral viewing and anterior segment latency with the system. However, we have shown that the 3D digital platform adequately visualizes the retina periphery in cases such as rhegmatogenous retinal detachments. With

the most recent platform, anterior segment latency has been nearly eliminated. The primary surgeons routinely perform anterior segment suturing of sclerotomies, as well as complex scleral sutured IOL cases without difficulty. Additional drawbacks include the high initial cost as currently both the surgical microscope and the 3D technology need to be purchased separately; however, future developments aim to have an integrated, stand alone system. The system does have a larger footprint compared to an operating microscope alone, so there needs to be enough physical space in the operating room for the anesthesiologists and nurses to maneuver around the display monitor. There is also learning curve associated with the transition from the surgical microscope to the 3D digital surgery. However, in our experience and those of others, 5–10 cases are often sufficient to become comfortable with 3D digital surgery. From attendings to fellows, we have not observed increased complications or operating times in novice users of the 3D digital system.

As with any study, there are limitations to this retrospective review. This is consecutive case series of two primary surgeons with extensive experience with the NGENUITY visualization system and therefore the generalizability to other surgeons and other 3D display systems is limited. However, it should be noted that fellows and residents did participate in many of these reported cases. There are other important variables that were not studied in this report including: length of procedure, clinical outcomes, e.g., visual acuity, patient satisfaction, trainee

experience, and intraoperative display and illumination settings. Additional studies are warranted to investigate how these factors may compare to the standard operating microscope as this study does not directly compare heads-up display systems to the traditional optical microscope.

In conclusion, we report the largest consecutive case series using the Alcon NGENUITY digital viewing system in a variety of vitreoretinal cases. This series illustrates the diverse types of vitreoretinal surgeries that can be performed on this system without compromising surgical viewing or increasing complications compared to the standard operating microscope. Moving from analog to digital, the 3D digital surgery platform opens up a plethora of additional opportunities to revolutionize vitreoretinal surgery, including the potential for augmented reality (AR) and artificial intelligence (AI). The current 3D digital surgery platform is safe and can be utilized on the majority of surgical cases encountered by a vitreoretinal surgeon.

Disclosure

John B Miller and Samuel K Houston III report personal fees from Alcon, outside the submitted work. The authors report no other conflicts of interest in this work.

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