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Retinal and Choroidal Imaging Update

Artifacts in optical coherence tomography

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Abstract

Optical coherence tomography (OCT) is now an integral part of management for numerous retinal diseases for diagnosis, treatment planning and follow up. OCT interpretation must involve the understanding of the associated artifacts. These artifacts can mislead physicians to wrong diagnosis or inappropriate management. This review article discusses the various types of artifacts in OCT scans obtained from various devices in various retinal diseases. This article would help to improve the understanding about the various artifacts and their clinical importance.

Keywords: Optical coherence tomography, Time domain optical coherence tomography, Spectral domain optical coherence tomography, Cirrus, TOPCON, Spectralis, Artifacts

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Introduction

Optical coherence tomography (OCT) is a non-invasive imaging modality useful for identification of lesions in the macula, optic disk and the anterior segment.[1] It provides a high resolution, in vivo optical biopsy of the tissue being scanned, using the principle of optical interferometry.[2,3] OCT can be in the form of Time Domain OCT (TD OCT) or Fourier domain OCT. In TD OCT a mechanically moving scanning reference arm sequentially measures the echo time delay.[1] Fourier domain OCT has a stationary reference arm which obtains an interference spectrum which then undergoes Fourier transformation allowing simultaneous measurements of all echo time delays thereby reducing the image acquisition time. Fourier domain OCT is again subdivided into Spectral Domain OCT (SD OCT) which uses a spectrometer and a line scan camera for image acquisition as opposed to a swept source OCT which has a rapidly tunable laser source for the same purpose.[4]

Information gathered from OCT can be qualitative or quantitative in nature. Qualitative data can be in the form of identification of retinal pathologies like vitreo macular traction, macular holes, cystoid macular edema and choroidal neovascular membrane.[1] Quantitative data such as foveal thickness are used to make treatment decisions like in conditions such as age related macular degeneration, diabetic macular edema and retinal vein occlusions.[5–8] Likewise retreatment decisions are also based to some extent on the foveal thicknesses obtained by an OCT scan.

Interpretation of these data and their implications in clinical situations must be tempered by the fact that images thus obtained are subject to artifacts.[3] These artifacts can mislead physicians to wrong diagnosis or inappropriate management. The first step for an examiner to address the issue of artifacts is to be aware of the presence of artifacts.[9] Knowledge about the possible artifacts in an OCT image will aid in better interpretation of the disease condition. Here we describe various types of artifacts and their clinical significance.

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Ray et al. were the first group to report and classify artifacts in TD OCT.[3] They had identified six types of OCT artifacts namely[1]: misidentification of the inner retinal layer,[2] misidentification of the outer retinal layer,[3] out of register artifact,[4] degraded image scan,[5] cut edge artifact and[6] off center artifact. These artifacts while originally reported in TD OCT can also be noted in SD OCT. There are certain other artifacts like mirror artifacts, which are noted exclusively in SD OCT on account of the technique involved in acquiring the image.[4] The artifacts can be a result of software errors (misidentification of retinal layers, mirror artifact, cut edge artifact), operator related error (degraded image scan, out of register artifact, off center artifact) or patient related factors (motion artifact, off center artifact, degraded image scan, mirror artifact) (Fig. 1). It is apparent from the above classification that the causes of some artifacts are not mutually exclusive.

Misidentification of inner retinal layer

All devices used the internal limiting membrane for the placement of the inner retinal layer. Misidentification of internal limiting membrane occurs due to software breakdown, mostly in eyes with epiretinal membrane (ERM), vitreomacular traction (VMT) or macular hole. Ray et al. found that on univariate analysis, inner layer misidentification was more common in eyes with neovascular age related macular degeneration (AMD), macular holes and eyes which have undergone photodynamic therapy (PDT).[3] However, on multivariate analysis, they found that the neovascular AMD was the only condition associated with inner layer misidentification. The authors also found inner layer misidentification in eyes with vitreo-retinal traction but the number was too small to analyze statistically.

Comparison over different OCT machines (STRATUS (Carl Zeiss Meditec, Dublin, CA), CIRRUS (Carl Zeiss Meditec, Dublin, CA), RTVue (Optovue, Inc., Fremont, CA), TOPCON (Topcon Medical Systems, Paramus, NJ)) showed that inner layer misidentification was a common feature with all machines showing artifact in more than 50% of cases.[1] Inner layer misidentification was most commonly noted in eyes with epiretinal membrane (ERM) followed by diabetic macular edema (DME) and macular hole in STRATUS OCT (Carl Zeiss Meditec, Dublin, CA). Vitreomacular traction (VMT) followed by ERM and cystoid macular edema (CME) were the most common conditions with CIRRUS machine (Carl Zeiss Meditec, Dublin, CA). VMT, ERM and macular hole were the most common conditions associated with inner layer misidentification with TOPCON (Topcon Medical Systems, Paramus, NJ) and RTVue (Optovue, Inc., Fremont, CA) SD OCT machines.[1] Inner layer misidentification involving the central 1 mm sub field was noted in 6.7% of CIRRUS (Carl Zeiss Meditec, Dublin, CA) SD OCT machine line scans and 1.3% of SPECTRALIS SD OCT machine (Heidelberg Engineering, Vista, CA).[10] AMD and uveitis were the two conditions where the central sub field inner layer misidentification was more common with the CIRRUS SD OCT machine (Carl Zeiss Meditec, Dublin, CA).

In a study comparing the various OCT machines (STRATUS (Carl Zeiss Meditec, Dublin, CA), CIRRUS (Carl Zeiss Meditec, Dublin, CA), TOPCON (Topcon Medical Systems, Paramus, NJ), RTVue (Optovue, Inc., Fremont, CA), SPECTRALIS (Heidelberg Engineering, Vista, CA) and COPERNICUS (Optopol Tech. SA, Zawiercie, Poland)), the maximum number of errors in the inner layer misidentification was noted in the COPERNICUS (Optopol Tech. SA, Zawiercie, Poland) SD OCT machine suggesting that an error in software may have a greater contribution in the artifact rather than the nature of the machine i.e. TD OCT or SD OCT.[11]

Misidentification of outer retinal layers

Different instruments use different reference points for outer retinal layers. The STRATUS uses the inner segment–outer segment junction (IS–OS junction) while the CIRRUS (Carl Zeiss Meditec, Dublin, CA) and RTVue (Optovue, Inc.,

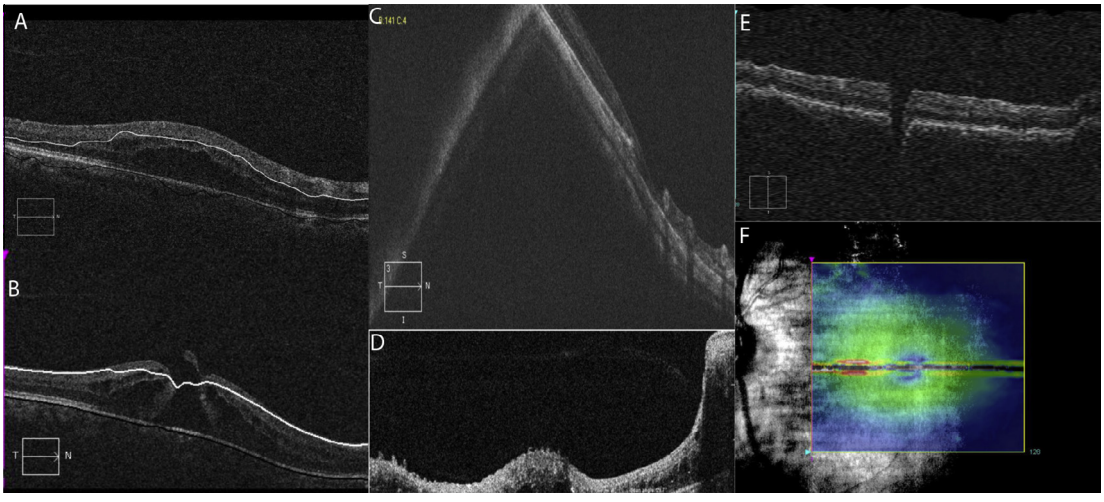

Figure 1. Common artifacts on Spectral Domain Optical Coherence Tomography. (A) Misidentification of inner and outer retinal layers: Image shows the incorrect automated segmentation; outer and inner boundaries are misidentified leading to an artifact. (B) Misidentification of inner layer: image shows the incorrect automated segmentation for inner boundary; outer boundary is correctly identified along the retinal pigment epithelium. (C) Mirror artifact: Image appears to be folded onto itself in a high myopic eye; called as mirror artifact. (D) Out of register artifact: Information from the outer retinal layers is not available from the OCT scan as it is shifted inferiorly; called as out of register artifact. (E) Blink artifact: OCT B scan appears discontinued with loss of retinal data in between due to blink during scan acquisition, which appears as dark line on rendered en-face image (F).