Study On the Effectiveness and Safety of FCVB Implantation

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Research Article

Keywords: Vitreoretinal disease; vitrectomy; FCVB; intraocular pressure

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Abstract

Background: To investigate the efficacy and safety of the foldable capsular vitreous body (FCVB) in the treatment of vitreoretinal diseases.

Methods: A retrospective analysis was conducted involving 20 patients (20 eyes) who underwent FCVB implantation in our hospital from September 2017 to April 2018. All the patients underwent vitrectomy and FCVB implantation, a standard three-port vitrectomy was performed, and the FCVB was implanted into the vitreous cavity. At 6 months after surgery, the visual acuity chart, Goldmann applanation tonometer, fundus photography, B-ultrasound examination, and optical coherence tomography (OCT) examination were performed on the treated eyes. The patients’ vision, intraocular pressure, retinal reattachment, and FCVB status were observed.

Results: Compared with the preoperative measurements, there was no change in visual acuity in 18 eyes at 6 months after FCVB implantation, and the difference was not significant (P=1.000); the intraocular pressure of these 18 eyes returned to normal, and the difference was significant (P=0.00001); in fundus photography images of these 18 eyes, B-ultrasound, OCT showed good retinal reattachment, FCVB distributed well in the vitreous cavity and evenly supported the vitreous retina and there was no obvious abnormality. The eyes were symmetrical, and the eyeball activity was normal. One patient developed eyeball atrophy after surgery, and one patient developed ocular inflammation after surgery. The condition improved after treatment.

Conclusions: FCVB is an effective and safe vitreous substitute during the 6-month implantation period and is able to maintain eye shape, intraocular pressure and good aesthetics.

Keywords: Vitreoretinal disease; vitrectomy; FCVB; intraocular pressure.

Background

The main physiological functions of the vitreous body are to support the retina, ocular refraction, cell barrier, nutrition and promote intraocular metabolism, etc. Due to the inability of the natural vitreous to regenerate, vitreoretinectomy is required when vitreoretinal diseases occur, such as retinal detachment due to severe ocular trauma, traumatic proliferative vitreoretinopathy, proliferative vitreoretinopathy, proliferative diabetic retinopathy or endophthalmitis. The natural vitreous body is excised and filled with capsular vitreous substitutes to repair the eye damage, support the retina, promote the anatomical reduction of the retina, re-establish visual function, and prevent the eyeball from shrinking. Currently, capsular vitreous bodies commonly used in clinical practice mainly include gases, heavy water, silicone oil, heavy silicone oil, etc., which, however, have a short-term life-span the eye, or suffer from serious disadvantages such as high toxicity, many complications, disordered flow in the eye or difficulty in taking out. Researchers have been working hard to find suitable capsular vitreous bodies and development of new capsular vitreous bodies has become the focus of research worldwide.
FCVB is an innovative product initially developed independently by China. It was designed by simulating the shape of the natural human natural vitreous cavity, possesses excellent mechanical properties, optical properties and biocompatibility, and can adequately maintain the shape and intraocular pressure of the eyeball, thus avoiding the risk of repeated replacement of silicone oil and eyeball removal\cite{4}, the complications of silicone oil associated with long-term compression of the retina, and does not require the placement of patients in special positions, such as the prone position, after the operation. The safety and efficacy of FCVB were initially confirmed through a series of animal studies, a standard process prior to clinical trials\cite{5-7}. However, the clinical applications of FCVB have not been verified yet, and the number of previous studies has also been relatively small. In this study, FCVB implantation was performed on 20 patients of different ages and genders including children, adolescents, middle-aged and older people, in order to further study and analyze the clinical safety and efficacy of FCVB.

**Methods**

**Research Objective**

A retrospective analysis of 20 cases involving 20 patients with FCVB implantation was conducted between September 2017 and April 2018. The basic demographic information of the patients is shown in Table 1. The average age was 40.05 years old (1-65 years old), including 17 males and 3 females. There were 13 cases of eyeball rupture, 5 cases of silicone oil dependent eyes, one case of endophthalmitis, and one case of eyeball atrophy. The inclusion criteria were as follows: eyeball atrophy, silicone oil dependent eye, visual acuity less than 0.05, severe eyeball rupture. The exclusion criteria were contraindications approved by the CFDA.

Before the operation, the patients and their families were informed about the operation and implant related matters, and an informed consent was signed. The study was approved by the hospital ethics committee (2017006).

**Treatment Methods**

FCVB implantation for this group of 20 patients with 20 eyes. Operating procedures: (1) Routine disinfection before operation, anaesthesia after eyeball block. (2) 3.5 mm behind the limbus as a standard three-channel, perfusion under the iliac crest, excision of the vitreous body, removal of the intraocular haemorrhage and the subchoroidal haemorrhage. For severe ocular trauma, retain and evaluate the retina as much as possible; extract silicone oil for silicone oil dependent eyes, fluid-air exchange and flat omentum. (3) Detect the airtightness of the balloon underwater. (4) Fold the capsular vitreous body into the pusher. (5) Enlarge the scleral puncture from 3 to 4 mm and insert the head of the pusher into the vitreous cavity. The incision can be enlarged from the contralateral side if the ciliary body is detached. (6) The lens portion of the balloon is placed upwards, the balloon is then fully deployed, and the mesh membrane is opened with the support of the FCVB. (7) Penetrate from the drainage valve of the balloon, and slowly push in the silicone oil to observe the position of the capsular vitreous body. If there is
tilting, use a blunt device to properly adjust the position and fill it to an intraocular pressure of approximately 15 mmHg. (8) The light guiding fibre is placed from the upper puncture port, and the retinal levelling and the colour of the optic disc are observed under the whole retina. (9) Ligate the balloon tail, fix under the conjunctiva of the iliac crest and suture the conjunctiva. Systemic and local anti-inflammatory and corticosteroid medications are given within 2 months after the operation.

Therapeutic Observations

The Snellen eye chart, Goldmann applanation tonometer, fundus photography, B-ultrasound and OCT were performed on the patients before and after the operation, and the patients' visual acuity, intraocular pressure, retina and FCVB status were recorded.

Statistical Analysis

Statistical processing was performed using SPSS 23.0 statistical software. The t-test was used to compare the data between the groups. P<0.05 was considered statistically significant.

Results

Analysis of The Efficacy of FCVB Implantation

Contrast analysis of visual acuity and intraocular pressure before and after the operation was conducted in 20 patients. Only one patient's visual acuity observed an improvement from LP-HM to FC/30 cm, while there were no significant changes in the visual acuity of the other patients before and after the operation (P=1.000), as seen from Table 2. The intraocular pressure was normal in 4 cases, low in 13 cases and high in 3 cases before operation, while 2 cases presented low intraocular pressures, and the other 18 cases of elevated intraocular pressure returned to normal in six months after the operation. The difference between preoperative and postoperative intraocular pressures was statistically significant (P=0.000017). The results are shown in Table 3.

Six months after FCVB implantation, B-ultrasound showed that 6 of the 20 patients had retinal reattachment, and the retina of the other 14 was lost or damaged before or during operation due to severe eye damage. The FCVB was properly positioned and was well distributed within the vitreous cavity. The retinal and FCVB status are detailed in case 3 and case 12.

Case 3- The preoperative B-ultrasound showed strong echogenic spots (bleeding) visible in the vitreous cavity connected to the wall of the ball (Fig. 1A). Case 12- The preoperative B-ultrasound showed visible banded echoes in the vitreous body and visible point sheet turbidity between the walls of the eyeball (Fig. 2A). The postoperative B-ultrasound of cases 3 and 12 showed the following: pseudo-expansion of the eyeball and good distribution of the FCVB in the vitreous cavity without any obvious abnormalities (Fig. 1B, Fig. 2B). Examination of the fundus showed that the fundus was clearly visible after the FCVB was filled, thus adequately supporting the retina and the entire eyeball. The retina was flat without wrinkles and the OCT showed that the fovea had a vague
structure and that there were no obvious abnormal signs on the omentum (Fig. 1D, Fig. 2D). The cornea of case 3 was transparent, the anterior chamber was clear, the FCVB position was positive, a layer of mechanical membrane was seen on the anterior surface and the intraocular pressure was 10 mmHg six months after operation (Fig. 1E). The cornea of case 12 was transparent, the anterior chamber was clear, the FCVB position was transparent and the intraocular pressure was 13 mmHg after 6 months (Fig. 2E). In cases 3 and case 12, the eyes were symmetrical and the eyeballs were normal after 6 months (Fig. 1F, Fig. 2F).

According to these data, it can be seen that the FCVB was well distributed in the vitreous cavity and that the support for the retina was uniform.

Safety Analysis of FCVB Implantation

All 20 patients had a successful operation, and there were no intraoperative complications. However, 3 patients presented a slight degree of haematocele in the anterior chamber after the operation. The presumed reason for this complication was that the incision may have haemorrhaged, or the tip of the product may have pierced the intraocular tissue during implantation. The haemorrhage of the anterior chamber disappeared after conservative treatments such as haemostasis and lowering of the intraocular pressure. Another patient developed an inflammatory reaction in the eye after the operation but the condition improved after treatment with anti-inflammatory and hormonal drugs. In addition, one patient developed eyeball atrophy after implantation of the FCVB due to the small design of the balloon. The condition was stable and the patient feedback was satisfactory after subsequent adjustments had been implemented. The remaining patients did not have obvious complications such as anterior chamber haemorrhage, development of a fibrous membrane, drainage tube exposure, balloon rupture, silicone oil spillage, and high intraocular pressure.

Discussion

The foldable capsular vitreous body changes the traditional supporting retinal pattern. The FCVB can support the retina with a 360-degree curved solid, with a long-lasting pressing effect on the entire retina, without limiting the patient's sleeping position, while the silicone oil is simply injected to avoid complications caused by silicone oil entering the anterior chamber, because of which the patient is often required to maintain a face-down position for a long time. However, the foldable capsular vitreous body implantation greatly reduces the occurrence of complications in elderly patients and patients who cannot tolerate the prone position [8]. The silicone oil can be extracted or injected with saline and silicone oil to regulate the intraocular pressure through the drainage valve of the FCVB [9]. In this study, 20 patients requiring vitrectomy were subjected to natural vitrectomy and FCVB filling. The clinical results showed that implantation of the FCVB can restore the eyeball structure and basic functions of the patient and maintain good aesthetics. This study shows that the FCVB is an effective and safe capsular vitreous body implantation technique and is superior to other capsular vitreous bodies used in the clinical treatment of patients who have undergone vitrectomy.
The current clinical applications of the FCVB are still in the exploration stage and there are currently no large-scale promotions. In domestic and foreign research reports, Lin et al.\[[10]\] performed 11 months of FCVB implantation in 11 patients with severe retinal detachment and conducted related laboratory analyses. The results showed that FCVB can safely and effectively promote the anatomical reduction of the retina to avoid the emulsification of the silicone oil into the anterior chamber, corneal damage and other complications, showing good application prospects. In addition, the efficacy and safety of the FCVB was demonstrated in another three-year follow-up trial\[[11]\]. In a recent study involving 4 clinical cases, Zhang Guisen et al.\[[12]\] suggested that FCVB implantation is safe and effective in treating severe ocular ruptures and silicone oil-dependent eyes, and can maintain eye shape and intraocular pressure well. In this study, the structure and partial functions of the eyes of 20 patients gradually recovered after 6 months of FCVB implantation. The intraocular pressure of the patients returned to normal after FCVB implantation. The FCVB was well distributed in the vitreous cavity and adequately supported the retina and the entire eyeball. The retina was flat without wrinkles. There were no obvious abnormal signs on the omentum, the appearance of the eye was good, and the eyeball activity was normal during the 6-month implantation period. This study concluded that FCVB was effective in this exploratory clinical trial and can be promoted based on these data.

At present, the common capsular vitreous body substitutes are often unable to maintain intraocular pressure for a long time and may cause complications such as silicone oil emulsification, corneal degeneration and secondary glaucoma\[[13][14]\]. It is worth mentioning that although silicone oil is widely used in intraocular fillings, the incidence rate of silicone oil emulsification is high. A study by Federman et al.\[[15]\] showed that silicone oil emulsification occurred in 150 eyes of their study subjects within one year. Another study showed that the silicone oil emulsification time ranged from 5 to 24 months, indicating that most silicone oil emulsification occurred within one year\[[16]\]. In this study, 20 patients were reviewed after 6 months from the operation. The results showed that there were no complications such as silicone oil emulsification, corneal degeneration and high intraocular pressure. Only two patients had adverse events; one had mild eyeball atrophy and the other had an inflammatory reaction, which improved and stabilized after treatment. The feedback from the latter patient was satisfactory. The results of this study further confirm the safety of FCVB implantation in a clinic setting.

In addition, compared with adult severe eye diseases, the prognosis for children after the operation is far worse than that of adults and the consequences are more serious\[[17]\]. A complete eyeball is more conducive to the development of the tibia of children. At present, vitrectomy is an indispensable means to treat severe ocular trauma in children, since it avoids any aesthetic defects caused by eyeball removal\[[18]\]. Three children were included in the study and their intraocular pressure returned to normal without the occurrence of any postoperative complications and adverse reactions. The aesthetics of these patients after vitrectomy and FCVB implantation was satisfactory. Aesthetics is an important factor, since it may affect not only the appearance of the patient but may also have an effect on their psychological state, which may have already been impacted by the loss of visual function.
Research on FCVB is also dedicated to its role in in vivo drug delivery systems (DDS). There are 300-nm pores in the FCVB balloon. FCVB can release dexamethasone sodium phosphate continuously and mechanically. Therefore, FCVB can also act as an in vivo drug delivery system apart from acting as a substitute for the vitreous body\textsuperscript{[19]}. FCVB is a new potential method for combining vitreous substitutes with drug therapy, and further research will be conducted by our group in this regard.

**Conclusions**

FCVB is an effective and safe vitreous substitute during the 6-month implantation period since it is able to maintain eye shape and intraocular pressure well. We will further expand the sample size and extend the observation time to determine the clinical efficacy of FCVB and accumulate more clinical data during the follow-up period.

**Abbreviations**

FCVB: foldable capsular vitreous body  
OCT: optical coherence tomography  
CFDA: China Food and Drug Administration  
SPSS: Statistical Product and Service Solutions  
LP: light perception  
HM: hand motion  
FC: finger count  
DDS: drug delivery systems

**Declarations**

**Ethics approval and consent to participate:** This study was approved by the health Authority BioMed Research International Ethical Committee of the 988 Hospital of People's Liberation Army. The parents of the patients under the age of 16 gave consent to participate on their behalf. All participants provided written informed consent.

**Consent for publication:** We have obtained consent for publication from the patients or the parents of patients under the age of 18 that have been included in our study.

**Availability of data and material:** Submission of our manuscript to a BMC journal implies that materials described in the manuscript, including all relevant raw data, will be freely available to any scientist poses, without breaching participant confidentiality.
**Competing interests**: We declare that we have no competing interests.

**Funding**: We have stated that we get no funding.

**Authors’ contributions**: XY Z designed this study. XM T and BK Z collected and analyzed the data and generated the figures. XY Z and LS G involved with the manuscript development and proofreading. XD L reviewed and revised the manuscript. XY Z, XM T and Y J approved the final version of the manuscript. All authors read and approved the final manuscript.

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Tables

Table 1 Preoperative general information and eye diagnosis information of patients
| Patient | Age (y) | Sex  | Diagnosis                                                                 |
|---------|---------|------|---------------------------------------------------------------------------|
| 01      | 29      | male | ophthalmorrhæxis,                                                        |
|         |         |      | irideremia, explosive choroidal haemorrhage                              |
| 02      | 45      | male | ocular rupture                                                            |
|         |         |      | irideremia, lens and chorioretinal loss, explosive choroidal haemorrhage   |
| 03      | 65      | male | ophthalmorrhæxis,                                                        |
|         |         |      | giant ciliary body detachment, explosive                                  |
|         |         |      | choroidal haemorrhage                                                     |
| 04      | 52      | male | ophthalmorrhæxis,                                                        |
|         |         |      | irideremia, lens loss, explosive choroidal haemorrhage                    |
| 05      | 27      | male | ophthalmorrhæxis,                                                        |
|         |         |      | irideremia, lens loss, explosive choroidal haemorrhage                    |
| 06      | 55      | female | ophthalmorrhæxis,                                                      |
|         |         |      | irideremia, lens loss, explosive choroidal haemorrhage                    |
| 07      | 63      | male | ophthalmorrhæxis,                                                        |
|         |         |      | irideremia, lens loss, explosive choroidal haemorrhage, ciliary body detachment |
| 08      | 18      | male | endophthalmitis                                                           |
|         |         |      | corneal degeneration, lens loss                                           |
| 09      | 62      | male | silicone oil dependent eye                                               |
|         |         |      | retinal detachment, macular hole                                          |
| 10      | 22      | male | eyeball atrophy, lens calcification, omental atrophy                     |
| 11      | 2       | male | ophthalmorrhæxis,                                                        |
|         |         |      | irideremia, explosive choroidal haemorrhage                              |
| 12      | 5       | female | silicone oil dependent eye                                              |
|         |         |      | retinal atrophy                                                           |
| 13      | 47      | male | ophthalmorrhæxis,                                                        |
|         |         |      | explosive choroidal haemorrhage                                          |
|   |   |   |   |   |
|---|---|---|---|---|
|14 | 51| male| silicone oil dependent eye  
corneal degeneration, irideremia, omental proliferation |
|15 | 6 | male| silicone oil dependent eye  
corneal degeneration, omental proliferation |
|16 | 48| male| ophthalmorrhæaxis,  
giant ciliary body detachment, explosive choroidal haemorrhage |
|17 | 39| female| ophthalmorrhæaxis,  
irideremia, lens loss, explosive choroidal haemorrhage |
|18 | 65| male| ophthalmorrhæaxis,  
irideremia, lens loss, ciliary body detachment |
|19 | 57| male| silicone oil dependent eye  
retinal atrophy |
|20 | 43| male| ophthalmorrhæaxis,  
irideremia, lens loss, explosive choroidal haemorrhage |

**Table 2 Preoperative and Postoperative Visual Acuity (Number of Eyes)**

| Visual Acuity | NLP | LP-HM | FC/30 cm |
|---------------|-----|-------|----------|
| Preoperative  | 7   | 13    | 0        |
| Postoperative | 7   | 12    | 1        |

**Table 3 Preoperative and Postoperative Changes in Intraocular Pressure (Number of Eyes)**

| Intraocular Pressure | Tn-2 | Tn-1 | Tn | Tn+1 | Tn+2 |
|----------------------|------|------|----|------|------|
| Preoperative         | 6    | 7    | 4  | 2    | 1    |
| Postoperative        | 0    | 2    | 18*| 0    | 0    |

Note: *P<0.05, postoperative compared to preoperative.
Figures

Figure 1

Results of 6-month FCVB implantation in patient 3 - (A) Preoperative B-ultrasound. (B) Review of B-ultrasound 6 months after operation. (C) Fundus photography 6 months after operation. (D) OCT 6 months after operation. (E) Anterior photography 6 months after operation. (F) Binocular appearance 6 months after operation.
Figure 2

Results of 6-month FCVB implantation in patient 12 - (A) Preoperative B-ultrasound. (B) Review of B-ultrasound 6 months after operation. (C) Fundus photography 6 months after operation. (D) OCT 6 months after operation. (E) Anterior photography 6 months after operation. (F) Binocular appearance 6 months after operation.