Clinical Ophthalmology

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ORIGINAL RESEARCH

Evaluation of a Modified Single-Stage Continuous Curvilinear Capsulorhexis Technique Using 18-Gauge Needle Decompression in Intumescent Cataracts

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Video abstract

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Objective: To evaluate the safety and efficacy of a modified anterior capsulorhexis technique using an 18-gauge needle puncture at the peripheral one-third of the anterior capsule to control intralenticular pressure and achieve single-stage continuous curvilinear capsulorhexis (CCC) in intumescent cataract surgery.

Methods: This prospective, cross-sectional descriptive study included patients with intumescent cataracts indicated for surgery at Saigon Vinh Eye Hospital from August 2024 to March 2025. Before CCC, all patients underwent an 18-gauge needle puncture at the peripheral one-third of the anterior capsule near the main incision.

Results: A total of 99 eyes from 99 patients were included in the study. The mean axial length was 23.12 ± 0.55 mm, anterior chamber depth 2.62 ± 0.43 mm, and lens thickness 4.91 ± 0.72 mm. In 65 patients (65.7%), the milky liquefied cortex escaped into the anterior chamber after the needle puncture. Single-stage CCC was successfully performed in 98 of 99 cases (98.9%) with a mean capsulorhexis diameter of 5.5 ± 0.3 mm. All surgeries were performed using standard phacoemulsification and in-the-bag IOL implantation (100%). Three months post-operatively, all patients had well-centered IOLs with a best-corrected visual acuity (BCVA) ≥ 4/10.

Conclusion: An 18-gauge needle puncture at the peripheral one-third of the anterior capsule offers effective decompression, improves safety, and facilitates CCC in patients with intumescent cataracts. This technique is simple, feasible, and highly applicable in clinical practice.

Keywords: intumescent cataract, capsulorhexis, 18-gauge needle, Argentinian flag sign

Introduction

Despite advances in PHACO technology and surgical instrumentation, white cataracts, particularly intumescent cataracts, remain a significant challenge for many surgeons. Visualizing the anterior capsule and performing continuous curvilinear capsulorhexis (CCC) are often difficult in such cases. Moreover, lens hardness and posterior segment status cannot be assessed, which complicates surgical planning and prognosis.[1]

Achieving a well-centered, appropriately sized, continuous curvilinear capsulorhexis in intumescent cataracts remains one of the most technically demanding steps in phacoemulsification. Multiple intraoperative challenges may compromise capsulorhexis control, including the absence of a red reflex, capsular fragility, calcification, and, most critically, markedly elevated intra-lenticular pressure.[1–3]

Upon anterior capsule puncture, sudden release of the liquefied cortex into the anterior chamber can obscure visualization, increase intraoperative pressure fluctuations, and precipitate loss of control during CCC.[4,5] In such cases, the anterior capsule is often thinned and structurally weakened, making it more susceptible to radial extension under elevated tensile stress.[6]

Received: 6 June 2025
Accepted: 6 September 2025
Published: 11 September 2025

A characteristic complication is the “Argentinean flag sign” (AFS), characterized by bilateral radial tears radiating from the puncture site, typically observed after Trypan Blue staining. Daniel Perrone first described this phenomenon.[7,8] If not promptly managed, AFS can lead to severe sequelae, including zonular dehiscence, posterior capsule rupture, nucleus drop, and malpositioning or decentration of the intraocular lens (IOL).[9,10]

Various decompression techniques have been developed to reduce the risk of AFS, including central capsule puncture using 25–30G needles or a phaco tip, followed by aspiration of liquefied lens material before CCC.[11–13] However, the central capsule is the thinnest (~14 µm) and most susceptible to rupture under pressure, according to Laplace’s law.[14]

In this study, we proposed and evaluated a modified technique using an 18-gauge needle (B. Braun Melsungen AG, Melsungen, Germany) to puncture the anterior capsule at the peripheral one-third near the main incision, where the capsule is thicker (~21 µm).[15] This allows gradual pressure release, facilitates the escape of liquefied material, maintains anterior chamber stability, and minimizes the risk of radial tears. This technique is simple, feasible, and potentially enhances the safety of intumescent cataract surgery.

Materials and Methods

This study was designed as a prospective, cross-sectional descriptive cohort study conducted at Saigon Vinh Eye Hospital. This study included 99 patients diagnosed with intumescent cataracts who met the inclusion criteria and were scheduled to undergo cataract surgery between August 2024 and March 2025. As this was a prospective observational case series, no formal sample size calculation was performed. Instead, all eligible cases within the defined timeframe were included to reflect real-world clinical practice. Cases with significant anterior capsule fibrosis, history of ocular trauma, and previous intraocular surgery were excluded from the study.

Before surgery, all patients were administered intraocular pressure (IOP), lowering medications, including oral acetazolamide 250 mg (Domesco Medical Import Export JSC, Dong Thap, Vietnam) and topical agents, including Combigan (Allergan Inc., Dublin, Ireland) and Azopt 1% (Alcon Laboratories Inc., Fort Worth, TX, USA), to reduce the IOP to below 18 mmHg. Patients whose IOP remained elevated were treated as outpatients with continued medical therapy and were re-evaluated after 3 days. Only patients who achieved the target IOP were included in the study, while others were excluded.

All procedures were performed by the same surgeon (Dr. Hoang Trung Kien) under topical anesthesia. A main temporal incision was made at 5:30, with a side port incision at 8:30. Trypan Blue was used to stain the anterior capsule for better visualization, followed by filling the anterior chamber with VISIOL (TRB Chemedica AG, Munich, Germany), with 2% sodium hyaluronate + 0.5% mannitol.

An 18-gauge needle (B. Braun Melsungen AG, Melsungen, Germany) with the bevel facing upward was used to puncture the anterior capsule at the peripheral one-third of the main incision site, which is an area with a capsule thickness of approximately 21 µm. This location was chosen over the central zone (~14 µm thickness) to reduce the risk of radial tears.[15] The liquefied cortical material gradually escaped through the puncture site, effectively lowering intralenticular pressure. The key steps of the decompression procedure are illustrated in Figure 1.

The same 18-gauge needle (B. Braun Melsungen AG, Melsungen, Germany) was then used to gently push the lens nucleus downward toward the opposite side, further promoting the release of trapped liquefied material through the

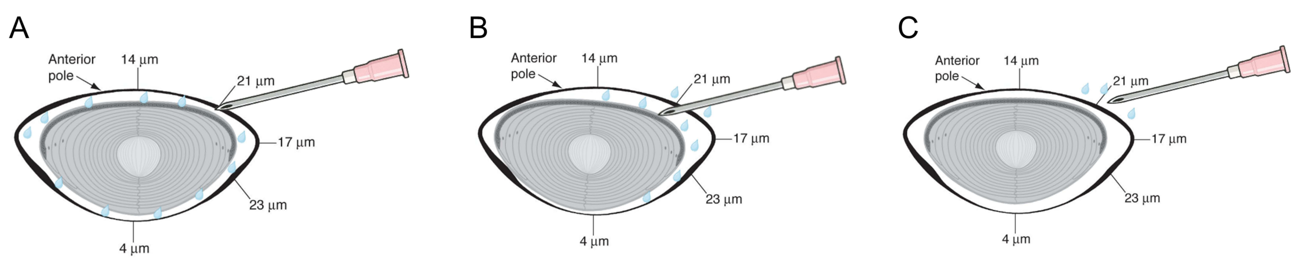

Figure 1 Illustration of the 18-gauge needle puncture technique for decompressing intralenticular pressure. (**A**) Initial needle entry at the peripheral one-third of the anterior capsule, near the edge of the main incision; (**B**) Gentle downward pressure on the nucleus facilitates partial release of liquefied material trapped beneath the nucleus; (**C**) Upon needle withdrawal, the liquefied material is nearly fully evacuated, and the nucleus returns to its original position.

incision. This maneuver compresses the residual fluid beneath the nucleus, causing it to shift upward and exit through the puncture site at the incision margin, thereby further reducing the intracapsular pressure.

Once the internal pressure was adequately reduced, Vannas scissors were used to make a vertical cut perpendicular to the initial needle track, creating two capsule flaps. One of the capsule flaps was used to initiate the CCC in a clockwise direction. If a difficulty was encountered, a second flap was used to perform CCC in the opposite direction. After successful CCC, surgery was performed according to standard phacoemulsification protocols with in-the-bag intraocular lens (IOL) implantation. All patients received an AcrySof IQ SN60WF intraocular lens (Alcon Laboratories, Inc., Fort Worth, TX, USA) implanted in the capsular bag following phacoemulsification.

The capsulorhexis flap was initiated and completed under viscoelastic coating (see Supplementary Video 1).

Data Analysis Method

The research data were processed using SPSS 20 statistical software (IBM Corp., Armonk, NY, USA), with $p < 0.05$ being a statistically significant difference.

Written informed consent was obtained from all participants prior to enrollment in the study, in accordance with the Declaration of Helsinki.

Research Ethics

The Ethics Committee of Biomedical Research approved this study, Sai Gon Vinh Eye Hospital, Vinh City, Nghe An Province, Vietnam (No: 102/HĐĐĐ-SGM).

Results

A total of 99 eyes of 99 patients diagnosed with intumescent cataracts were included in the study. Figures 2 and 3 illustrate the capsulorhexis process and intraoperative fluid egress in a typical case. The average age was 75.8 ± 9.8 years (range: 57–93 years), with a female-to-male ratio of approximately 2.1:1.

Preoperative visual acuity was poor in all cases: 34.7% had hand motion vision (LogMAR 2.3) and 65.3% had only light perception (LogMAR 2.7). Intraocular pressure (IOP) was within the normal range in 40.4% of cases (mean: 18.6 mmHg), while 59.6% exhibited elevated IOP (maximum recorded value: 48 mmHg). Of the patients with elevated IOP, 39 underwent same-day surgery after medical control, whereas 20 required outpatient IOP-lowering treatment and underwent surgery after reaching the target IOP.

Biometric measurements showed a mean axial length of 23.12 ± 0.55 mm, anterior chamber depth 2.62 ± 0.43 mm, and lens thickness 4.91 ± 0.72 mm.

Continuous curvilinear capsulorhexis (CCC) was successfully performed in 98 of 99 cases (98.9%), with a mean diameter of 5.5 ± 0.3 mm. As illustrated in Figures 2 and 3, successful capsulorhexis was achieved following proper decompression, even in challenging cases. One patient experienced a peripheral radial tear during clockwise capsulorhexis at the 3 o'clock position, which was completed using the opposite flap in a counterclockwise direction. All the patients underwent standard phacoemulsification with in-the-bag IOL implantation.

Post-operative visual acuity improved significantly. At one week and one month post-op, the mean LogMAR visual acuity was 0.4. The best postoperative acuity was logMAR 0.1 (equivalent to 20/25), while one patient retained only light perception (logMAR 2.7). Eight patients with poor visual recovery (≤ 20/200), including five with advanced glaucoma, two with high myopia-related maculopathy, and one with proliferative diabetic retinopathy. One patient had uncontrolled IOP (28 mmHg) one month post-operatively and underwent trabeculectomy.

Discussion

Studies have shown that performing anterior capsulorhexis combined with an 18-gauge needle in PHACO surgery is effective and safe in patients with white cataracts. This approach helps reduce intralenticular pressure prior to performing CCC. By inserting an 18-gauge needle into the anterior capsule before capsulorhexis, the liquefied lens material is allowed to flow into the anterior chamber and out through the main incision, thereby equalizing the pressure between the capsular bag and the anterior chamber. This pressure balance helps prevent the anterior capsule from tearing radially

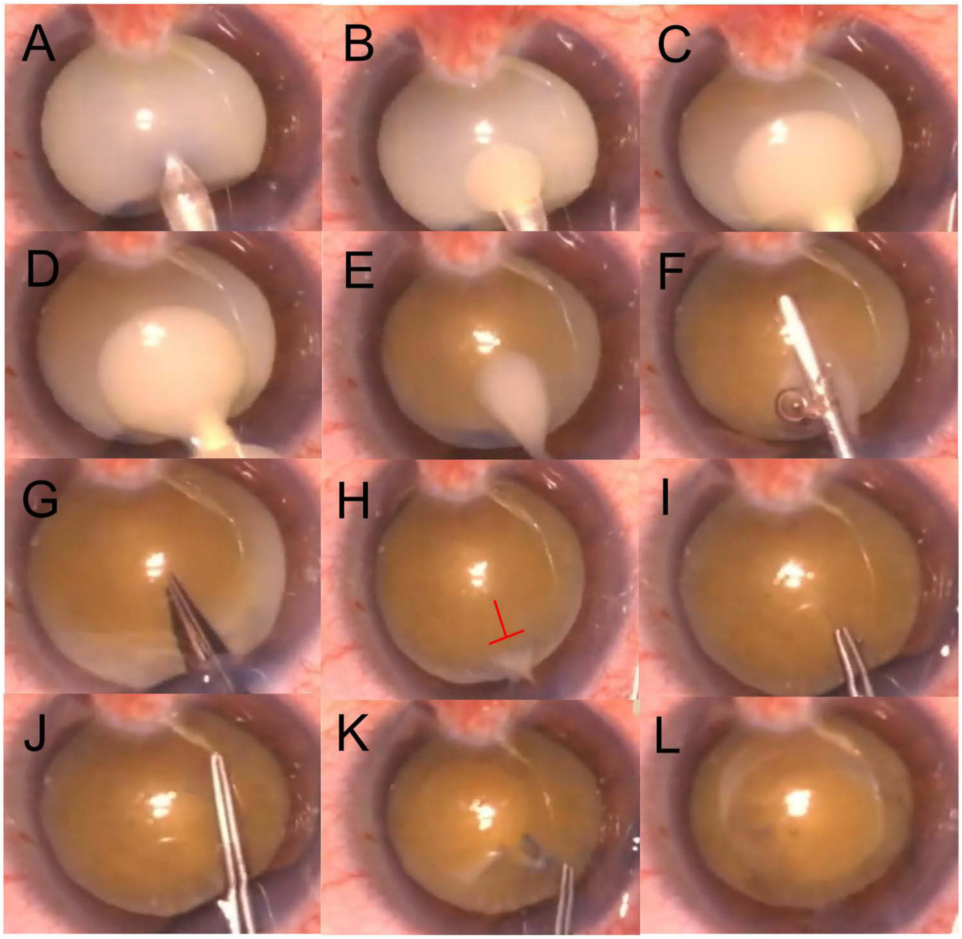

Figure 2 Steps of anterior capsulorhexis in a case of intumescent white cataract with liquefied cortical material escaping into the anterior chamber. (**A**) Needle insertion at the outer one-third of the anterior capsule near the main incision site; (**B–E**) Liquefied lens material flows out through the incision. Gentle downward pressure is applied to the nucleus using an 18-gauge needle to facilitate the upward movement of the subnuclear fluid; (**F**) ophthalmic viscosurgical device (OVD) is injected to reform the anterior chamber and promote the expulsion of any remaining liquefied material; (**G** and **H**) A reverse T-shaped flap is created using Vannas scissors (The red inverted T-shaped mark highlights the site of the anterior capsular flap tear); (**I–L**) The capsulorhexis is completed in a clockwise direction.

toward the equator. Nabil et al compared conventional manual capsulorhexis with a needle-assisted technique in patients with intumescent cataracts. The rate of anterior capsule tears was 20% in the manual capsulorhexis group, whereas no tears were observed in the needle-assisted group.[16]

In intumescent cataracts, the cortex and nucleus undergo proteolytic degradation, resulting in liquefaction and elevated intralenticular pressure. Upon anterior capsule puncture, this pressurized fluid may escape explosively into the anterior chamber, increasing the risk of uncontrolled capsular tears. According to Laplace's law ($T = P \times r / 2t$), tension on the capsular surface increases with pressure (P) and radius of curvature (r), and decreases with capsule thickness (t).[14] Given that the central anterior capsule is approximately 14 µm thick, significantly thinner than the peripheral capsule (21 µm), central decompression carries a higher risk of radial extension. Therefore, selecting a puncture site in the peripheral one-third of the capsule, where thickness is greater and wall tension is lower, represents a biomechanically rational strategy to improve capsular integrity.

Additionally, the direction of decompression influences fluid dynamics and mechanical stability. Central puncture typically induces vertical pressure displacement beneath the nucleus, which may result in a larger contact area between the liquefied cortex and the posterior capsule. In contrast, eccentric puncture with a peripheral 18-gauge needle allows a lateral decompression trajectory and enables oblique tilting of the nucleus. This reduces the contact surface area and facilitates efficient fluid escape. According to the fluid mechanics principle $F = P \cdot A$,[17] where F is the applied force, P is internal pressure, and A is contact area, minimizing the area of contact helps reduce the required force and enhances

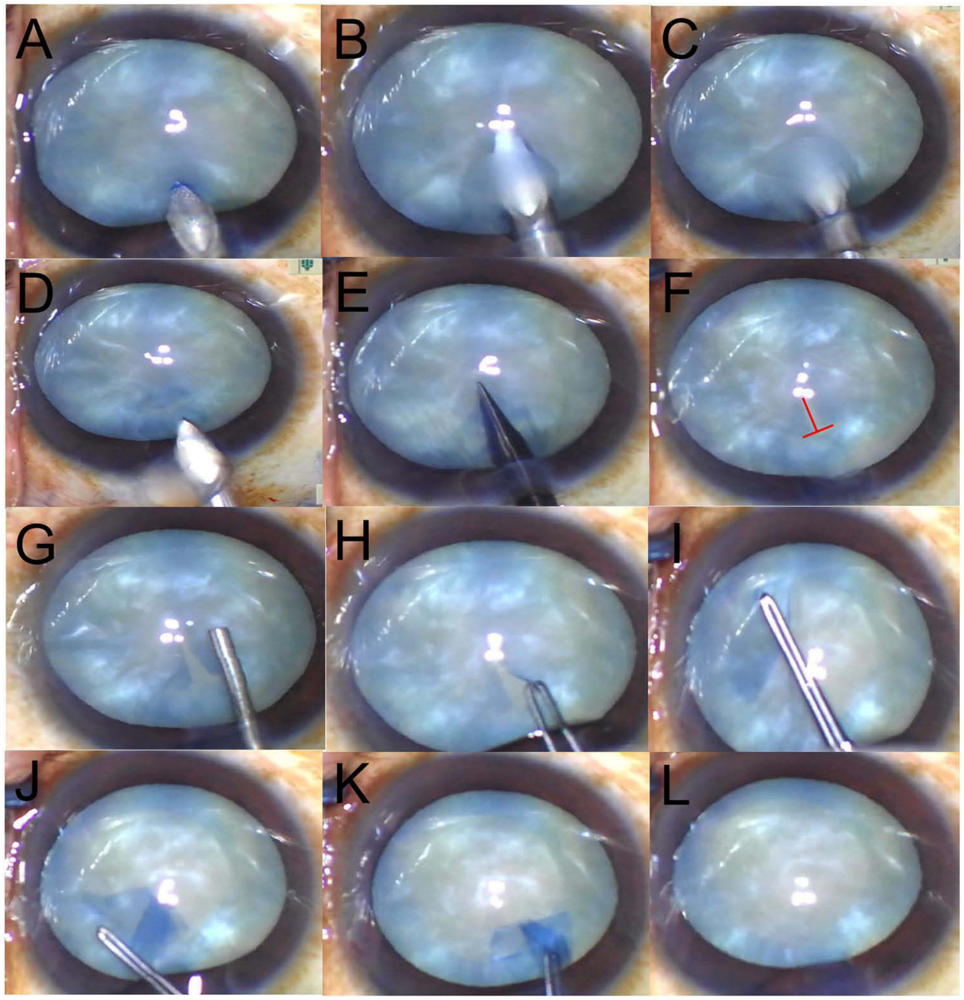

Figure 3 Steps of capsulorhexis in a case of intumescent white cataract with liquefied lens material escaping into the anterior chamber. (**A**) Needle puncture at the outer one-third near the main incision site; (**B–D**) Liquefied lens material escapes through the incision; an 18-gauge needle is used to gently press down on the nucleus, facilitating the upward flow of the liquefied substance from beneath the nucleus; (**E** and **F**) A reverse T-shaped flap is created using Vannas scissors (The red inverted T-shaped mark highlights the site of the anterior capsular flap tear); (**G**) OVD injection to reform the anterior chamber and expel the remaining liquefied material; (**G–L**) Continuous curvilinear capsulorhexis is performed in a clockwise direction.

control. This fluid shift may also prevent posterior displacement of the nucleus and reduce the risk of a capsular blowout or zonular stress.

These observations suggest that needle entry site selection should not be based solely on anterior capsule thickness but must also take into account the contact geometry and intralenticular fluid dynamics. Such considerations are essential for optimizing the pressure release pathway and ensuring capsular integrity during phacoemulsification in cases of intumescent cataract.

An 18-gauge needle (Brown) was selected based on both technical and physiological rationale. In mature, intumescent white cataracts, decompression of the lens is essential to reduce the risk of anterior capsular tears, particularly the "Argentinian flag sign" caused by elevated intralenticular pressure. Among available gauges, the 18-gauge needle offers optimal fluid dynamics and mechanical stability. Its long-beveled tip and large diameter (~1.2 mm) provide a stable fit at the incision, minimizing OVD leakage and helping preserve anterior chamber depth and pressure. This is critical to prevent chamber collapse and forward lens prolapse, which could stress the anterior capsule. The wide lumen also allows controlled aspiration of liquefied cortical material. According to Poiseuille's law, flow increases with the fourth power of radius, making the 18-gauge needle highly efficient for decompression.[18] Additionally, its mechanical rigidity improves control during manipulation, especially valuable in eyes with shallow chambers and tense lenses, features commonly seen in hypermature cataracts.

Various techniques have been proposed to manage intralenticular pressure and reduce the risk of capsular rupture. Bhattacharjee et al described performing capsulorhexis under high magnification and oblique illumination, using viscoelastic to modulate pressure.[19] More recently, Kılıç et al introduced a two-stage capsulorhexis.[18] First, a small central opening (1.5–2 mm) was created using Utrata forceps; if liquefied cortex obscured the view, it was aspirated with a 25-gauge needle. The second stage involved completing a standard 5–6 mm capsulorhexis. However, complications included one radial tear during the second stage and two capsule ruptures during aspiration. Importantly, this technique did not include gentle nucleus depression, potentially leaving residual fluid trapped beneath the nucleus. This may have contributed to persistent intralenticular pressure and increased the risk of capsular tears. Ucar introduced a spiral capsulorhexis technique combined with continuous fluid pressure to maintain the anterior chamber, offering improved control of intralenticular pressure and reduced capsular rupture risk.[20] These techniques share a common aim: effective pressure management to enable safer capsulorhexis. However, most prior studies have focused on the timing and method of capsulorhexis and fluid evacuation, with limited consideration of the geometric and mechanical implications of needle entry site and the direction of nucleus displacement. Our approach adds a new perspective by highlighting the role of optimal needle placement in enhancing fluid egress and minimizing intraoperative complications.High-cohesive ophthalmic viscosurgical devices are considered the most effective agents for preventing anterior capsular tears and the AFS in tense, intumescent cataracts, owing to their superior capability to maintain anterior chamber depth and counteract posteriorly directed forces.[21,22] Improper application of OVDs during CCC may allow posterior pressure to displace the crystalline lens nucleus anteriorly, generating centrifugal forces that predispose to capsular rupture.[5] In this study, VISIOL (TRB Chemedica AG, Munich, Germany), a formulation comprising 2% sodium hyaluronate and 0.5% mannitol, was employed to flatten the anterior convexity of the lens, buffer against intralenticular pressure, and minimize peripheral extension of capsular tears during CCC.

Creating a capsular incision perpendicular to the needle entry using Vannas scissors allows the formation of two symmetrical capsular flaps, enhancing control during CCC. This configuration offers a contingency: if one flap becomes unstable or tears, the surgeon can switch to the contralateral flap and complete the capsulorhexis in reverse. In our study, a capsular tear occurred at the 3 o'clock position but did not extend beyond the equator. The affected area showed capsular fibrosis and zonular weakness. Upon detecting abnormal tear behavior, the surgeon immediately withdrew the forceps, released the lid speculum, and injected cohesive OVD to stabilize the chamber. The contralateral flap was then used to complete CCC in the opposite direction. The rest of the surgery was uneventful, with successful in-the-bag IOL implantation. At 3-month follow-up, the IOL remained centered, BCVA improved to 20/40, and the patient reported satisfactory visual recovery.

In addition to mechanical decompression techniques, laser-assisted methods have also been explored to reduce the risk of anterior capsular tears in intumescent cataracts. For example, preoperative Nd: YAG laser anterior capsulotomy can create a controlled capsular opening, thereby minimizing the chance of uncontrolled radial extension.[23,24] Similarly, femtosecond laser-assisted capsulotomy offers precise and reproducible capsular incisions, which may reduce the likelihood of capsular rupture, particularly in eyes with elevated intralenticular pressure.[25,26] However, the use of these technologies may be limited by their high cost and limited accessibility in many surgical settings. By contrast, our technique requires no expensive laser equipment, relies solely on standard surgical instruments, and is therefore more suitable for routine use in low-resource environments and developing countries.

Limitations

This study has several limitations. First, it was a single-center study conducted at a tertiary eye hospital, which may limit the generalizability of the findings to other clinical settings with different levels of surgical expertise or equipment availability. Second, all surgeries were performed by a single experienced surgeon, which ensures consistency but may not reflect outcomes in broader clinical practice where surgical skill levels vary. Third, the study lacked a control group using conventional decompression techniques, which would have allowed for a direct comparison of outcomes, such as capsulorhexis completion rates and complication incidence. Finally, long-term outcomes beyond the three-month postoperative period were not assessed, which may have overlooked delayed complications such as capsular contraction or IOL decentration. Future studies with larger, multicenter cohorts and randomized controlled designs are warranted to validate these findings and to explore the clinical advantages of this technique further.

Conclusion

The 18-gauge needle decompression technique applied at the peripheral one-third of the anterior capsule demonstrates clear efficacy in safely relieving intralenticular pressure, enabling controlled CCC, and significantly reducing the risk of radial capsule tears such as the Argentinian flag sign. With its high success rate, simplicity, and feasibility for routine clinical practice, this modified technique presents a practical and effective approach to enhance safety and surgical outcomes in intumescent cataract cases with elevated internal lens pressure.

Funding

The authors received no financial support for the research, authorship, or publication of this manuscript.

Disclosure

The authors declare no conflicts of interest related to this study.

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