

Optical Path Redirection Device for Optical Coherence Tomography Angiography of Recumbent Patients Under General Anesthesia

Lucas A. Iezzi¹ and Lauren A. Dalvin¹

¹ Department of Ophthalmology, Mayo Clinic, Rochester, Minnesota, United States

Correspondence: Lauren A. Dalvin, Department of Ophthalmology, Mayo Clinic, 200 1st St SW, Rochester, MN 55905, USA. e-mail: dalvin.lauren@mayo.edu

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Purpose: Optical coherence tomography angiography is useful for the noninvasive imaging of retinal and choroidal vasculature, but some patients are unable to cooperate for imaging in clinic. We created a device that allows for imaging in the recumbent position under anesthesia.

Methods: A three-dimensional printed prototype was designed to attach to the Optovue AngioVue. Within the device, a right-angled mirror was positioned to redirect the optical path of the optical coherence tomography angiography machine downward into the eye of a recumbent, intubated patient.

Results: Three image sequences were successfully performed using the first test device. The image clarity was adequate, but the field of view was limited, potentially owing to an increased distance between the subject's pupil and the lens of the machine or obstruction of the optical path from the attachment device.

Conclusions: A right-angled mirror system is a viable solution for imaging patients who require sedation to obtain readable images.

Translational Relevance: This system will allow for broader study of optical coherence tomography angiography imaging features, especially in children, by adapting the Optovue AngioVue for use in recumbent patients under anesthesia.

Introduction

Optical coherence tomography angiography (OCTA) has become a powerful tool for the noninvasive imaging of the retinal and choroidal vasculature.¹ However, the focal precision of the machine that allows imaging with a resolution of 5 microns requires patients to remain still for several seconds of exposure time to avoid artifacts or motion blur that obstruct the image.^{2,3} For pediatric patients and those with cognitive impairment, remaining still can be challenging, often necessitating general anesthesia to complete an adequate retinal examination. Multimodal imaging can be performed to aid in diagnosis while the head and eyes are motionless under anesthesia, but there is not currently an OCTA device approved by the US Food and Drug Administration designed for supine imaging in the United States.⁴ Although a sedated patient could

be rolled on their side or propped upright to position their eye in the optical path of the OCTA machine, the recumbent position provides greater stability. Herein, we present a prototype device that uses a right-angled mirror attachment to redirect the image path to the patient's eye in a stable, recumbent position under general anesthesia.

Methods

Our device consists of a three-dimensional printed tube-shaped body that mounts to the lens of the Optovue AngioVue OCTA machine and an angled mirror that directs the optical path downward toward the patient as shown in [Figure 1](#). The Optovue AngioVue OCTA machine uses primarily infrared light, so the mirror used for this system is an infrared

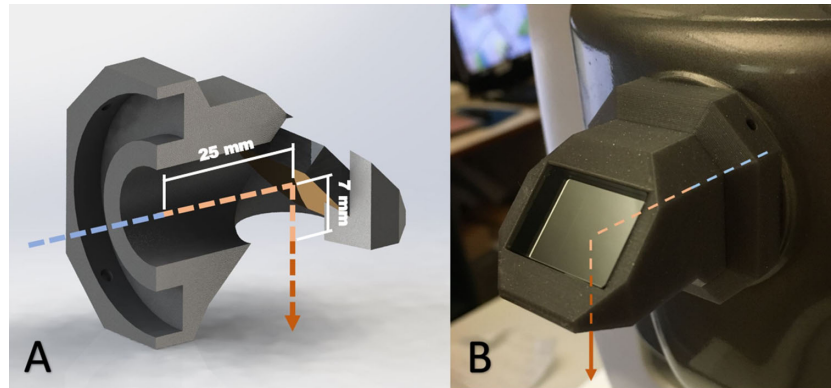


Figure 1. Optical path extension and redirection device for OCTA of recumbent patients under general anesthesia. **(A)** Cross-sectional CAD model of the attachment device with the optical path marked (*dotted line*) and **(B)** image of the device mounted on the Optovue AngioVue OCTA machine with the optical path marked (*dotted line*) from the machine through the mirror and down toward the patient's eye.

optimized gold first surface mirror with greater than 96% reflectance at 840 nanometers with 4 to $6/\lambda$ flatness sold by Edmund Optics. The three-dimensional printer used in the making of this prototype is a Prusa i3 MK3 (Prusa Research, Partyzánská, Praha Czech Republic) and the material used was Fillamentum Extrafill Vertigo Galaxy PLA. The file that was printed for this version of the prototype has been made open source and can be found at <https://grabcad.com/library/octa-optical-path-redirection-attachment-1>. It should be noted that the prototype is designed to fit the aperture of the Optovue AngioVue OCTA machine; however, this dimension could be modified to fit any OCTA machine with a similar circular aperture.

The Optovue AngioVue OCTA machine is advertised to have a 22-mm working distance; however, by adjusting the diopter slider, a maximum working distance of approximately 40 mm was achieved. This focal distance restricts the mirror placement to less than 30 mm extended from the lens to allow for at least 10 mm of clearance between the mirror and the eye. This extension distance must be long enough to span from the temporal fossa to the center of the pupil to properly center the image on the eye. This distance is around 35 mm in adults. The plastic housing in its first test state extends 25 mm between the lens of the machine and the mirror allowing a young child's face to fit below the eyepiece.

Institutional review board approval was obtained from the Mayo Clinic Institutional Review Board for use of the device for research purposes, and informed consent was obtained. This study complied with the Health Insurance Portability and Accountability Act and adhered to the tenets of the Declaration of Helsinki.

Results

Preliminary testing of the right-angled imaging attachment was done in a 3-year-old boy with retinoblastoma seen in [Figure 2](#). Although group E retinoblastoma with media opacity did not permit adequate imaging of the affected eye, images were able to be obtained for the fellow eye. The fellow eye had no identifiable abnormalities, serving as an example of a normal eye for use in evaluating the quality and limitations of the prototype imaging device. Imaging was obtained with a clearance of 12 mm between the cornea and the eyepiece. The images showed vignetting for all scans, indicating that the beam pivot point was misaligned anteriorly to the pupil plane and the edges of the image were blurred or obstructed by the edges of the iris or cornea as shown in [Figure 3](#).⁵ The 12-mm scans produced images that spanned 8 mm on the retina; 9.8-mm scans were limited to 7.5 mm of lateral extent and 8-mm scans were limited to 6.25 mm in diameter. The OCTA showed good flow maps.

Discussion

We developed an attachment device that permits use of the US Food and Drug Administration–approved Optovue AngioVue to obtain OCTA images of recumbent patients under general anesthesia. Although there is currently technology that allows for OCT imaging of recumbent patients under anesthesia, there is no US Food and Drug Administration–approved method of obtaining OCTA images of such patients, which prompted development of our prototype device. In its

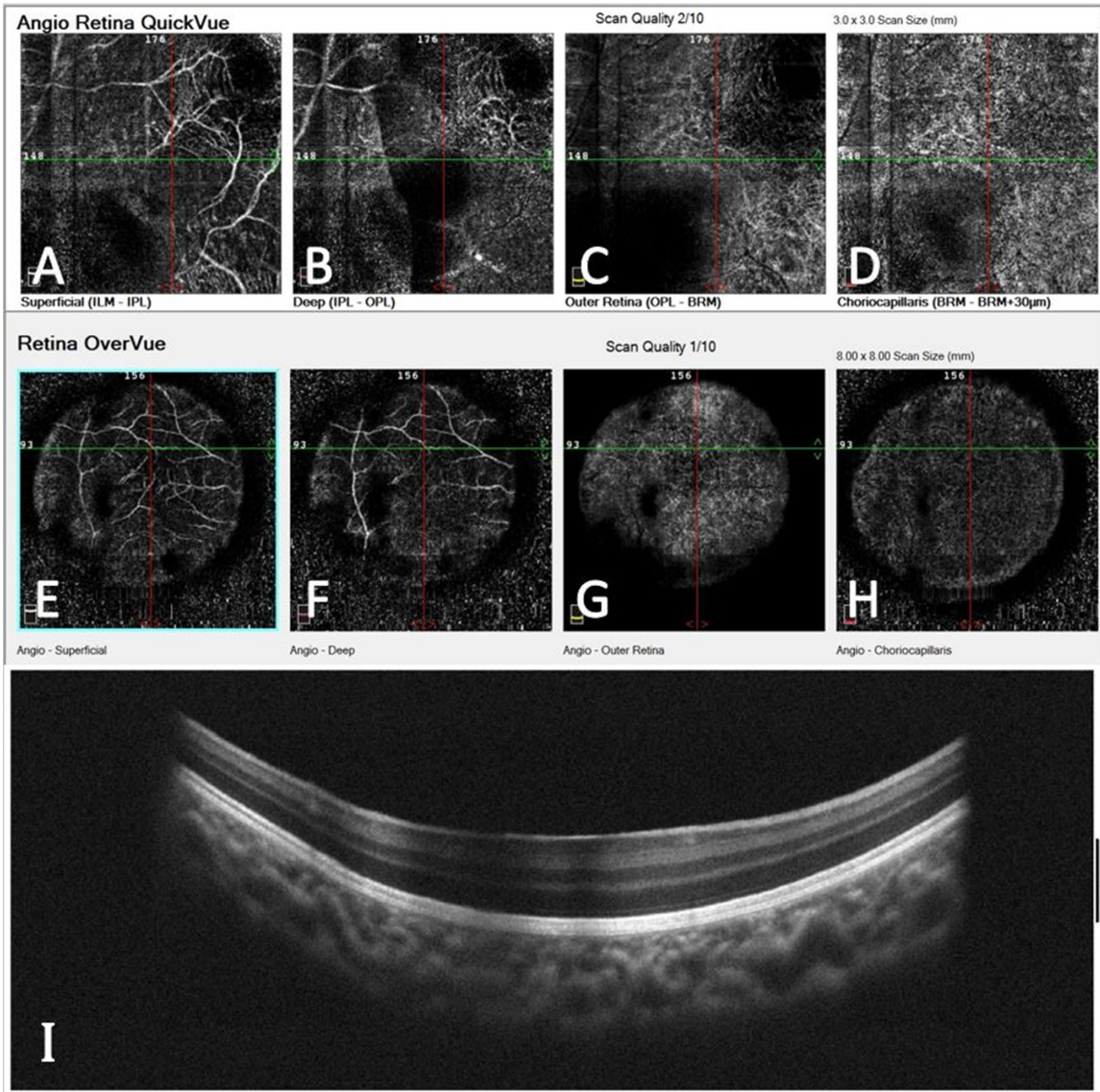


Figure 2. Optical path extension and redirection device for OCTA of recumbent patients under general anesthesia. Preliminary angiography results from a recumbent pediatric patient at the (A) superficial, (B) deep, (C) outer retina, and (D) choriocapillaris layers in 3-mm and corresponding 8-mm (E-H) scan widths demonstrate retention of image quality but limited field of view using the attachment device. (I) OCT could be obtained with good resolution and image clarity.

current state, adult faces will not fit under the eye piece. To fix this, the angle of the mirror should be decreased and the patient's head should be rotated slightly to one side using a neck rest to stabilize the head. To solve the vignetting, the optical path may have to be shortened, which may be possible if the angle of the mirror is decreased. Another solution to extending the working distance of the machine is a relay lens; however, this strategy would add complexity to the design and increase the cost. This relay lens solution should be explored if the simpler solution of changing the angle of the mirror and shorten-

ing the optical path does not solve the vignetting issues and does not accommodate adult heads. Regardless of the imaging limitations, this device could be valuable for the long-term monitoring of patients, because imaging artifacts may remain stable for a given patient, allowing for adequate comparison of images over time.

This device has proven to produce good quality OCTA imaging of patients sedated in a recumbent position. It enables imaging of patients who otherwise would not be able to be imaged and expands OCTA potential in retinal diagnoses.

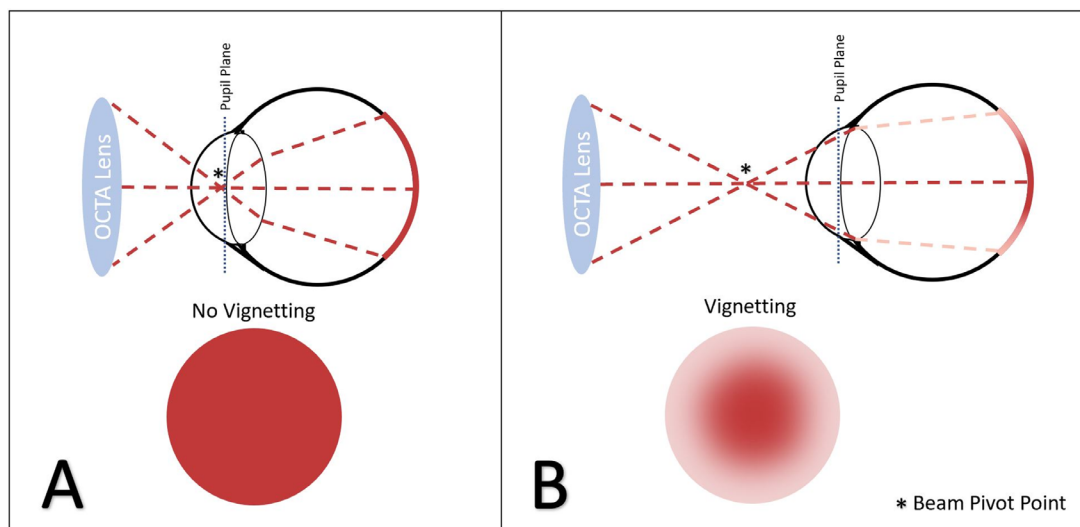


Figure 3. Optical path extension and redirection device for OCTA of recumbent patients under general anesthesia. Visualization of OCTA beams (A) when the scan pivot point is properly aligned with the pupil producing a clear image and (B) when the pivot point is too far forward showing vignetting around the edges of the image.

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Lauren A. Dalvin, MD, has had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Disclosure: **L.A. Iezzi**, None; **L.A. Dalvin**, None

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