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ORIGINAL RESEARCH

The "Triangle" Sign: A Novel Ultrasound Marker for Diagnosing Total Choroidal Detachment and Total Suprachoroidal Hemorrhage

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Purpose: This study aims to explore the diagnostic utility of ultrasound B-scan while introducing the "Triangle" sign as a novel indicator. It also validates the sign's efficacy in distinguishing between choroidal detachment (CD) and suprachoroidal hemorrhage (SCH) from retinal detachment (RD) and vitreous hemorrhage (VH).

Patients and Methods: Retrospective analysis of consecutive cases of total CD and SCH undergoing B-scan at a single tertiary imaging center. The study examined the presence of the "Triangle" sign (a hypoechoic/anechoic triangular shape of vitreous noted anterior to the optic disc) in total CD & SCH, categorized cases by subtype and etiology, and its role in differentiating from RD and VH.

Results: Thirty-six eyes with a total CD and SCH were analyzed. Amongst the cases of total SCH 31 (86.1%), (58.1%) were linked to intraocular surgery, and (41.9%) were linked to post-traumatic events. The "Triangle" sign was consistently present in all 36 eyes, with additional findings indicating concurrent VH (52.8%) or RD (5.6%). Among the 31 eyes with total SCH, 58.3% initially had detectable choroidal membrane seen on B scan, while 41.7% did not. Despite this, the "Triangle" sign was consistently visible in all 36 eyes, and monitoring with B-scans revealed choroidal membrane as the hemorrhage resolved.

Conclusion: The "Triangle" sign is a distinctive and reliable ultrasound feature for total CD and SCH diagnosis, offering clarity in challenging cases where traditional methods face limitations.

Keywords: choroidal detachment, suprachoroidal hemorrhage, ultrasound B-scan

Introduction

Choroidal detachment (CD), characterized by the separation of the choroid from the sclera, encompasses a spectrum of clinical scenarios, presenting both serous and hemorrhagic manifestations (Figure 1).[1,2] Serous detachment involves the accumulation of fluid in the suprachoroidal space, often caused by hypotony, inflammation, or uveitis.[3–5] Hemorrhagic choroidal detachment (SCH), on the other hand, results from bleeding into the same potential space, leading to a more complex clinical picture necessitating accurate differentiation from other ocular conditions.[3–5]

Despite advancements in diagnostic imaging, differentiating CD and SCH from retinal detachment (RD) and vitreous hemorrhage (VH) remains challenging, particularly in cases with media opacities that obscure direct visualization of intraocular structures. Historically, clinicians have relied on ophthalmoscopic examination, which is often inadequate in such scenarios.[6] As a result, ultrasound B-scan imaging, a non-invasive modality utilizing high-frequency sound waves to generate detailed cross-sectional images of ocular structures, has become a cornerstone in diagnosing CD and SCH.[7]

Existing diagnostic criteria for CD and SCH on B-scan include the visualization of a thickened, irregular choroidal membrane and suprachoroidal hypoechoic spaces. However, these features often overlap with those seen in RD and VH, leading to diagnostic ambiguity.[8–10] Moreover, the limited data evaluating these features in clinical practice necessitates

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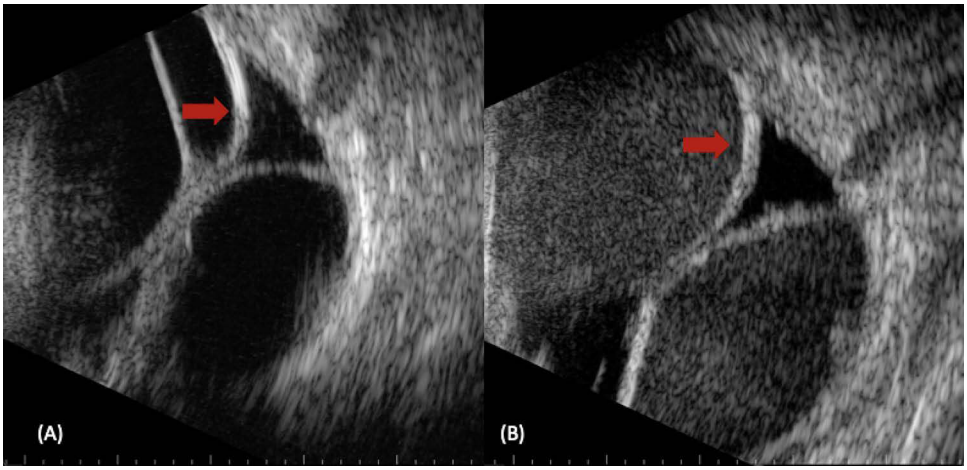

Figure 1 Choroidal detachment, (**A**) serous choroidal detachment (red arrow), (**B**) Suprachoroidal Hemorrhage (red arrow).

further exploration. While recent advances in imaging, such as optical coherence tomography (OCT) and OCT angiography (OCTA), have gained prominence, ultrasound B-scan retains unique utility in cases with severe media opacity where newer modalities may not be feasible.

The anatomy of the suprachoroidal space is essential in understanding the pathophysiology of CD and SCH. The potential space between the choroid and sclera can accumulate fluid or blood, leading to the detachment of the choroid. During CD, the normal relationship between the choroid and sclera is disrupted, resulting in the detachment visible on ultrasound. The anatomical basis for the proposed "Triangle" sign lies in the fact that the choroid does not extend to the optic disc.[6,10] Therefore, in cases of total CD and SCH, a hypoechoic or anechoic triangular shape of the vitreous anterior to the optic disc becomes apparent, which serves as a distinguishing feature from RD and VH. Accurate diagnosis is of paramount importance in cases of CD, given the distinct treatment modalities associated with each potential differential diagnosis. The need to differentiate between serous and hemorrhagic detachments, as well as from RD and VH, underscores the necessity for reliable and precise diagnostic indicators.

While several studies have documented the imaging characteristics of these conditions, currently, there is limited data on the utility of ultrasound B-scan in diagnosing CD with a focus on specific diagnostic criteria that can reliably differentiate it from other pathologies. In light of this, the proposed "Triangle" sign could provide a novel, reliable indicator for distinguishing CD from RD and VH, improving diagnostic accuracy. This research aims to explore the diagnostic value of B-scan in detecting total CD and SCH and to validate the "Triangle" sign as a potential clinical tool. By enhancing diagnostic precision, this study seeks to impact clinical decision-making, ensuring that treatment is appropriately tailored to each condition.

Materials and Methods

This study is a non-interventional retrospective analysis of consecutive cases of patients with total CD and SCH, undertaken at a single ophthalmic imaging center in Mumbai, India, from January 2007 to December 2023. The study was carried out in accordance with the tenets outlined in the Declaration of Helsinki and received approval from the Harmony Ethics Research Committee, Mumbai, India. All patients provided written informed consent for both scanning and publication.

Design

The study included patients with both serous CD and SCH who had undergone ultrasound B-scan. The patient cohort comprised cases with diverse etiologies, including trauma, post-operative complications, hypotony, inflammation, and other pathologies like glaucoma and ocular tumors. All ultrasound B-scans were conducted by a single imaging expert with over 30 years of experience in ophthalmic imaging, ensuring uniformity and reliability in data acquisition.

Imaging Technique

Ultrasound B-scan examinations were performed using high-frequency ultrasound probes. In the early part of our study, we used a Paradigm B-scan machine (Paradigm Medical Industries; LA; USA) with a 10 MHz probe, while in the later part of the study, a Sonomed HD machine (Sonomed Escalon; PA; USA) with a 12 MHz probe was utilized. All scans were conducted on the closed eyelid with the patient in a seated position. Horizontal and vertical scans were obtained, focusing on the optic disc region. A detailed imaging protocol was followed, with specific attention to the vitreous anterior to the optic disc to capture the hypoechoic/anechoic triangular shape of vitreous, defining the "Triangle" sign. For optimal image acquisition, we used a 10 MHz ophthalmic probe with a small diameter to ensure good contact with the ocular surface, enhancing visualization. The brightness setting was maintained at 105 dB, which was ideal for visualizing echogenic choroidal hemorrhage and differentiating them from the surrounding structures. Image optimization techniques were employed for better visualization. Specifically, we used a log gain setting of 100 dB and exp gain of 0 dB, referred to as the "deep choroidal setting", to improve visualization of choroidal detachments and choroidal hemorrhages.

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For patients with a history of trauma or those who were post-surgical, a gentle scan technique was employed to minimize discomfort and potential complications. This approach was implemented to ensure patient safety and enhance the quality of imaging for accurate diagnostic analysis.

"Triangle" Sign Identification

The proposed "Triangle" sign, defined as the hypoechoic/anechoic triangular shape of the vitreous anterior to the optic disc in cases of total CD (Figure 2), was used as a distinguishing feature. Diagnostic indicators for CD were meticulously evaluated and compared with traditional B-scan images to assess their reliability in distinguishing CD from RD and VH. The identification and validation of the "Triangle" sign were integral to the study objectives.

Data Collection

Retrospective analysis involved collecting electronic medical records, including patient demographics, clinical history, and ultrasound B-scan images. The analysis focused on instances of total CD and SCH, with emphasis on identifying the "Triangle" sign as a distinguishing feature.

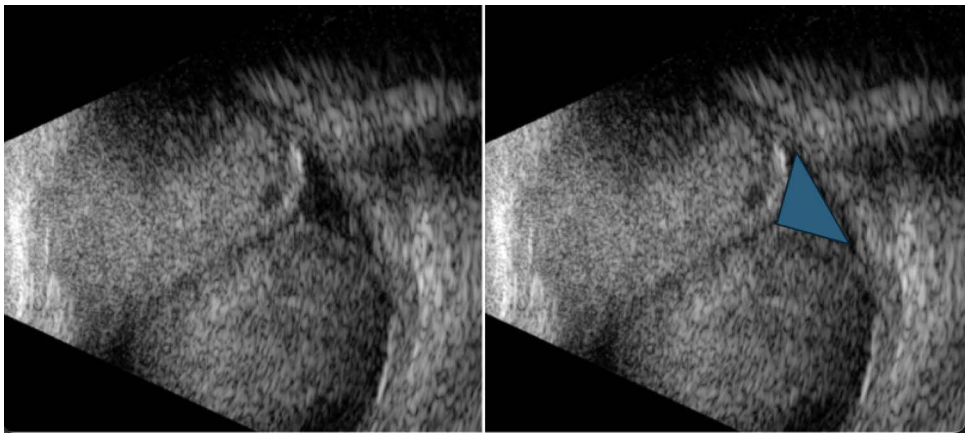

Figure 2 "Triangle" sign, triangular shape of vitreous noted anterior to the optic disc (blue triangle).

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Statistical Analysis

Statistical analysis was conducted using SPSS software, version 23.0. Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Continuous variables, such as age, were presented as means with standard deviations (SD), while categorical variables, such as gender and the type of CD, were presented as frequencies and percentages. For data regarding the presence of the choroidal membrane and the "Triangle" sign, frequencies and percentages were used to report the distribution.

Results

Thirty-six eyes of 36 patients with total CD and SCH were included in the study. The mean age of the study population was 56.5 (Interquartile range: 41.5–69.5) years. Among the participants in the study, there were slightly more males than females (M: F = 20:16).

Choroidal Detachment Analysis

Out of the 36 eyes diagnosed with total CD, a larger proportion of eyes (31 eyes; 86.1%) exhibited the hemorrhagic subtype (SCH), while fewer (5 eyes; 13.9%) showed the serous form of CD. Out of the eyes that presented with SCH, 58.1% (18 eyes) had been related to intraocular surgery (cataract surgery: 9 eyes, glaucoma filtration surgery: 9 eyes), while 41.9% (13 eyes) have been related to post-traumatic events.

Out of the 36 eyes with total CD and SCH, the choroidal membrane was detected in 21 eyes, accounting for 58.3%. However, in the remaining 15 eyes (41.8%), the choroidal membrane was not identifiable (Figure 3). All these 15 eyes were monitored with periodic B-scans, and the choroidal membranes became evident as the suprachoroidal blood / exudates began to resolve (Figure 3).

The "Triangle" Sign

The triangular area of hypoechogenic/anechogenic character, ie, the "Triangle" sign was visible in all the 36 study eyes. On additional detailed assessment, it was noted that a majority of these eyes (19 eyes; 52.8%) exhibited dot hyperechogenicities in the triangular region, indicating the presence of concurrent VH. This was followed by the absence of any echogenicity in 15 eyes (41.7%) and the presence of an additional hyperechoic membrane attached to the optic disc in the remaining 2 eyes (5.6%), suggestive of a concurrent RD (Figure 4).

Discussion

The current study investigates the diagnostic utility of ultrasound B-scan in detecting total CD, encompassing both serous and hemorrhagic manifestations. A novel sign termed the "Triangle" sign is introduced, characterized by the triangular shape of the vitreous anterior to the optic disc in cases of total CD, owing to the anatomical fact that the choroid does not extend to the optic disc.[10] Reviewing retrospectively 36 eyes with total CD, we observed that the vast majority of them were hemorrhagic SCH (86.11%) and that intraocular surgical complications were the most common cause (58.06%). An in-depth B-scan examination found that the "Triangle" sign was seen in every single one of the cases. It is noteworthy that the "Triangle" sign was present in all of these eyes even at baseline, even though the choroidal membrane was not initially identifiable in 41.67% of cases, due to masking by echogenic hemorrhage and only became visible during follow-up B-scans when the supra-choroidal echoes began to resolve.

Non-invasive imaging techniques are crucial for accurate diagnosis of CD due to limitations in clinical examination, especially in cases with media opacity.[6,7] Ultrasound B-scan has emerged as a valuable tool for visualizing ocular structures, providing detailed images that are often challenging to obtain through traditional methods.[6–8] Literature reveals a growing body of evidence supporting the use of ultrasound B-scan for various posterior segment pathologies, including CD, RD, and VH.[6–9] In static and dynamic evaluations, ultrasound can detect and differentiate RD, CD, and VH by position and morphology in most cases.[6,10] However, accurately differentiating between them remains challenging, especially in the presence of total RD, total CD, total SCH and dense VH. Dynamic B-scan ultrasound plays a critical role in such cases, as it allows differentiation between membranes like RD and PVD. The hallmark feature of

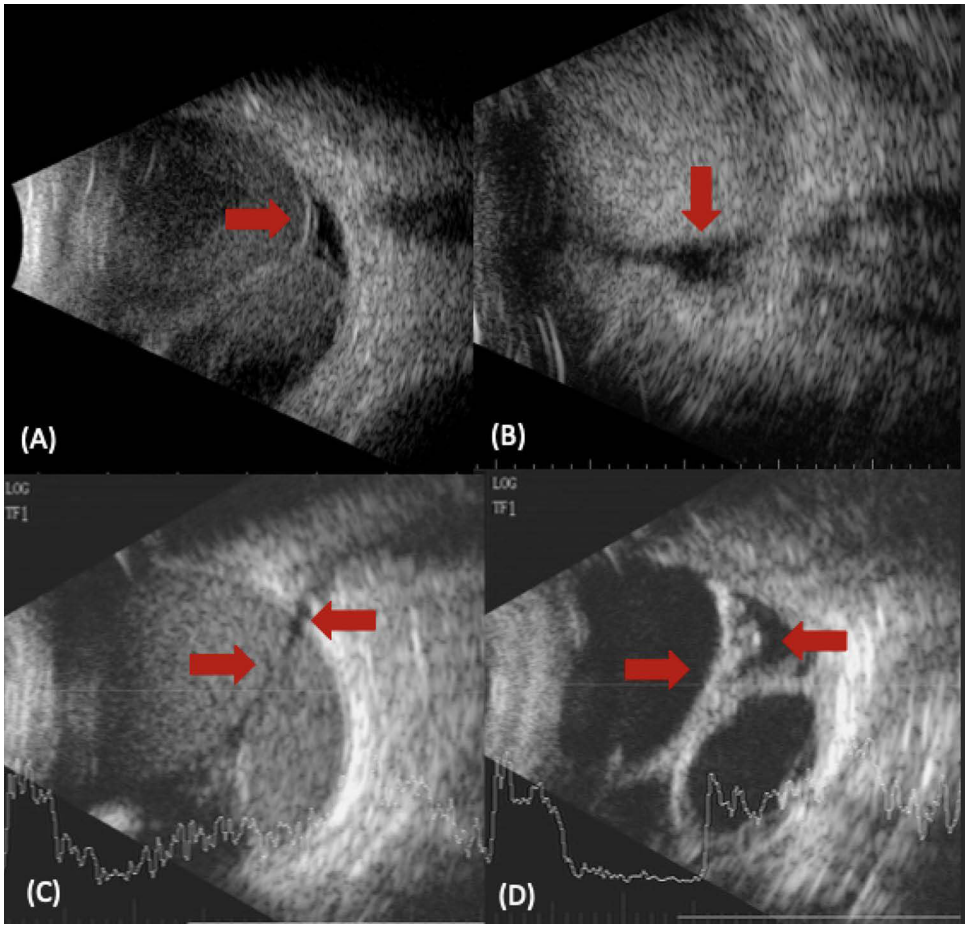

Figure 3 Suprachoroidal haemorrhage, (**A**) Choroidal membrane is visualized (right arrow), (**B**) Choroidal membrane is not visualized (down arrow), Suprachoroidal haemorrhage follow up. (**C**) At first visit the choroidal membrane is not visualized (right arrow), masked by the echogenic hemorrhage but the "Triangle" sign is visualized (left arrow), (**D**) on follow up after absorption of hemorrhage the choroidal membrane is visualized (right arrow), with the "Triangle" sign (left arrow).

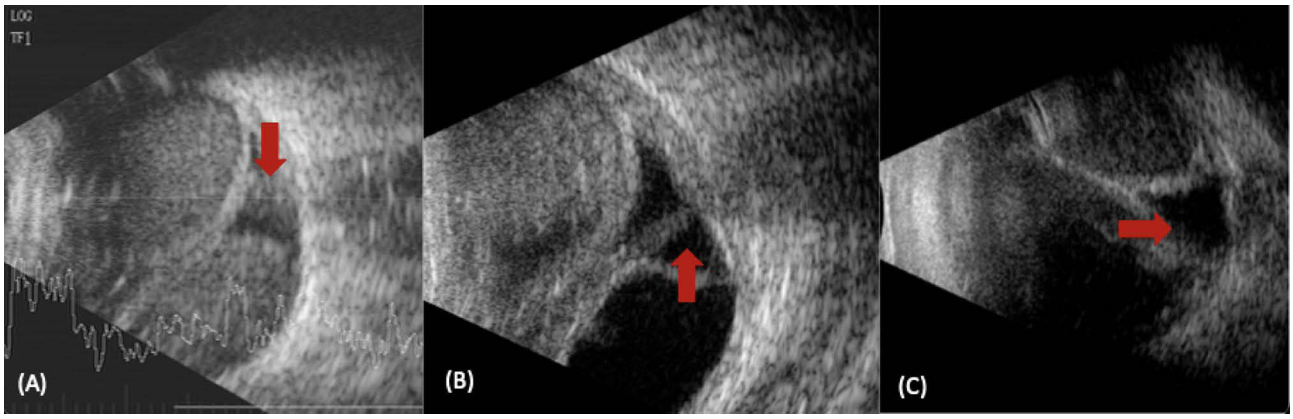

Figure 4 Contents of the triangle in the "Triangle" sign, (**A**) post-traumatic suprachoroidal haemorrhage shows hemorrhage, down arrow (**B**) total retinal detachment, up arrow (**C**) clear vitreous, right arrow.

a CD is the lack of mobility on dynamic B-scan, accompanied by a smooth, dome-shaped elevation which does not extend beyond the vortex veins. This lack of mobility is in contrast to the undulating movements often seen with PVD, while the RD, though also has minimal after movements, but is connected to the optic disc. In cases of CD, the triangular shape observed in the vitreous anterior to the optic disc is characterized by two hyperechoic borders with no after-

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movements on dynamic evaluation, representing the edges of the detached choroid. The third edge of the triangle is formed by the globe itself. This unique ultrasound signature becomes particularly crucial in cases where traditional diagnostic methods, such as indirect ophthalmoscopy, face limitations due to media opacity.

Understanding the layers of the eye is essential for interpreting the pathology revealed by the "Triangle" sign. The choroidal attachment is anterior to the ciliary bodies and posterior to the venous exit foramina.[6,10] Consequently, CDs protrude convexly into the vitreous on ultrasonography but do not extend posteriorly to the optic disc.[6,10] On the other hand, the retina is connected to the ora serrata anteriorly and to the optic disc posteriorly.[6,10] As a result, it assumes a "V" or funnel-shaped configuration within the vitreous cavity due to its continuous attachment to the optic nerve head.[6,10] This anatomical distinction is critical for understanding and interpreting the triangular vitreous configuration observed in the "Triangle" sign, providing a clear demarcation between CD and other ocular pathologies.

Imaging the "Triangle" sign involves a detailed and standardized ultrasound B-scan examination, with specific attention to the vitreous anterior to the optic disc. The hypoechoic/anechoic triangular shape, characteristic of the "Triangle" sign serves as a distinguishing feature in cases of total CD and SCH. The study notes that dot hyperechogenicity is observed in the triangular region of the "Triangle" sign in the majority of cases, indicating the presence of concurrent VH. This echogenicity may also be attributed to proteinaceous or inflammatory deposits within the vitreous, potentially resulting from the persistent hypotony associated with CD, which contributes to the increased echogenicity. Additionally, the absence of any echogenicity or the presence of an additional hyperechoic membrane attached to the optic disc is also reported, suggesting concurrent RD. These nuances in imaging details further enhance the clinical utility of the "Triangle" sign in differentiating CD from other ocular pathologies.

In clinical practice, distinguishing between total RD and total CD, especially in serous CD where membranes may appear fused, can be challenging. The "Triangle" sign serves as a crucial tool in such scenarios, clinching the diagnosis of CD by highlighting the triangular vitreous configuration anterior to the optic disc. This is particularly significant when membranes in serous CD mimic RD, potentially leading to diagnostic ambiguity (Figure 5). The "Triangle" sign, by virtue of its consistent presence and distinctive appearance, provides clarity in differentiating these entities. Moreover, our study demonstrates a noteworthy scenario where "Triangle" sign, suggestive of total CD, can coexist with RD, as evidenced by additional membranous echoes attached to the disc. This emphasizes the importance of considering both the "Triangle" sign and additional findings in ensuring a comprehensive and accurate diagnosis of ocular pathologies. The ability of ultrasound B-scan to provide detailed insights into the morphology and position of ocular structures further solidifies its role in distinguishing between CD and RD, contributing to improved clinical decision-making.

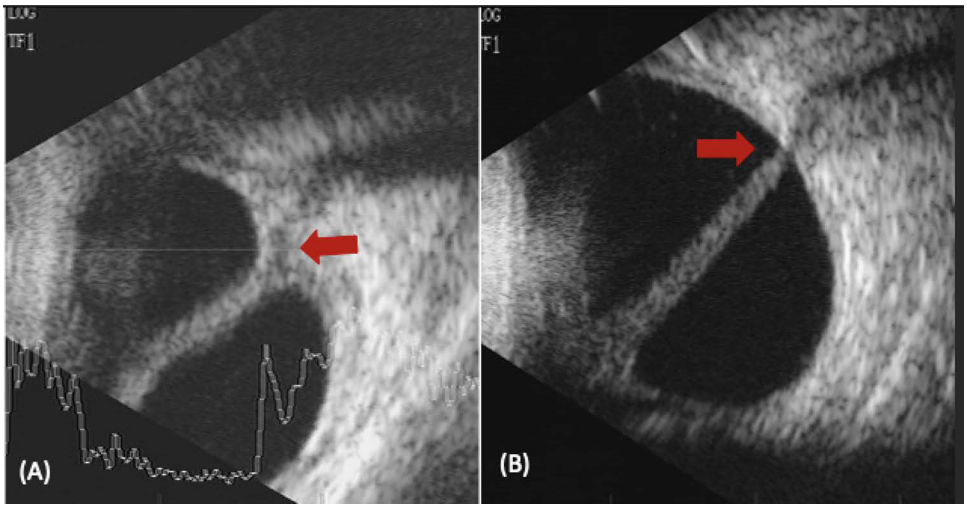

Figure 5 "Triangle" sign differentiates between total RD & CD, (**A**) total serous CD shows a small "Triangle" sign (left arrow), (**B**) total RD does not shows "Triangle" sign (right arrow).

In the context of distinguishing between VH and total SCH, where membranes may be fused and challenging to identify, the "Triangle" sign becomes a decisive factor. Dense VH typically presents as uniform, moderate dot echoes throughout the vitreous cavity, mimicking the appearance of total SCH.[7,8] However, the presence of the "Triangle" sign helps clinch the diagnosis of CD in such cases (Figure 6). Our study aligns with the challenges mentioned, as we found that choroidal membranes were not visible in 41.67% of the eyes, a phenomenon consistent with the character of acute SCH. In this acute state, the echoes of the blood are bright due to the tight choroidal space, effectively masking the echo of the choroidal membrane. This further emphasizes the difficulties in membrane identification, highlighting the importance of considering additional diagnostic factors. Furthermore, our findings support the principle that as the blood liquefies, the choroidal membrane becomes visible due to hypoechoic nature of liquefied blood being lower than the choroidal membrane. This insight aligns with the intricacies observed in our case example, where "Triangle" sign, indicative of total CD, coexisted with VH. The additional moderate dot echoes within the vitreous cavity, akin to the blood echoes, accentuate the need to consider both the "Triangle" sign and supplementary findings for a comprehensive and accurate diagnosis of ocular pathologies. Moreover, recognizing the importance of diagnosing in the acute state, as highlighted by the principle, underscores the significance of early detection in our study. The consistent presence of the "Triangle" sign and the timely identification of choroidal membranes, influenced by the liquefaction process, make ultrasound B-scan examinations a reliable tool for enhancing diagnostic accuracy in challenging clinical scenarios. This integrated approach contributes to a more nuanced understanding of ocular pathologies and facilitates improved patient care.

The introduction of the "Triangle" sign opens avenues for future research and exploration. Future studies could explore the "Triangle" sign in a broader population, considering the diverse demographics and etiologies of CD. Multicenter studies may validate the sign's utility in different clinical settings and patient populations, establishing its specificity and sensitivity across various scenarios. Longitudinal studies could investigate the prognostic implications of the "Triangle" sign in monitoring CD resolution and treatment outcomes. Collaborative initiatives among ophthalmic imaging centers may contribute to the development of consensus guidelines for incorporating the "Triangle" sign into routine ultrasound B-scan examinations.

While the "Triangle" sign shows promise as a novel and reliable diagnostic indicator, it is crucial to acknowledge the limitations of the current study. The retrospective, single-center design introduces the potential for selection bias and limits the generalizability of the results. The relatively small sample size, although providing valuable insights, calls for cautious interpretation, and the "Triangle" sign is highly sensitive for total CD, it may not capture the full spectrum of CDs. Furthermore, while the "Triangle" sign has shown high sensitivity for total CD, it may not fully encompass the entire spectrum of CD presentations, potentially limiting its applicability in broader clinical scenarios. Additionally, the absence of a control group and the involvement of multiple observers are factors that we recognize as limitations, and their inclusion could further strengthen the findings of future studies. Finally, as this study is observational in nature and

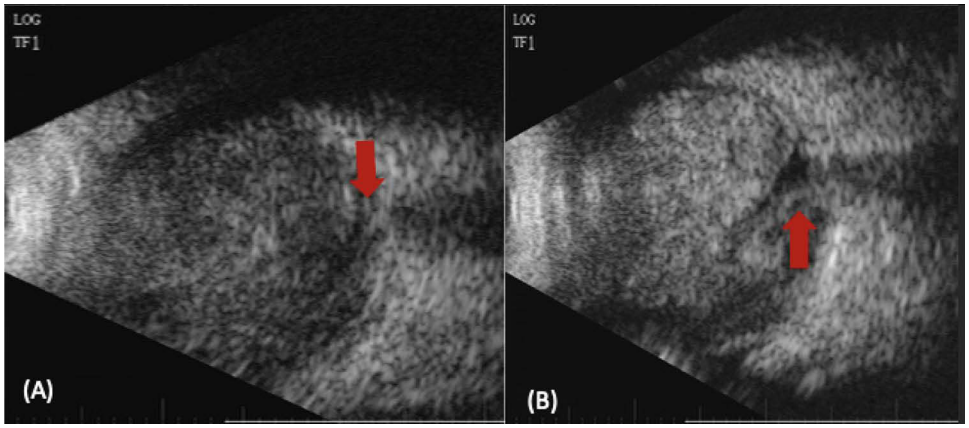

Figure 6 "Triangle" sign differentiates between total VH and total suprachoroidal haemorrhage, (**A**) total VH shows dense echoes occupying the entire vitreous cavity including the area anterior to the disc (down arrow), (**B**) total suprachoroidal haemorrhage is identified with the help of "Triangle" sign (up arrow).

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does not involve a control population, sensitivity and specificity calculations, as well as formal statistical validation, were not performed and would be inappropriate given the study design. Future studies with larger sample sizes and control groups are needed for further validation of the "Triangle" sign.

Conclusion

In conclusion, the "Triangle" sign presents a promising preliminary finding as a diagnostic indicator for total CD, offering clear anatomical and imaging distinctions that may help differentiate CD from other ocular pathologies. However, the findings are based on a single-center study, and further validation is needed to establish its clinical utility. Prospective, multi-center studies with control groups and statistical validation are essential to confirm the reliability and accuracy of this sign. While the study provides valuable insights into the imaging characteristics of the "Triangle" sign, future research is necessary to explore its potential integration into routine clinical practice and to standardize its application in diverse clinical settings.

Disclosure

The authors report no conflicts of interest in this work.

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