Application of capsular bag relaxation for capsular contraction syndrome

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Abstract. The present study analyzed the surgical method and clinical effects of capsular bag relaxation surgery (CBRS) for the treatment of capsular contraction syndrome (CCS), which usually occurs post-phacoemulsification. The retrospective case study comprised of a total of 25 patients (25 eyes) who developed CCS after phacoemulsification and subsequently underwent CBRS. Among these patients, 15 patients (15 eyes) received actinoid relaxing incisions and 10 patients (10 eyes) underwent a second continuous curvilinear capsulorhexis. Postoperative naked-eye visual acuity was determined and compared with preoperative naked-eye visual acuity. Size changes of the transparent zone of the anterior capsule opening were observed under a slit lamp, as well as the anterior and posterior capsular membrane conditions and position of the intraocular lens (IOL). In addition, the presence of any subjective symptom, including glare or monocular diplopia, was investigated. A final 6-month postoperative follow-up was conducted for each patient. Visual acuity of all operated eyes improved to various extents. Notably, glare and monocular diplopia were no longer evident and patients could observe things clearly. Visual differences pre- and post-surgery were statistically significant (u=5.143, P<0.01). In addition, capsular bag shrinkage and relaxation were revealed under a slit lamp, the area of the transparent zone of the anterior capsule opening was expanded and the IOL remained centered. To conclude, CBRS is an effective treatment method for patients with CCS who are not suitable to receive laser treatment.

Introduction

Capsular contraction syndrome (CCS) was first named by Davison in 1993, and has been correlated with the application of continuous curvilinear capsulorhexis (CCC) in phacoemulsification (1,2). CCS primarily occurs within 3-30 weeks following surgery (1,2). Manifestations of CCS include the equatorial diameter reduction of the capsula lentis and narrowing of the CCC opening in operated eyes post-surgery; fibrosis opacification development in the anterior capsular membrane; and tilting, displacement or dislocation of the intraocular lens (IOL), which leads to decreased visual acuity and quality, and obstruction of fundoscopy and treatment (3). Neodymium-doped yttrium aluminum garnet (Nd:YAG) laser treatment is an effective and safe treatment method for CCS that can loosen the hyperplastic fibers (also known as annular fibers) of the contracted capsular bag, enlarge the capsular opening area and restore visual function (4). However, for patients with serious CCS, the severe hyperplasia of fibers could not be shattered by the laser, the large fragments of fibrous membrane was not absorbed spontaneously following the shattering of the hyperplastic fibers or the hyperplastic fibers were in the central optical area; in addition, Nd:YAG laser treatment may damage the intraocular lens (5). For patients who cannot tolerate Nd:YAG laser treatment, who cannot sit for long periods, with nystagmus or who are in areas without laser equipment and other medical equipment, capsular bag relaxation surgery (CBRS) is a suitable option (6,7). The present study investigated the effect of CBRS on 25 eyes from 25 patients with CCS in order to determine whether CBRS has good therapeutic effects.

Materials and methods

Subjects. The retrospective case study comprised of the data from 25 patients, who received CBRS due to CCS in the Ophthalmology Center of Taizhou City Hospital between January 2005 and December 2015. Among these patients, 10 patients with 10 diseased eyes were male and 15 patients with 15 diseased eyes were female. The age of these patients ranged from 60 to 79 years old, with a mean age of 71.0±3.5 years old. A total of 4 patients developed cataracts following glaucoma trabeculectomy and received phacoemulsification and foldable IOL implantation. A total of 21 patients received phacoemulsification and foldable IOL implantation due to cataracts. All surgeries were successful and no early intraoperative or postoperative complications occurred. Visual acuity upon discharge following cataract surgery ranged between 4.4 and 4.9. None of the 25 patients unwent Nd:YAG treatment.

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Occurrence of CCS. Time for CCS occurrence was monitored between discharge from hospital following phacoemulsification and the date patients complained of decreased visual acuity during the 4-, 12- and 24-week follow-ups. A total of 4 cases (4 eyes) of CCS occurred within week 4 to 5 following phacoemulsification, and the same number occurred within week 7-9; however, 7 cases (7 eyes) of CCS occurred within week 11-14, 8 cases (8 eyes) of CCS occurred within week 18-22 and 2 cases (2 eyes) of CCS occurred within week 24-27. The mean time was 14±2 weeks following phacoemulsification.

Clinical manifestations. All patients complained that the visual acuity of the operated eye significantly decreased compared with the visual acuity upon discharge following cataract surgery. Among these patients, 6 eyes had a visual acuity of <4.0, 14 eyes had a visual acuity that ranged between 4.0-4.2 and 5 eyes had a visual acuity that ranged between 4.3-4.5. In addition, glare occurred in 7 eyes and monocular diplopia occurred in 3 eyes. Seven eyes (7 patients) exhibited a white anterior capsular membrane behind the pupillary margin under a slit lamp. During pupil examination, white hyperplasia of the fibrous membrane appeared under the anterior capsule, annular fiber of the anterior capsule opening proliferated and thickened, and dislocation of the anterior capsule opening occurred in all cases. Furthermore, the transparent area shrunk and was deformed, with a diameter that ranged within 1.5-2.5 mm. Surrounding capsule shrinkage and folds of the posterior capsule were evident. In addition, the central optical region was covered completely (Fig. 1). Seven eyes exhibited IOL decentration and 5 eyes exhibited tilted IOL. Furthermore, the IOL was clamped inside the capsule in 1 eye and 2 eyes exhibited opacity in the mid-peripheral part of the cornea. The ocular fundi in the majority of diseased eyes could not be clearly viewed.

Surgical indications. Several indications suggested eyes were not suitable to receive Nd:YAG laser treatment. First, if the anterior capsule opening and anterior capsule hyperplasia were thicker, the fiber ring width was ≥1.5 mm and the anterior capsule opening was closed or ≤1.5 mm, it was determined that laser treatment would not achieve a beneficial therapeutic effect. The anterior capsule opening and anterior capsule hyperplasia were determined to be 'thicker' based on the experiences of the examining doctor. Furthermore, Nd:YAG laser treatment was not suitable if IOL deviation was evident, the IOL was hard to spontaneously reset following laser capsular relaxation, corneal scarring was present (this made it difficult for the laser to accurately focus on the eye), nystagmus or fixation could not be achieved, patients did not cooperate, IOL was prone to laser damage or the IOL was clamped inside the capsule.

Surgical methods. Radial incision surgery were performed. Prior to surgery, mydriasis was fully induced using compound tropicamide eye drops. Under surface anesthesia, a 3.0-mm corneal incision was made at the 11 o'clock position and the viscoelastic agent was injected into anterior chamber and under the anterior capsule. For eyes with adhesions, the fibrous membrane and IOL edge were separated with a discission needle or the loop adhesion was separated to fully free the anterior capsular membrane at the predetermined incision. The organized thickening edge of the anterior capsule opening was cut into four to six 1.5-2.5 mm equidistant actinoid incisions using capsule scissors. The IOL was adjusted to reset the correct position. If the fibrous membrane at the 2 o'clock position of the anterior capsule opening was difficult to cut, an aperture was first made at the site 1.5-2.5 mm from the fibrous membrane of the anterior capsule opening edge using a paracentesis knife or capsulotomy. Following this, the viscoelastic agent was injected into the aperture to induce swelling. The inferior scissor of the capsule scissors was pierced into the aperture and the membrane was cut off at the central opening. Following actinoid relaxing incision, the anterior capsule opening would grow zig-zag-like or hub-and-spoke-organized anterior capsular segments. These thick and tough segments can be cut off from the root with capsule scissors or removed using a vitrectomy knife. These surgical procedures can expand the anterior capsule opening to a relative circular shape. In the present study, a total 15 eyes (15 cases) underwent actinoid relaxing incisions (Fig. 2). Other patients did not receive actinoid relaxing incisions, as the surgeons were able to perform annular capsulorhexis.

CCC was also performed twice on diseased eyes to remove the fiber membrane under specific conditions. For these diseased eyes that had a completely closed anterior capsule opening, an aperture was first made in the center, paracenter or edge of the fibrous membrane with a straight knife or 1-ml needle bend at the head, which was used as a cystotome. Subsequently, the viscoelastic agent was injected into the aperture to separate the adhesion between the fibrous membrane and the optical part of the IOL, and a strip of triangle segment obliquely stretching beneath the nose or temporal was made on the edge of the aperture. Following this, the root of the triangle segment was clipped with capsulorhexis forceps to remove the fibrous membrane using the CCC method. For diseased eyes with an anterior capsule opening that was almost closed, a triangle segment was made at the 3 or 9 o'clock position on the edge of the anterior capsule opening, followed by a secondary CCC. Following capsule relaxation, the IOL was stretched to a flat shape by itself. An appropriate adjustment should be conducted to reset the IOL to the correct position. In the present study, a total of 10 diseased eyes (10 cases) received CCC (Fig. 3). In the remaining patients, the fibrous membrane could not be dissected during CCC due to the thick hyperplasia of the Lens Epithelial Cells.

Slit lamp examination. All operated eyes were examined using a slit-lamp, under non-mydriatic and mydriatic states. During the 1-, 3- and 6-month follow-ups, non-mydriatic and mydriatic slit lamp examinations were conducted.

Visual acuity examination. In the present study, preoperative and postoperative visual acuity was assessed using the quintile method (8). Patients were followed-up once at 1, 3 and 6 months following surgery.

Statistical analysis. Data were analyzed using SPSS 13.0 statistical analysis software (SPSS, Inc., Chicago, IL,

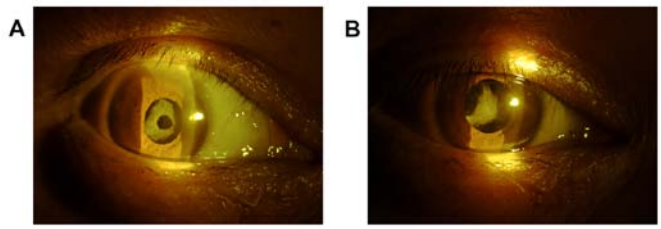

Figure 1. Slit-lamp micrograph of capsule contraction syndrome. (A) At 4 weeks following phacoemulsification and foldable IOL implantation for cataracts, the circular fibers of the capsulorhexis were thickened, the anterior capsule had turned white and the transparent area of the capsulorhexis was reduced. (B) At 6 weeks following phacoemulsification and foldable IOL implantation for cataracts, fibrous rings were further reduced until the central optical area was completely covered.

Table I. Comparison of preoperative and postoperative the final follow-up.

Variable	Number of preoperative eyes	Number of postoperative eyes
Eyesight score		
<4.0	6	0
4.0-4.2	14	1
4.3-4.5	5	5
4.6-4.8	0	15
>4.8	0	4
Total number	25	25

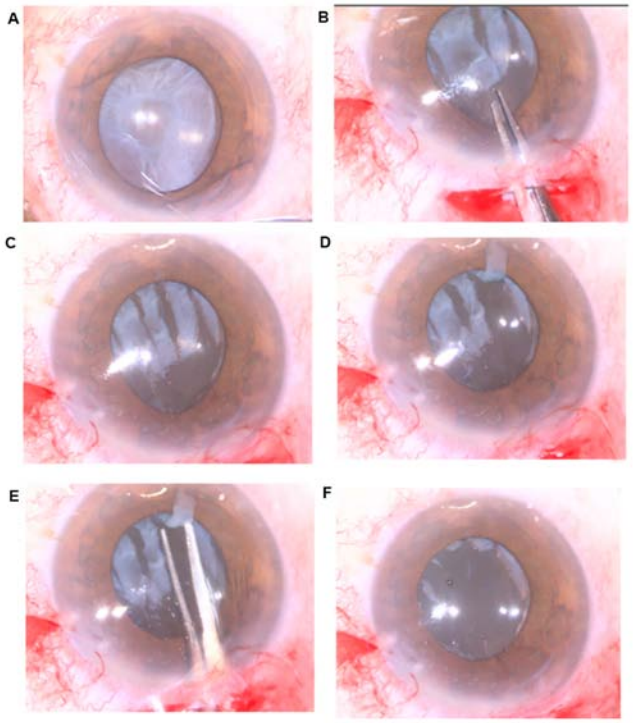

Figure 2. Surgical microphotograph of patients who are made a radial incision. (A) Prior to capsular bag relaxation, the circular fibers of the capsulorhexis were thickened, the anterior capsule had turned white and the transparent area of the capsulorhexis was reduced until complete membranous seclusion. (B and C) The anterior capsule was cut off using capsulotomy scissors in a radial shape. The cut capsule pieces were strip-shaped. (D) Stripped fibrous membrane pieces were warped with a viscoelastic agent. (E) Stripped fibrous membrane pieces were removed with capsulotomy scissors. (F) Once the fibrous membrane pieces were removed piece by piece, that pupil area was clear.

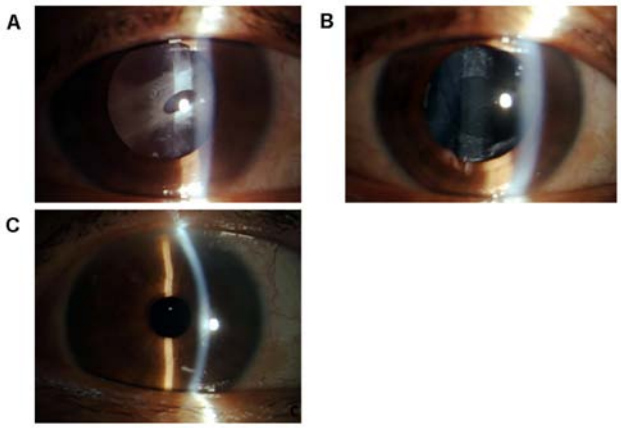

Figure 3. Slit-lamp micrograph of patients who receive a second annular capsulorhexis. (A) Prior to surgery, the annular fiber hyperplasia of the capsulorhexis became thickened, the anterior capsule had turned white, the transparent area of the capsulorhexis was reduced and deformed, becoming oval in shape. (B) Image under mydriatic status following the surgery. Fbrous rings were relaxed at the edge of the capsulorhexis, the capsule was contracted and was no longer evident, the transparent area of the capsulorhexis had markedly expanded. (C) Image under nonmydriatic status following the surgery. The pupil area was clear.

USA). Preoperative and postoperative visual acuity changes were compared using a signed rank sum test. P<0.05 was considered to indicate a statistically significant difference.

Results

Postoperative visual acuity. Visual acuity of all operated eyes improved to different extents. Visual differences pre- and post-surgery were statistically significant (u=5.143; P<0.01), suggesting the objective visual clarity was significantly improved following surgery. Glare and monocular diplopia were no longer evident. Preoperative and postoperative uncorrected visual acuity (UCVA) obtained during the final follow-up are indicated in Table I. One diseased eye with a postoperative UCVA of 4.1 at the final follow-up was confirmed to have cystoid macular edema following a fundus examination and optical coherence tomography. Notably, this condition may be associated with the stimuli on the macula in the cataract surgery, radial incision surgery and a second CCC.

Slit lamp examination. Under the non-mydriatic state, all pupil areas were clear and no white fibrous membrane of the anterior capsule was observed. Under the mydriatic state, the fibrous ring of anterior capsule opening was identified as relaxed, the lens capsular bag shrunk or was no longer evident and the area of the transparent zone of the anterior capsule opening was expanded to a diameter of 5.0-6.0 mm. The IOL was located inside the lens capsular bag and was centrally positioned without deviation or tilt. The optical part of the IOL was stretched, flat and not clipped. There was also no occurrence of fracture of the IOL optical section, zonular

dehiscence or actinoid tear at any site, except for the anterior or posterior capsular membranes. The posterior capsule was closely attached to the posterior surface of the IOL. Sectional edges of the anterior capsule openings of diseased eyes that underwent actinoid relaxing incisions were slightly serrated, while diseased eyes that underwent secondary CCC were smooth.

Postoperative follow-up. Patients were followed-up once at 1, 3 and 6 months postoperatively. Under the non-mydriatic state, the pupil area was clear and the anterior capsule opening edge was not visible. Under the mydriatic state, the IOL position was good, the area of the transparent zone of the anterior capsule opening did not reveal any shrinkage and no recurrence of CCS was identified. At the last follow-up, only one operated eye that underwent secondary CCC was indicated to have fibrous ring hyperplasia at the edge of the CCC. The capsular opening was not reduced in this case.

Discussion

CCS is a rare complication that occurs after phacoemulsification if a CCC procedure is adopted (9). CCS is associated with surgical trauma, IOL material stimulus, postoperative inflammation, damage of the blood aqueous barrier and blood-retinal barrier, the inappropriate small diameter of CCC and decentration (8,9). The above factors cause residual lens epithelial cells (LECs) under the anterior capsular membrane to proliferate and differentiate into fibroblasts with the sphincter contraction effect. LECs begin to accumulate under the capsulorhexis opening and the surrounding capsule, forming a thick fibrous ring membrane, which causes the anterior capsule to undergo centripetal contraction (10,11). Subsequently, the anterior capsule opening area and the equatorial diameter is reduced; causing visual impairment, glare, refractive change, IOL tilt and deviation (12). Hence, CCS is a rare clinical manifestation that can occur after CCC, and LECs serve a leading role in capsule contraction (13,14).

At present, the primary treatment for CCS is Nd:YAG laser treatment or surgery (5). Nd:YAG laser treatment is an effective, safe, convenient and cheap treatment method for CCS (15). This method can expand the area of the anterior capsule opening transparent zone and restore visual function (15). However, some diseased eyes are not suitable for laser treatment due to a number of reasons. Patients with obvious IOL deviations whose IOL was difficult to spontaneously reset following laser capsular release, whereas in other patients with corneal scars, focusing the laser accurately into the eyes is difficult; in addition, patients who had nystagmus, whose IOL was easily damaged by laser and or with the intracapsular clamping of IOL are also not suitable for laser treatment (5,14). In the authors' clinical experience, they have determined that for some diseased eyes that have received laser treatment without therapeutic effect, although increased laser energy can cut off the anterior capsule, under this condition, the adverse reaction has been severe, the number of complications has been large and the relaxing effect has been poor. Additionally, the authors of the current study have found that the deviated or clipped IOL has been difficult to reset, or have even caused damage to the IOL (16,17). Therefore, surgical treatment (CBRS) should be performed (18). Our previous study reported the results of CBRS (19). On the basis of previous studies (4,5,7), more cases and imaging data were collected to assess the surgical procedure of CBRS more visually in the present study.

In the present study, the CBRS procedure comprised of two methods; namely, the actinoid relaxing incision and secondary CCC. Actinoid relaxing incisions can be applied to the following types of patients: Patients who refuse to cooperate, patients whose eyes are not tolerant to Nd:AG laser treatment or patients who do not have serious anterior capsular membrane closure. In actinoid relaxing incisions, capsule scissors were pierced in the aperture from the edge of the anterior capsule opening. Following this, an incision was cut every 60˚ or 90˚ to form an actinoid shape. When cutting, the incisions were made to co-elongate and be equidistant as far as possible in order to achieve the following objectives: Make the incision tension equal, ease capsular tension, enable the edge of the anterior capsule opening to cover the edge of the IOL optical part at 0.5-1.0 mm and flatten the IOL optical part. In addition, the IOL was adjusted to a central position. Since corneal incisions are located at the upper part of the fibrous hyperplastic membrane, it is difficult to cut off the fibrous ring at the edge of the anterior capsule opening. If the fibrous ring cannot be cut off, dicing should be conducted with the side cutting edge of the discission needle. For diseased eyes with a thick fibrous ring at the anterior capsule opening, an aperture should be pre-made in the fibrous membrane above the anterior capsule opening with a straight knife or capsule-cutting knife. The inferior scissor of the capsule scissors was pierced into the aperture, and the fibrous ring of capsule opening was cut as described previously (14). Following this, in the present study, relaxing incisions in other parts were made. From the clinical experience of the authors of the current study, once actinoid relaxing incision was performed, the anterior capsule opening can grow zig-zag-like or hub-and-spoke-organized anterior capsular segments. The authors have found that the majority of these segments are thick and tough, and some of the front-end may cock up and move with the contraction and relaxation of the pupil. Additionally, the authors determined that these may rub the pupil edge and iris pigment membrane, and lead to iritis or the accumulation of free iris pigments in the anterior chamber angle; and further result in elevated intraocular pressure. Therefore, considering this situation, these large, long, thick and tough segments should be cut off from the root with capsule scissors and taken out or removed using a vitrectomy knife; expanding the capsulorhexis opening to a relative circular shape. However, resection using an anterior vitrectomy knife can be time consuming (20). In the present study, 15 eyes underwent actinoid incisions of the anterior capsule opening; in which fibrous segments were removed from 4 eyes using a vitrectomy knife.

The CCC method is also known as secondary capsulorhexis; that is, an expanding capsulorhexis is conducted again outside the narrowing anterior capsule opening (21). The present study found that this method is suitable for diseased eyes that have closed or near-closed fibrotic tissue in the anterior capsule opening in patients who exhibited no fibrosis or thin fibrosis in the peripheral anterior capsule

of the fibrous membrane. The authors also demonstrated that the edge of the anterior capsule opening can be swollen with viscoelastic agent, an oblique segment can be made at the 3 or 9 o'clock position with capsule scissors, the root of the segment may be clipped with capsulorhexis forceps and secondary expanding CCC is conducted. Following this, the IOL may be adjusted and restored to its correct position. In the present study, the area of the transparent zone was set to 5.0-6.0 mm in diameter and the effect was the optimal when the edge of anterior capsule opening covered 0.5 mm of the edge of the IOL optical part. From the clinical experience of the authors of the current study, if the anterior capsule opening is completely closed, an aperture should be made on the fibrous membrane of the anterior capsule in advance, as aforementioned. Then, CCC may be conducted. However, the authors note that it is sometimes difficult to conduct capsulorhexis, since the trajectory is exactly on the thick fibrous membrane. Hence, an oblique segment should be made on the other side, and reverse capsulorhexis can be conducted. When necessary, a combination of tearing and cutting should be used; that is, when a fibrous tissue is difficult to tear apart, it can be cut open using capsule scissors; and then, these are torn apart. The authors advise that when tearing and cutting, caution should be given in performing these procedures and making excessive expansions or rupturing the capsular opening should be avoided. The advantage of the CCC method is that its edge is smooth; hence, the stability of the IOL in the capsule is improved (22). However, the authors of the current study noted that during their clinical experience, if the fibrous membrane is wide and thick, the zonule would be tugged during the capsulorhexis. A forced capsulorhexis may lead to rupture of the zonule. Hence, under this condition, the authors hypothesize that the actinoid segment method is suitable.

The disadvantage of the radial incision sac lysis and annular capsulorhexis lysis methods is indicated during poor zonular function, when the procedure may injure a zonule and induce the IOL to deviate, particularly in diseased eyes with a can-shaped capsular opening (15). Primary complications, including anterior vitreous prolapse, pupillary block, elevated intraocular pressure, capsular rupture, zonular dehiscence, corneal edema and macular edema have been specified in a previous study (23). However, in the present study, these complications did not occur. Measures should be taken to avoid these injuries and care should be taken during the separation of the adhesion. Furthermore, force should be avoided when shearing the tough, thick fibrous membrane or performing secondary capsulorhexis. From their clinical experience, the authors of the current study observed that adhesions between the fibrous membrane and anterior capsule membrane or IOL were sometimes serious and were difficult to separate. Hence, these adhesions should be first sliced with a discission needle once the edge of the anterior capsule opening is exposed. Cutting should be performed whilst pushing with the capsule scissors to fully free the anterior capsular membrane being removed. The authors of he current study also found that the proliferation ability of LECs was reduced 3 months after cataract surgery; hence, the possibility of recurrence of CCS following CBRS was very small. CCS relapse depends on the condition of capsular lens bag, which can be normal or contracted and the front of anterior capsule opening can be normal or contracted. Although one case had an edema, this occurred in the macula retinae, not in the lens capsular bag. Therefore, in the present study, no CCS relapse was identified in the 25 diseased eyes.

CCS is a rare complication after cataract phacoemulsification that is associated with CCC contraction (9). In order to avoid this, focus should be made on prevention, emphasis should be made on perfecting phacoemulsification, the CCC procedure should be normalized, the fibrous membrane should be removed thoroughly, the capsule should be polished and the implanted IOL should be centered (24). Furthermore, patients should be regularly followed-up following phacoemulsification and IOL implantation. Mydriatic examination should be conducted when patients complain of vision or visual change in order to detect CCS early and provide timely treatment. Laser and surgery are the primary treatments for CCS (25,26). However, in some severe cases or cases not suitable for laser treatment, surgery is the sole choice. In the present study, CBRS was conducted. Actinoid relaxing incision and secondary CCC methods were demonstrated to have positive effects. Hence, a suitable method should be chosen based on the local features of CCS or a combination of these two methods.

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Availability of data and materials

The datasets used and/or analyzed during the present study available from the corresponding author on reasonable request.

Authors' contributions

DJX performed the surgery and drafted the manuscript. LJZ revised the manuscript and guided the treatment plan. HJW acquired, analyzed and interpretation of data.

Ethics approval and consent to participate

The current study was conducted with approval from the Ethics Committee of Taizhou Municipal Hospital of Taizhou University (Zhejiang, China). Written informed consent was obtained from all individuals involved.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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