Optical Coherence Tomography of the Anterior Eye Segment

Description

Optical coherence tomography (OCT) is a high resolution method of imaging the ocular structures. OCT for the anterior eye segment is being evaluated as a rapid and non-invasive diagnostic and screening tool for the detection of angle closure glaucoma, to assess corneal thickness and opacity, evaluate pre-surgical and postsurgical anterior chamber anatomy, calculate intraocular lens power, guide laser-assisted cataract surgery, assess complications following surgical procedures, and to image intracorneal ring segments. It is also being studied in relation to pathologic processes such as dry eye syndrome, tumors, uveitis and infections.

Background

OCT is a noninvasive method that creates an image of light reflected from the ocular structures. In this technique, a reflected light beam interacts with a reference light beam. The coherent (positive) interference between the 2 beams (reflected and reference) is measured by an interferometer, allowing construction of an image of the ocular structures. This method allows cross-sectional imaging at a resolution of 6 to 25 μm. The Stratus OCT™ (Carl Zeiss Meditec), which uses a 0.8-μm wavelength light source, was designed for evaluating the optic nerve head, retinal nerve fiber layer, and retinal thickness (see Policy No. 9.03.06). The Zeiss Visante OCT™ and AC Cornea OCT (Ophthalmic Technologies) use a 1.3-μm wavelength light source designed specifically for imaging the anterior eye segment. Light of this wavelength penetrates the sclera, allowing high-resolution cross-sectional imaging of the AC angle and ciliary body. The light is, however, typically blocked by pigment, preventing exploration behind the iris. Ultrahigh resolution OCT can achieve a spatial resolution of 1.3 μm, allowing imaging and measurement of corneal layers.

An early application of OCT technology was the evaluation of the cornea before and after refractive surgery. Because this is a noninvasive procedure that can be conducted by a technician, it has been proposed that this device may provide a rapid diagnostic and screening tool for the detection of angle closure glaucoma. The classification of glaucoma (primary open angle or angle closure) relies heavily on knowledge of the anterior segment (AS) anatomy, particularly that of the AC angle. Angle closure glaucoma is characterized by obstruction of aqueous fluid drainage through the trabecular meshwork (the primary fluid egress site) from the eye’s AC. The width of the angle is one factor affecting the drainage of aqueous humor. A wide unobstructed iridocorneal angle allows sufficient drainage of
aqueous humor, whereas a narrow angle may impede the drainage system and leave the patient susceptible to angle closure glaucoma. The treatment for this condition is a peripheral iridotomy (laser) or peripheral iridectomy (surgery).

Slit lamp biomicroscopy is typically used to evaluate the AC; however, the chamber angle can only be examined with specialized lenses, the most common of these being the gonioscopic mirror. In this procedure, a gono lens is applied to the surface of the cornea, which may result in distortion of the globe. Ultrasonography may also be used for imaging the anterior eye segment. (1) Ultrasonography uses high frequency mechanical pulses (10-20 MHz) to build up a picture of the front of the eye. An ultrasound (US) scan along the optical axis assesses corneal thickness, AC depth, lens thickness, and axial length. US scanning across the eye creates a 2-dimensional image of the ocular structures. It has a resolution of 100 μm but only moderately high intra-observer and low inter-observer reproducibility. US biomicroscopy (~50 MHz) has a resolution of 30 to 50 μm. As with gonioscopy, this technique requires placement of a probe under topical anesthesia.

Regulatory Status

A number of OCT systems have been cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k) process. These include the following:

- The Visante™ OCT is indicated as “a noncontact, high resolution tomographic and biomicroscopic device indicated for the in vivo imaging and measurement of ocular structures in the AS, such as corneal and LASIK flap thickness.”

- The RTVue® (Optovue), is a commercially available Fourier-domain optical coherence tomography (OCT) system with a resolution of 5 μm. Although indicated for posterior segment imaging, a lens is available to allow imaging of the AS. FDA product code: HLI.

- The Slit-Lamp OCT (SL-OCT, Heidelberg Engineering) is intended as an aid for the quantitative analysis of structures and the diagnosis and assessment of structural changes in the AS of the eye. “The SL-OCT examination system is not intended for the analysis of the cross-sectional images to obtain quantitative measured values. Neither the obtained measured values nor the qualitative evaluation of the images should be used as the sole basis for therapy-related decisions.” FDA product code: MXK.

- Microscope-integrated OCT devices for intra-operative use include the ReScan 700 (Zeiss) and the Haag-Streit iOCT® system (Haag-Streit).

- Portable devices for intra-operative use include the Bioptigen Envisu™ (Bioptigen) and the Optovue iVue® (Optovue).

- Ultrahigh resolution OCT devices include the SOCT Copernicus HR (Optopol Technologies).

Commercially available laser systems such as the LenSx® (Alcon), Catalys® (OptiMedica), and VICTUS® (Technolas Perfect Vision) include OCT to provide image guidance for laser cataract surgery. FDA product code: OOE.

Custom-built devices, which do not require FDA approval, are also used. The AC Cornea OCT from Canada is not cleared for marketing in the United States.
Related Policies

9.03.05 Corneal Topography/Computer-Assisted Corneal Topography/Photokeratoscopy
9.03.06 Ophthalmologic Techniques of Evaluating Glaucoma
9.03.21 Aqueous Shunts and Stents for Glaucoma
9.03.22 Endothelial Keratoplasty

**Policy**

This policy statement applies to clinical review performed for pre-service (Prior Approval, Precertification, Advanced Benefit Determination, etc.) and/or post-service claims.

Scanning computerized ophthalmic (e.g., OCT) imaging of the anterior eye segment is considered **not medically necessary**.

**Benefit Application**

The BCBS FEP contract stipulates that FDA-approved biologics, drugs and certain devices may not be considered investigational when used for their intended purpose and thus these products may only be assessed based on medical necessity.

**Rationale**

Recent literature searches have found numerous studies that use optical coherence tomography (OCT) to evaluate the anatomy of the anterior segment (AS) and report qualitative and quantitative imaging and detection capabilities. Although these studies provide evidence for the technical performance of OCT, assessment of a diagnostic technology typically focuses on 3 categories of evidence:

Technical performance. Technical performance refers to how well the technology measures and records the parameter(s) that it is purported to evaluate. Evaluation of technical performance may include various measures of validity (e.g., criterion validity, construct validity, etc) and reliability (eg, test-retest reliability, agreement among multiple reviewers, etc).

Diagnostic accuracy. Diagnostic accuracy is the ability of a test to accurately diagnose a clinical condition in relevant populations of patients, in comparison with a reference standard. Measures of diagnostic accuracy include sensitivity, specificity, predictive values, likelihood ratios, and area under the curve analysis.

Demonstration that the diagnostic information can be used to improve patient outcomes is essential to determining the utility of a diagnostic technology. Direct evidence on the impact of the diagnostic technology on health outcomes may be available if controlled trials have been performed. In most
cases, an indirect chain of evidence needs to be constructed to determine whether there is a tight linkage between the diagnostic technology and improvement in health outcomes.

Technical Performance

Reproducibility of Measurements

Maram et al (2014) assessed the reproducibility of angle metrics using the Visante OCT. (2) The anterior chamber angle from 20 eyes of 20 healthy subjects (open angle) were measured 1) by masked expert graders on 2 occasions, 1 week apart, to assess intra-observer reliability, and 2) by 2 independent reviewers to assess inter-observer reliability. Intra-observer reproducibility was high (intraclass correlation coefficients [ICC], ≥0.93), although the inter-observer reproducibility was modest (ICC, 0.49-0.82) for measurements of the angle-opening distance, trabecular iris space area, and scleral spur angle. The percentage error ranged from 9.29% for the scleral spur angle to 21.18% for the trabecular iris space area.

Diagnostic Performance

Optical Coherence Tomography versus Gonioscopy

Several studies have compared optical coherence tomography (OCT) with gonioscopy for the detection of primary angle closure. For example, Nolan and colleagues assessed the ability of a prototype of the Visante OCT to detect primary angle closure in 203 Asian patients. (3) The patients, recruited from glaucoma clinics, had been diagnosed with primary angle closure, primary open-angle glaucoma, ocular hypertension, and cataracts; some had previously been treated with iridotomy. Images were assessed by 2 glaucoma experts, and the results compared to an independently obtained reference standard (gonioscopy). Data were reported from 342 eyes of 200 individuals. A closed angle was identified in 152 eyes with gonioscopy and 228 eyes with OCT; agreement was obtained between the two methods in 143 eyes. Although these results suggest low specificity for OCT, it is noted that gonioscopy is not considered to be a gold standard. The authors suggest three possible reasons for the increase in identification of closed angles with OCT: lighting is known to affect angle closure, and the lighting conditions were different for the two methods (gonioscopy requires some light); placement of the gonioscopy lens on the globe may have caused distortion of the anterior segment; and landmarks are not the same with the two methods. The authors noted that longitudinal studies will be required to determine whether eyes classified as closed by OCT but not by gonioscopy are at risk of developing primary angle closure glaucoma.

Narayanaswamy et al. conducted a community-based cross-sectional study of glaucoma screening. (4) The study population consisted of individuals 50 years or older who underwent anterior segment OCT by a single ophthalmologist and gonioscopy by an ophthalmologist who was masked to the OCT findings. Individuals were excluded if they had a history of intraocular surgery, any evidence of aphakia/pseudophakia, or penetrating trauma in the eye; previous anterior segment laser treatment; a history of glaucoma; or corneal disorders such as corneal endothelial dystrophy, corneal opacity, or pterygium, all of which could influence the quality of angle imaging by OCT. The angle opening
distance (AOD) was calculated at 250, 500, and 750 microns from the scleral spur. Of 2,047 individuals examined, 28% were excluded due to inability to locate the scleral spur (n=515), poor image quality (n=28), or software delineation errors (n=39). Of the remaining 1,465 participants, 315 (21.5%) had narrow angles on gonioscopy, defined as having a narrow angle if the posterior pigmented trabecular meshwork was not visible for at least 180 degrees on nonindentation gonioscopy with the eye in the primary position. Out of those who had an acceptable image, the area under the receiver operating characteristic curve was highest at 750 microns from the scleral spur in the nasal (0.90) and temporal (0.91) quadrants. A noted limitation of this quantitative technique for screening of angle closure glaucoma was the inability to define the scleral spur in 25% of the study population.

A 2009 publication examined the sensitivity and specificity of the Visante OCT when using different cut-off values for the angle-opening distances (AOD) measured at 250, 500, and 750 microns from the scleral spur. (5) OCT and gonioscopy records were available for 303 eyes of 155 patients seen at a glaucoma clinic. The patients were asked to look at prepositioned targets to prevent image distortion with low- and high-resolution OCT. The parameters analyzed could not be measured by commercially available software at the time of the study, so the images were converted to a format that could be analyzed by ultrasound biomicroscopy software. Blinded analysis showed sensitivity and specificity between 70% and 80% (in comparison with gonioscopy), depending on the AOD and the cut-off value. Correlation coefficients between the qualitative gonioscopy grade and quantitative OCT measurement ranged from 0.75 (AOD 250) to 0.88 (AOD 750). As noted by these investigators, “a truer measure of occludable angles is whether an eye develops angle-closure glaucoma in the future.” Long-term follow-up of patients examined with these two methods would be informative.

OCT versus Ultrasound Biomicroscopy

Garcia and Rosen evaluated the clinical utility of AC Cornea OCT (Ophthalmic Technologies Inc., Toronto, Ontario, Canada) by comparing image results with ultrasound biomicroscopy (UBM) in patients with conditions of the anterior segment. (6) The patients were recruited from various specialty clinics, and imaging with OCT and ultrasound was performed sequentially after obtaining informed consent. Eighty eyes with pathologic conditions involving the anterior ocular segment were included in the study; 6 cases were reported in detail to demonstrate the imaging capabilities of OCT and UBM. Comparison of OCT and UBM images shows that while the AC Cornea OCT has high resolution for the cornea, conjunctiva, iris, and anterior angle, ultrasound biomicroscopic images are also clear for these areas. In addition, ultrasound biomicroscopy was found to be superior at detecting cataracts, anterior tumors, ciliary bodies, haptics, and posterior chamber intraocular lenses. OCT was found to be superior at detecting a glaucoma tube and a metallic foreign body in the cornea when imaging was performed in the coronal plane.

Mansouri and colleagues published a study that compared the accuracy in measurement of the anterior chamber (AC) angle by anterior segment optical coherence tomography (AS-OCT) and UBM in European patients with suspected primary angle closure (PACS), primary angle closure (PAC), or primary angle-closure glaucoma (PACG). (7) In this study, 55 eyes of 33 consecutive patients presenting with PACS, PAC, or PACG were examined with AS-OCT, followed by UBM. The
trabecular-iris angle (TIA) was measured in all four quadrants. The angle-opening distance (AOD) was measured at 500 microns from the scleral spur. In this comparative study, the authors concluded that OCT measurements were significantly correlated with UBM measurements but showed poor agreement with each other. The authors do not believe that AS-OCT can replace UBM for the quantitative assessment of the anterior chamber angle.

Several retrospective studies have compared OCT with UBM for AS tumors. Bianciotto et al. reported a retrospective analysis of 200 consecutive patients who underwent both anterior segment OCT and UBM for anterior segment tumors. (8) When comparing the image resolution for the 2 techniques, UBM was found to have better overall tumor visualization.

Optical Coherence Tomography versus Slitlamp Biomicroscopy

Jiang et al. reported a cross-sectional, observational study of the visualization of aqueous tube shunts by high resolution OCT, slitlamp biomicroscopy, and gonioscopy in 18 consecutive patients (23 eyes). (9) High resolution OCT demonstrated the shunt position and patency in all 23 eyes. Compared to slitlamp, 4 eyes had new findings identified by OCT. For all 16 eyes in which the tube entrance could be clearly visualized by OCT, growth of fibrous scar tissue could be seen between the tube and the corneal endothelium. This was not identified in the patient records (retrospectively analyzed) of the slitlamp examination.

Effect on Health Outcomes

The literature indicates that OCT is being evaluated to assess AC angle, measure corneal thickness and opacity, evaluate presurgical and postsurgical anterior chamber anatomy, calculate intraocular lens power, guide surgery, assess complications following surgical procedures (e.g., blockage of glaucoma tubes, detachment of Descemet membrane, disrupted keratoprosthesis-cornea interface), image intracorneal ring segments, and evaluate pathologic processes such as dry eye syndrome, tumors, uveitis, and infections. Evidence for the effect of AS-OCT on health outcomes follows.

Cauduro et al. provided a retrospective review of 26 eyes of 19 pediatric patients (range, 2 months to 12 years) who presented with a variety of anterior segment pathologies. (10) OCT was used to clarify the clinical diagnosis. No sedation was needed for this non-contact procedure, and only 1 eye of a 2-month old patient required topical anesthesia. The impact of the procedure on patient care was not reported.

Angle-closure Glaucoma

The clinical utility of OCT for diagnosing glaucoma is closely related to its ability to accurately diagnose glaucoma, because treatment is generally initiated on confirmation of the diagnosis. Therefore, if OCT is more accurate in diagnosing glaucoma than alternatives, it can be considered to have clinical utility above that of the alternative tests.
A key question is whether the increase in cases of angle closure identified by AS OCT compared to the current standard of gonioscopy represents true cases of the disease. In 2015, Baskaran et al reported a comparative cohort study of the ability of OCT to predict incident gonioscopic angle closure. (11) A total of 2052 mostly Chinese participants attending a community health center underwent gonioscopy and AS OCT by examiners who were masked to the other test. Of these, 591 participants had angle closure on AS OCT. Of the 342 participants who were qualified for and consented for follow-up, 65 had open angles on both tests at baseline (control group) and 277 had open angles on gonioscopy but closed angles determined by OCT at baseline (experimental group). At 4-year follow-up, 17.3% of the experimental group had gonioscopic angle closure compared to none of the control group. These results indicate that OCT detects more cases of mild angle closure than gonioscopy. However, it is not known whether clinical outcomes are improved with early monitoring based on AS OCT compared to clinical evaluation.

**Cataract Surgery**

As of 2013, studies that compare the risk-benefit of OCT-laser assisted cataract surgery vs. traditional phacoemulsification are ongoing. (12) Anterior segment OCT is also being reported for preoperative evaluation of intraocular lens power and postoperative assessment of intraocular stability of phakic lens and optic changes related to intraocular lens or ocular media opacities. (14)

**Endothelial Keratoplasty**

Use of OCT is being reported for intraoperative and postoperative evaluation of graft apposition and detachment in endothelial keratoplasty procedures. In 2011, Moutsouris et al. reported a prospective comparison of anterior segment OCT, Scheimpflug imaging, and slit-lamp biomicroscopy in 120 eyes of 110 patients after Descemet membrane endothelial keratoplasty (DMEK). (13) All slit-lamp biomicroscopy and OCT examinations were performed by the same experienced technician and all images were evaluated by 2 masked ophthalmologists. From a total of 120 DMEK eyes, 78 showed a normal corneal clearance by all of the imaging techniques. The remaining 42 eyes showed persistent stromal edema within the first month, suggesting (partial) graft detachment. Biomicroscopy was able to determine the presence or absence of a graft detachment in 35 eyes. Scheimpflug imaging did not give additional information over biomicroscopy. In 15 eyes, only OCT was able to discriminate between a “flat” graft detachment and delayed corneal clearance. Thus, out of the 42 eyes, OCT had an added diagnostic value in 36% of cases. This led to further treatment in some of the additional cases. Specifically, a secondary DSAEK was performed for total graft detachment, while partial graft detachments were rebubbled or observed for corneal clearing. There were no false negatives (graft detachment unrecognized) or false positives (an attached graft recognized as a graft detachment).

**Neoplastic Disease**

The criterion standard for the diagnosis of ocular surface tumors such as squamous neoplasia (OSSN) is histologic examination of tissue specimens from excisional biopsy. (14) In a 2014 review, Thomas et al noted that non-invasive methods of diagnosing OSSN will be increasingly important as treatment
moves toward medical therapy, although future studies will be needed to evaluate technical performance and diagnostic accuracy for this indication. (15)

**Uveitis of the Anterior Segment**

In a study from India, Agarwal et al. evaluated the AC inflammatory reaction by anterior segment high-speed optical coherence tomography (OCT). (16) This was a prospective, nonrandomized, observational case series of 62 eyes of 45 patients. Hyper-reflective spots suggesting the presence of cells in the AC from the OCT images were counted manually and by a custom-made automated software package and correlated with clinical grading using Standardization of Uveitis Nomenclature criteria. Of 62 eyes, grade 4 aqueous flare was detected by OCT imaging in 7 eyes and clinically in 5 eyes. The authors concluded that AS-OCT can be used as an imaging modality in detecting inflammatory reaction in uveitis and also in eyes with decreased corneal clarity. Additional studies are needed to further evaluate these results and to demonstrate the clinical utility of using OCT in this situation.

**Ongoing and Unpublished Clinical Trials**

Some currently unpublished trials that might influence this review are listed in Table 1.

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<th>NCT No.</th>
<th>Trial Name</th>
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<td>NCT01746537</td>
<td>A prospective, observational, case series investigating the feasibility of utilizing OCT scans of the anterior chamber of eyes with uveitis.</td>
<td>1500</td>
<td>Jun 2018</td>
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NCT: national clinical trial

**Practice Guidelines and Position Statements**

In 2015, the American Academy of Ophthalmology (AAO) published preferred practice patterns (PPP) on primary angle closure.17 AAO states that gonioscopy of both eyes should be performed on all patients in whom angle closure is suspected and that AS imaging should be considered when angle anatomy is difficult to assess on gonioscopy. AS imaging methods discussed were ultrasound biomicroscopy, Scheimpflug imaging and AS OCT, although it was noted that AS OCT is limited to evaluating the iridocorneal angle.

**U.S. Preventive Services Task Force Recommendation**

Not applicable.
Medicare National Coverage
There is no national coverage determination (NCD). In the absence of an NCD, coverage decisions are left to the discretion of local Medicare carriers.

Summary of Evidence

The evidence for OCT in individuals who have anterior segment disease includes case series and cohort studies. Relevant outcomes include test accuracy, other test performance measures, symptoms, change in disease status, and morbid events. Ideally, a diagnostic test would be evaluated based on its technical performance, diagnostic accuracy (sensitivity, specificity, predictive value), and effect on health outcomes. Current literature consists primarily of assessments of qualitative and quantitative imaging and detection capabilities. Technically, anterior segment (AS) OCT has the ability to create high-resolution images of the AS. In addition, studies indicate that AS OCT detects more eyes with narrow or closed angles than gonioscopy, suggesting that the sensitivity of OCT is higher than that of gonioscopy. However, because of the lack of a true criterion standard, it is not clear to what degree these additional cases are true positives versus false positives, and therefore the specificity and predictive values cannot be determined. Evaluation of the diagnostic performance depends, therefore, on evidence that the additional eyes identified with narrow angle by OCT are more likely to progress to primary angle closure glaucoma. OCT imaging may be less sensitive in comparison with ultrasound biomicroscopy for other pathologic conditions of the AS, such as cataracts, anterior tumors, iris, ciliary bodies, haptics, and posterior chamber intraocular lenses. Evaluation of the clinical utility of AS OCT depends on demonstration of an improvement in clinical outcomes. For example, outcomes will be improved if OCT detects additional cases of primary angle closure glaucoma, which represent true cases of glaucoma and not false positives, and if these cases are successfully treated for glaucoma. It is not currently possible to determine the frequency of false-positive results with OCT, therefore, it cannot be determined whether health outcomes are improved. For other potential indications (eg, to aid in diagnosis of AS pathology or guide surgical procedures), evidence is currently limited. The evidence is insufficient to determine the effects of the technology on health outcomes.

References


7. Mansouri K, Sommerhalder J, Shaarawy T. Prospective comparison of ultrasound biomicroscopy and anterior segment optical coherence tomography for evaluation of anterior chamber dimensions in European eyes with primary angle closure. *Eye (Lond).* Feb 2010;24(2):233-239. PMID 19444291


**Policy History**

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<tr>
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<td>New policy</td>
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<td>June 2013</td>
<td>Update Policy</td>
<td>Policy updated with literature search, Policy title changed to Optical Coherence Tomography (OCT) of the Anterior Eye Segment; references added and reordered, policy statement unchanged</td>
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<td>September 2016</td>
<td>Update Policy</td>
<td>Policy updated with literature review through July 12, 2016; references 11 and 17 added. Policy statement unchanged.</td>
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**Keywords**

- AC Cornea OCT
- Anterior Segment Optical Imaging
- Closed Angle Glaucoma
- Optical Coherence Tomography
- Visante OCT
- Stratus OCT

**This policy was approved by the FEP® Pharmacy and Medical Policy Committee on September 16, 2016 and is effective October 15, 2016.**

**Signature on File**

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