Review Article

Segmentation Error Correction of the Optical Coherence Tomography Angiography Images in Peer-Reviewed Studies

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Abstract

Purpose: To assess the percentage of published articles reporting optical coherence tomography angiography (OCTA) metrics regarding the report of segmentation error correction.

Methods: A comprehensive search was conducted using the PubMed database for articles on OCTA imaging published between January 1, 2015, and January 1, 2021. All original articles reporting at least one of the OCTA metrics were extracted. The article text was reviewed for the segmentation correction strategy. In addition, the number of articles that mentioned the lack of segmentation error correction as a limitation of the study was recorded.

Results: From the initial 5288 articles, 1559 articles were included for detailed review. One hundred ninety-six articles (12.57%) used manual correction for segmentation errors. Of the remaining articles, 589 articles (37.8%) excluded images with significant segmentation errors, and 99 articles (6.3%) mentioned segmentation errors as a limitation of their study. The rest of the articles (675, 43.3%) did not address the segmentation error. Multiple logistic regression analysis revealed that ignorance of segmentation error was significantly associated with lower journal ranks, earlier years of publication and disease category of age-related macular degeneration, and glaucoma (all $P < 0.001$).

Conclusions: A significant proportion of peer-reviewed articles in PubMed, disregarded the segmentation error correction. The conclusions of such studies should be interpreted with caution. Editors, reviewers, and authors of OCTA articles should pay special attention to the correction of segmentation errors.

Keywords: Artifact, Optical coherence tomography angiography, Segmentation error, Vessel density

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Introduction

Optical coherence tomography angiography (OCTA) has emerged as a promising alternative modality to conventional dye-based angiography. It provides depth-resolved, three-dimensional images enabling visualization of the retinal vasculature at different depths without the need for dye injection.[1,2]

Several OCTA-derived metrics have been reported as useful measures to evaluate microvascular networks in various retinal and choroidal disorders.[3-9] Accurate identification of retinal and choroidal layers is a prerequisite for incorporating these parameters into research and clinical practice. Misidentification of retinal boundaries, also known as segmentation error, is a major source of artifact in 33%–100% of OCTA images and may occur in any OCTA device.[10-13] If it remains uncorrected, segmentation error may lead to a wrong diagnosis or significant change in OCTA-derived measurements.[14-17]

Despite the importance of segmentation errors, many OCTA studies fail to report their segmentation error correction

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strategy. The aim of this study was to assess the published articles reporting OCTA metrics regarding their segmentation error correction strategy.

Methods

In this study, a comprehensive PubMed (MEDLINE) search was conducted using the search terms: "optical coherence tomography angiography" OR "OCT-A" OR "OCTA" OR "OCT angiography" to retrieve articles reporting OCTA imaging published between January 1, 2015, and January 1, 2021. Only original articles reporting at least one of the OCTA metrics including vessel density, vessel length, vessel diameter, fractal dimension, capillary nonperfusion, choriocapillaris density, and foveal avascular zone size were included in the study. Articles not written in English and animal studies were excluded from the study.

Initially, abstracts of the OCTA studies were evaluated by one of the two graders and those articles that did not report OCTA metrics were excluded. Then, full texts of the remaining articles were assessed for the segmentation error correction strategy, and the method of segmentation correction was recorded. In addition, the number of articles that mentioned the lack of segmentation correction as a limitation of the study was recorded. In all stages of the study, an expert retina specialist (P.A.) supervised the graders.

The ranking of the publishing journal in 2020 was extracted as CiteScore from the Scopus website (available at https://www.scopus.com/sources). Articles were divided into two groups. Group 1 consisted of studies addressing segmentation errors by manual correction, exclusion of images with significant segmentation errors, or mentioned as a limitation. Group 2 consisted of articles with complete ignorance of segmentation errors. Data were analyzed using SPSS software (IBM Inc. Chicago, IL, USA). Univariate and multiple logistic regression analyses were used to assess the correlation between ignoring segmentation error, journal ranking, disease category, and year of publication. $P < 0.05$ was considered significant.

Results

Overall, 5288 articles were found using the aforementioned search terms from PubMed. Figure 1 shows the flowchart for the exclusion, review, and classification of the articles. Initially, 3729 articles were excluded because of the study type, nonhuman subjects, non-English language, or not reporting quantitative OCTA metrics. Finally, 1559 articles were included for detailed review. Among these, 256 (16.4%) articles were on diabetic patients, 252 (16.2%) on glaucoma, 130 (8.3%) on age-related macular degeneration (AMD), 122 (7.8%) on normal eyes, and 760 (51.3%) on other posterior segment pathologies (including retinal vein occlusion, uveitis, tumor, and pachychoroid each comprises <5% of total articles). One hundred ninety-six articles (12.5%) used manual correction for segmentation errors. Of the remaining 1363 articles, 589 articles (37.8% of total articles) opted to exclude images with significant segmentation errors, and 99 articles (6.3%) mentioned segmentation errors as a limitation of their study. Six hundred seventy-five articles (43.3%) did not address segmentation errors in any part of the article [Figure 2].

In univariate logistic regression analysis (Group 1 vs. Group 2 as dependent variable), ignorance of segmentation error was significantly associated with lower journal ranks, earlier years of publication, and disease category (all $P < 0.001$). Multiple logistic regression analysis showed that these associations remained statistically significant, independently. *Post hoc* analysis on disease categories demonstrated that articles regarding AMD and glaucoma had a higher chance of ignoring segmentation errors compared with other categories.

Discussion

In this study, 43.3% of peer-reviewed PubMed articles on OCTA imaging disregarded the segmentation error. Considering significant changes in OCTA metrics after segmentation correction, all OCTA images should be checked and manually corrected before statistical analysis.[14] This is especially important in the presence of posterior segment pathologies that the segmentation error is more common.[12] Interestingly, only 12.5% of articles reported manual correction of segmentation errors. Manual correction of segmentation error was difficult with older versions of OCTA software, as it was necessary to correct all OCT B-scans of an enface image. However, recent advances in software algorithms allow for faster and easier segmentation correction.[14,16] On the other hand, segmentation correction may not be possible in OCTA images with severe distortion and therefore, exclusion of these images is unavoidable.

Our results showed that 37.8% of articles excluded the OCTA images with significant segmentation errors. Although this suggests that many authors pay attention to the "significant" segmentation artifact, the presence of mild or moderate uncorrected segmentation error may still lead to measurement error. In addition, excluding OCTA images with significant segmentation errors may lead to a selection bias of less severe diseases. As shown in regression analysis, reporting segmentation correction was significantly improved in recent years and in higher-ranked journals. This may reflect the improvement in the software algorithms as well as the knowledge of the authors and reviewers.

In addition to the improvements in software, several methods have been suggested to reduce the impact of the segmentation artifact on final analysis and interpretation. The segmentation error is more prevalent in low-quality images.[11] Before imaging, proper patient preparation and device optimization may help to improve the quality of the images and reduce the artifacts.[18] After imaging, a rapid review of images helps to identify the artifacts, repeating the imaging process may improve the quality of the image. Manual correction is an

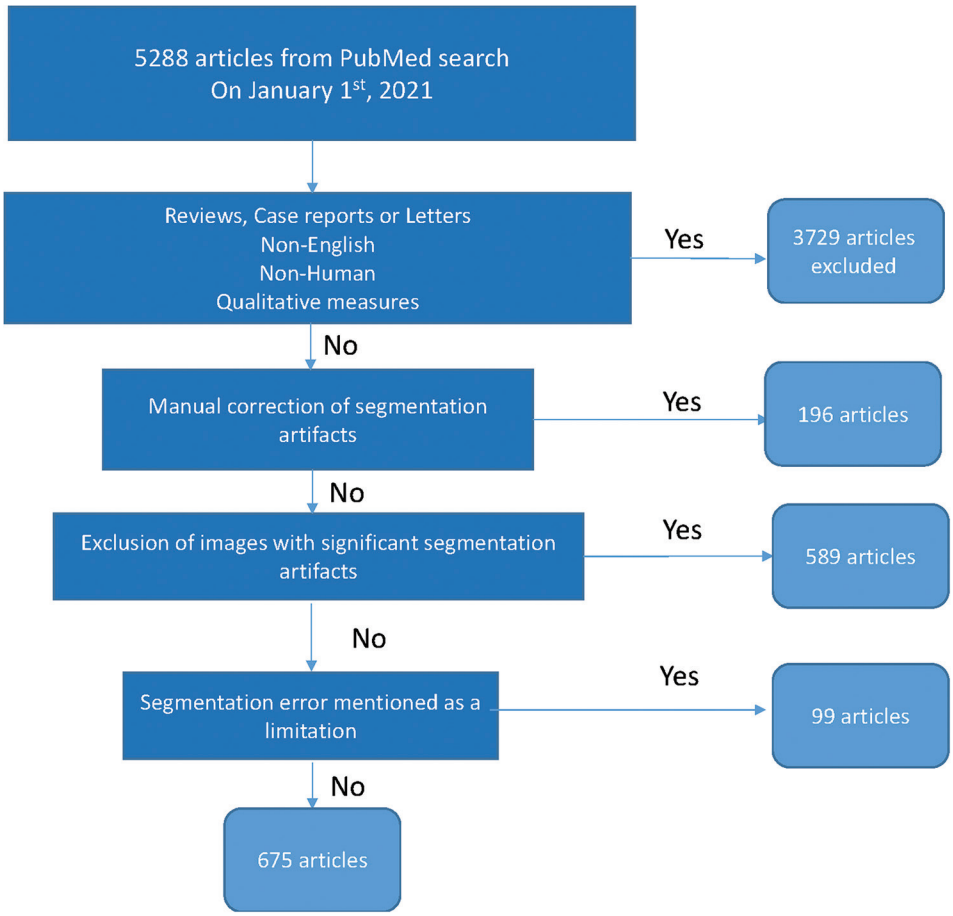

Figure 1: Flowchart for exclusion and review of the articles

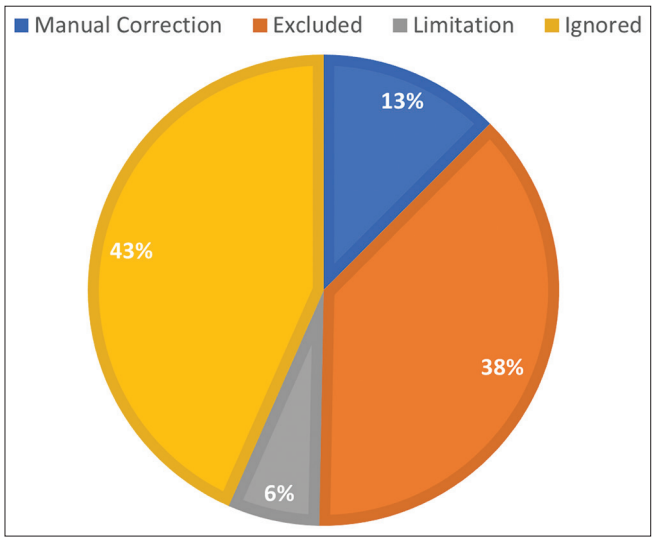

Figure 2: Pie chart shows the distribution of article's strategies toward segmentation errors: Manual correction, exclusion of images with significant segmentation errors, acknowledging limitations, and ignorance of segmentation errors

essential step before OCTA data extraction. In addition, artificial intelligence was found promising in improving the segmentation.[19,20]

This study has some limitations. This study was focused on a single OCTA artifact, and the search was limited to English articles in the PubMed database. Furthermore, we were not able to show the quantitative impact of segmentation error on OCTA measurements. In addition, the correlation of the reporting of the segmentation error with the device type and version was not evaluated.

In conclusion, this study shows that a significant proportion of OCTA articles in peer-reviewed journals did not report the segmentation correction. Without knowing the method for the management of segmentation error, the data are inaccurate and interpretation may be misleading. Authors, reviewers, and editors should pay attention to the report of segmentation errors and its management.

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Conflicts of interest

There are no conflicts of interest.

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