· Clinical Research ·

Application of immersion B-scan ultrasonography in diagnosis of complex retinal detachment, persistent hyperplastic primary vitreous and intraocular tumors

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Abstract
• **AIM:** To evaluate the diagnostic value of panoramic immersion B-scan ultrasonography (Pano-immersion B-scan, PIB) in complex retinal detachment (RD), persistent hyperplastic primary vitreous (PHPV) and intraocular tumors.
• **METHODS:** The clinical data of 44 patients collected from May 2012 to December 2019 in Chinese PLA General Hospital was retrospectively studied. All of these patients underwent PIB of the eye, because it was difficult to diagnose by routine ocular fundus examination, conventional ultrasound or/and ultrasonic biomicroscope (UBM) due to opacity of refractive media, pupillary occlusion, large involvement or special location of the lesion. The imaging features of difficult cases in PIB were analyzed. The diagnosis accuracy rating of PIB were evaluated and contrasted with conventional ultrasound or UBM by the standard of intraoperative diagnosis or/and pathological results.
• **RESULTS:** According to intraoperative diagnosis or pathological results as gold standard, among the 44 cases, there were 19 cases missed diagnosis, misdiagnosed or difficult-to-diagnose by conventional ultrasound or UBM, including 4 cases of long-standing RD difficult to diagnose, 4 cases misdiagnosed, and 11 cases incompletely observed or miss diagnosed. The diagnostic accuracy rate of PIB and conventional ultrasound or UBM were 100% (44/44) and 56.82% (25/44), and the sensitivity of them were 100% and 56.82%. All the patients underwent PIB and were diagnosed as RD (15 cases), retinal and choroidal detachment (4 cases), subchoroidal hematocele (1 case), vitreous opacity and/or organic membrane formation (4 cases), PHPV (12 cases), iris and/or ciliary body tumors (3 cases), and choroidal tumors (6 cases). According to the intraoperative diagnosis or pathological results, the diagnostic coincidence rate of PIB was 100%, which was significantly higher than conventional ultrasound and UBM.
• **CONCLUSION:** PIB can help to accurately diagnose complex RD, PHPV, and intraocular masses with special location or/and excessive size. It has important diagnostic value for patients with equivocal findings at conventional ultrasound examination.
• **KEYWORDS:** immersion; ultrasonography; panoramic; retinal detachment; persistent hyperplastic primary vitreous; intraocular tumor
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INTRODUCTION

B-scan ultrasound, mainly used to help diagnose vitreous and retinal diseases, is a routine diagnostic method in ophthalmology because of it is convenient, low cost, non-invasive and not affected by opacity of refractive media[1-3]. Ultrasonic biomicroscope (UBM), because of its high frequency, can clearly image the anterior segment (from cornea to posterior capsule of lens) under normal condition, mainly used to observe the pathological changes of cornea, anterior chamber, ciliary body and lens[4-9]. The combination of B-Scan ultrasound and UBM can help to achieve accurate diagnosis and differential diagnosis of most common ocular diseases.

However, during clinical work, we found some special cases, such as lens abnormalities (*e.g.*, lens sublaxation), large space-occupying lesions in iris and ciliary body, and extensive fundus lesions were hard to diagnosis, because none of B-scan ultrasound, UBM, or their combination can help to achieve comprehensive observation. Based on our previous studies on the application of immersion B-scan ultrasonography (immersion B-scan) for preoperative axial length measurement in patients with complex cataract and for observation of lens in patients with severe chemical injury[10-11], it is potential that Pano-immersion B-scan (PIB) can help to make comprehensive observation and clear diagnosis of complex retinal detachment (RD), persistent hyperplastic primary vitreous (PHPV) and intraocular tumor of anterior position or/and excessive size. So, the present study used PIB to help diagnose complex RD, PHPV, and intraocular masses with equivocal findings at conventional ultrasound examination, and analyzed its clinical value.

SUBJECTS AND METHODS

Ethical Approval This is a retrospective non-control case study. The case data were obtained from PLA General Hospital. All subjects signed informed consent. And the study was approved by the Medical Ethics Committee of PLA General Hospital and in accordance with the ethical requirements of clinicl trials and the Declaration of Helsinki.

We collected clinical data of 44 patients who underwent PIB of the eye, because it was difficult to diagnose by routine ocular fundus examination, conventional ultrasound or/and UBM due to opacity of refractive media, pupillary occlusion, large involvement or special location of the lesion, from May 2012 to December 2019 in Chinese PLA General Hospital. There were 25 males and 19 females, aged from 2 to 83y. We analyzed the imaging features and advantages of PIB, compared with conventional ultrasound or UBM. And its diagnostic accuracy was evaluated according to intraoperative diagnosis or/and pathological results.

Conventional Ultrasound and Pano-immersion B-scan The conventional ultrasound and PIB were both performed with the A/B ultrasonic diagnostic instrument produced by Tianjin Suowei Company (SW-2100; SOUER, China). Conventional ultrasound examination: The patient was in the supine position, and the coupling agent was applied to the eyelid skin. The contact examination was carried out and the image was frozen. PIB: Filled the eye cup with normal saline, and A/B ultrasound probe was touched the water surface. Adjusted patient's eye position, probe immersion depth and ultrasound gain in real time according to B-scan ultrasound images. We took panoramic images of the eye and saved the local or global ones according to the location and extent of the lesion. All the ultrasound examinations were performed by three experienced physicians.

UBM examination: UBM produced by Tianjin Suowei Company (SW-3200, SOUER, China). In the supine position of the patient, after the cornea surface anesthesia by 0.4% obucaine hydrochloride eye drops, chose suitable type of eye cups to be placed in the conjunctival sac according to the size of palpebral fissure. The eye cup for the eye with symblepharon was partially buckled or placed on the eyelid skin with the palpebral fissure as wide as possible, and filled it with saline. The probe was placed in the solution and scanned horizontally and vertically, and the images are collected.

Treatment Method Patients with vitreous opacity combined with organic membrane traction were treated with vitrectomy and membrane peeling (with or without photocoagulation). Patients with RD with or without choroidal detachment were treated with vitrectomy combined with silicone oil tamponade. Patients with cataract underwent lens extraction and combined with intraocular lens implantation as needed. PHPV was mainly treated by surgery and its main purpose was the beauty of eyeball, prevention and treatment of complications and improvement of visual acuity. And its surgical method depended on the location of lesion and the complications, mainly lens extraction and/or vitrectomy, others including intraocular lens implantation, laser exfoliation and ciliary process photocoagulation, *etc*. Intraocular tumors were treated by tumor excision or eyeball enucleation according to the location, size and nature of lesions.

Statistical Analysis All the data were statistically analyzed in R3.6.3. Taking the results of surgery or pathology as the gold standard, we compared the diagnostic coincidence rate of conventional ultrasound, UBM, and PIB.

RESULTS

Assessment Method Taking the intraoperative and/or pathological results as the gold standard, the imaging features of PIB in difficult cases were analyzed, and the diagnostic accuracy was compared with conventional ultrasound and/or UBM.

Imaging Features of Pano-immersion B-scan Normal eye: The axis section image of PIB can show the whole eyeball structure (Figure 1A); RD: The beginning, the end, the continuity and the overall morphology of detached retina were observed in an all-round way. It generally showed "V" shape in total RD (Figure 1B). Some of the long-standing RD showed "Y" or even "T" shape (Figure 1C). The ends of detached retina and the morphology and internal echo of lens were observed simultaneously; RD with choroidal detachment: In addition to RD's imaging features, there were double layered band-

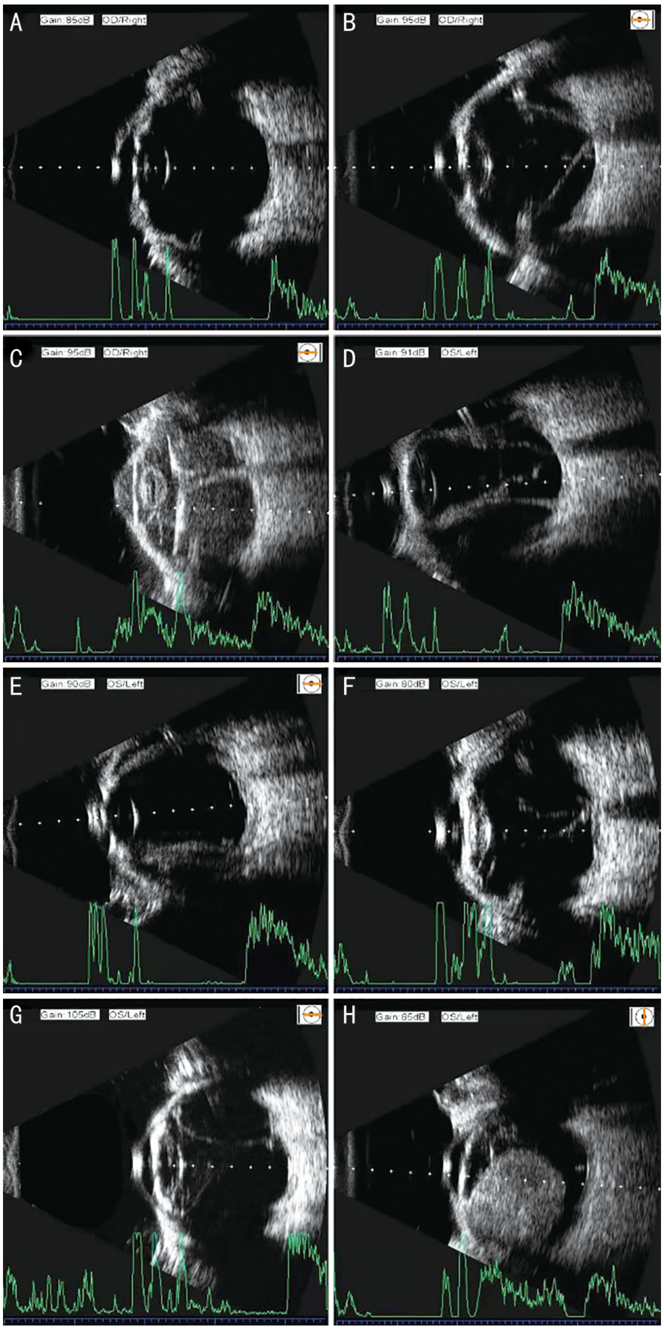

Figure 1 The imaging features of Pano-immersion B-scan A: Normal eye; B: Generally showed "V" shape after total RD; C: Long-standing RD showed "T" shape; D: RD with choroidal detachment; E: Choroid detachment; F: Vitreous opacity and organic membrane vitreous mechanization; G: Persistent hyperplastic primary vitreous; H: Intraocular tumor. RD: Retinal detachment.

echoes in the peripheral eyeball wall (Figure 1D); Choroidal detachment: The layered band-echo started from the eyeball wall but not from optic disc, and ended at the anterior segment of the eyeball wall. And the convex eyeball wall showed a "kiss" shape (Figure 1E); Vitreous opacity and/or organic membrane: The membranous echo was or was not connected to the optic disc, uneven or discontinuous in thickness, and had no ends connected to the eyeball wall (Figure 1F); PHPV: The stiff membranous echo extending from the optic disc to the posterior capsule of the lens was a band, regular or inverted triangle kind of shape (Figure 1G). The band-echo was characterized by a linear band extending from the optic disc to the posterior capsule of the lens. The regular triangular echo showed a membranous diaphragm with a wide base extending from the optic disc to the posterior capsule of the lens, and got narrower in the anterior part. The inverted triangle echo showed a membranous diaphragm with the base extending from the optic disc to the posterior capsule of the lens, and the anterior part was wider; Intraocular tumor: Fully displayed the location and size of solid mass echo in the eye as well as its relationship with the surrounding tissue (Figure 1H).

Diagnosis with Pano-immersion B-scan Table 1 shows the basic information, conventional ultrasound and/or UBM diagnosis, PIB diagnosis, intraoperative and/or pathological diagnosis, and treatment method according to registration order of 44 patients. All the patients either were unable to undergo optical examination because of the opacity of refractive media or the difficulty of cooperation at a too-small age, or the lesion was too large to make complete diagnosis. There were 23 patients diagnosed as RD or difficult to diagnose by conventional ultrasound and/or UBM diagnosis, included 16 males and 7 females with an average age of 44.77±21.77 (range 8 to 83)y. There were 12 patients diagnosed as PHPV by conventional ultrasound, included 4 males and 8 females with an average age of 12.33±9.95 (range 2 to 32)y. There were 9 patients diagnosed as intraocular tumors by conventional ultrasound and/or UBM diagnosis, included 5 males and 4 females with an average age of 49.25±12.76 (range 27 to 74)y. The basic clinical features were classified shown in Table 2. Many patients with RD were missed diagnosis, misdiagnosed or difficult-to-diagnose by conventional ultrasound. It was difficult to diagnose Cases 24, 33, 35, 42 by conventional ultrasound, but they were diagnosed as RD and cataract by PIB. Among them, Case 42 of lens opacity with abnormal posterior capsule morphology (Figure 2) was intraoperatively diagnosed with lens posterior capsular rupture (PCR), complex rhegmatogenous RD combined with severe proliferative vitreoretinopathy (PVR) formation. In Case 2, after PIB examination, the misdiagnosis of anterior vitreous opacity by conventional ultrasound was corrected to the opaque and swollen lens, and intraoperative diagnosis was RD with lens opacity (Figure 3). In Cases 5, 7, 17, PIB examination helped to revised the misdiagnosis RD to cataract with vitreous organic membrane traction formation which was confirmed by the surgery.

Many patients with PHPV were missed diagnosis by conventional ultrasound. In Case 3, the diagnosis of anterior vitreous opacity was added after PIB (Figure 4), and the intraoperative diagnosis was vitreous hemorrhage. In Case

Table 1 Demographics, preoperative and postoperative data of enrolled patients

Case	Gender	Age (y)	Eye	Conventional ultrasound/UBM diagnosis	Pano-immersion B-scan diagnosis	Intraoperative/pathological diagnosis	Surgical treatment
1	F	5	OD	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+2'IOL
2	F	75	OS	RD+aVO	RD+Cata	RD+Cata	Phaco+V+OIL+IOL
3	F	8	OS	PHPV+aVO	Cata+PHPV	Cata+PHPV	Phaco+PV+2'IOL
4	M	11	OS	RD+RC	RD+RC (hydrops)	RD+RC (hematocele)	V+OIL
5	M	40	OD	RD+VO	Cata+VO	Cata+VH	Phaco+V+IOL
6	F	67	OD	RD	Cata+RD	Cata+RD	Phaco+V+IOL+ OIL
7	M	32	OS	RD+VO+VP	VO+VP	VH+RD	V
8	M	56	OD	CD+SE	Cata+CD+SE	Cata+IUES	Phaco
9	M	54	OS	RD	Cata+RD	Cata+RD	Phaco+V+IOL+OIL
10	M	63	OD	RD+VO	Cata+RD	Cata+RD	Phaco+V+IOL+OIL
11	F	59	OS	RD+CD+VO	RD+CD+VO	RD+CD+VH	V+OIL
12	M	8	OS	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
13	F	65	OS	RD	Cata+RD	Cata+RD	Phaco+V+IOL+OIL
14	M	8	OS	RD+CD	Cata+RD+CD	Cata+RD+CD	Phaco+V+OIL+IOL
15	F	10	OS	PHPV	Cata+PHPV+VP	Cata+PHPV+VP	Phaco+V+IOL
16	M	39	OS	RD+CD	Cata+RD+CD	Cata+RD+CD	Phaco+V+OIL+IOL
17	F	63	OS	RD+VO	Cata+VO+VP	Cata+VH+VP	Phaco+V+IOL
18	M	83	OS	RD+VO	RD+VO	RD+VO	V+ OIL
19	F	5	OD	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
20	M	26	OD	RD	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
21	F	29	OD	RD	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
22	M	22	OS	RD	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
23	M	59	OD	RD	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
24	M	16	OD	Undiagnosable	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
25	F	2	OS	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
26	F	51	OD	IT+RD	IT+RD	IT+RD	EE
27	M	32	OS	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
28	M	50	OD	IT	IT	IT	EE
29	F	31	OD	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
30	F	48	OD	RD	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
31	F	23	OS	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
32	F	11	OD	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
33	M	52	OD	Undiagnosable	Cata+RD+VP	Cata+RD+VH	Phaco+V+OIL+IOL
34	M	43	OS	IT	IT	IT	EE
35	M	12	OS	Undiagnosable	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
36	F	27	OS	ICBT	ICBT	ICBT	EE
37	M	4	OS	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
38	M	9	OD	PHPV	Cata+PHPV	Cata+PHPV	Phaco+PV+IOL
39	M	44	OS	IT	IT	IT	EE
40	F	74	OS	IT	IT	IT	EE
41	M	39	OS	CBT	CBT	CBT	EE
42	M	54	OS	Undiagnosable	Cata+RD	Cata+RD	Phaco+V+OIL+IOL
43	M	53	OS	IT	IT	IT	EE
44	F	56	OS	CBT	CBT	CBT	EE

OS: Left eye; OD: Right eye; Cata: Cataract; CD: Choroidal detachment; EE: Eyeball enucleation; CBT: Ciliary body tumor; ICBT: Iris ciliary body tumor; 2'IOL: Intraocular lens implantation in a second procedure; IT: Intraocular tumor; IUES: Idiopathic uveal effusion syndrome; OIL: Silicone oil tenponade; Phaco: Phacoemulsification; PHPV: Persistent hyperplastic primary vitreous; RC: Retinal cyst; RD: Retinal detachment; SE: Subchoroidal effusion; V: Vitrectomy; VH: Vitreous hemorrhage; VO: Vitreous opacity; aVO: Anterior vitreous opacity; VP: Vitreous proliferation.

Table 2 The basic clinical features of enrolled patients

Conventional ultrasound/UBM diagnosis		Gender (M/F)	Age (y)	Pano-immersion B-scan diagnosis	Intraoperative/ pathological diagnosis	Surgical treatment
RD/undiagnosable (23)	RD+/aVO+/VO+/VP+RC (15) RD+CD+/VO (3) CD+SE (1) Undiagnosable (4)	16/7	8-83 (44.77±21.77)	RD+/ Cata+/RC+/ VH+/VP+VO (16) VO+VP+/Cata (3) RD+CD+/ Cata+VO (3) CD+SE+Cata (1)	RD+/Cata+/RC+ /VH+/VP+VO (16) VO+/VP+/Cata (3) RD+CD+/ VH+Cata (3) CD+SE+Cata (1)	Phaco+V+OIL+IOL (15) Phaco+V+IOL (2) V+OIL (3) Phaco+IOL+/V (3)
PHPV (12)	PHPV+/aVO	4/8	2-32 (12.33±9.95)	Cata+PHPV (12)	Cata+PHPV (12)	Phaco+PV+IOL/2'IOL
Intraocular tumors (9)	IT+/RD (6) CBT+/ICBT (3)	5/4	27-74 (49.25±12.76)	IT+/RD (6) CBT+/ICBT (3)	IT+/RD (6) CBT+/ICBT (3)	EE (9)

Cata: Cataract; CBT: Ciliary body tumor; CD: Choroidal detachment; EE: Eyeball enucleation; ICBT: Iris ciliary body tumor; 2'IOL: Intraocular lens implantation in a second procedure; IT: Intraocular tumor; IUES: Idiopathic uveal effusion syndrome; LA: Lens abnormality; OIL: Silicone oil tenponade; Phaco: Phacoemulsification; PHPV: Persistent hyperplastic primary vitreous; RC: Retinal cyst; RD: Retinal detachment; SE: Subchoroidal effusion; V: Vitrectomy; VH: Vitreous hemorrhage; VO: Vitreous opacity; aVO: Anterior vitreous opacity; VP: Vitreous proliferation.

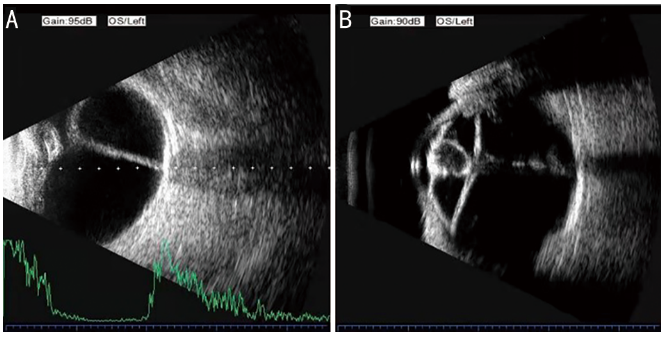

Figure 2 Case of difficult diagnosis of retinal detachment A: Conventional B-ultrasound image; B Pano-immersion B-scan ultrasound imaging diagnosis of retinal detachment with abnormal lens shape.

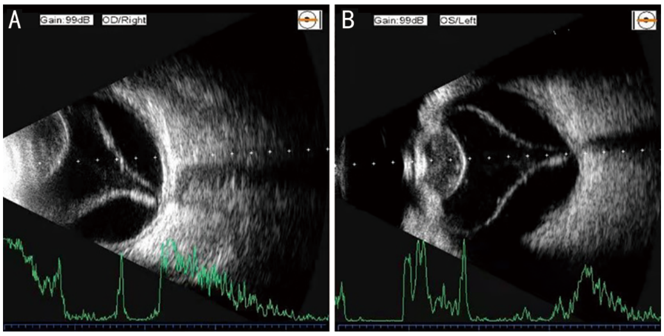

Figure 3 Misdiagnosed case of RD A: RD combined with anterior vitreous opacity by conventional B-ultrasound diagnosis; B: RD combined with lens swelling opacity by Pano-immersion B-scan ultrasonography. RD: Retinal detachment.

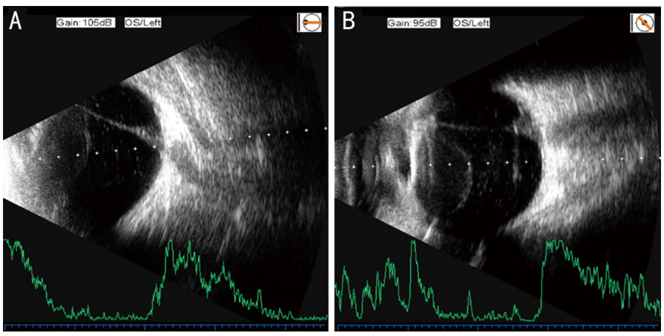

Figure 4 Misdiagnosed case of PHPV A: PHPV diagnosed by conventional B-ultrasonography; B: PHPV combined with vitreous hemorrhage in the anterior segment diagnosed by Pano-immersion B-scan ultrasonography. PHPV: Persistent hyperplastic primary vitreous.

15, PIB examination helped to add the diagnosis of anterior vitreous membrane, and the intraoperative diagnosis was anterior vitreous PVR.

Some patients with intraocular tumor were missed diagnosis or difficult-to-diagnose by conventional ultrasound or/ and UBM because the location of the tumor was anterior or/ and the tumor was large. Cases 36, 41, 44 were incompletely observed about anterior tumor using conventional ultrasound and/or UBM, but they were completely imaged by PIB. Pathology returned that Cases 36 and 41 were iris and ciliary body melanoma, and Case 44 was ciliary body melanoma (Figure 5). Cases 26, 28, 34, 39, 40, 43 were incompletely observed and difficult-to-diagnosed about posterior tumor using conventional ultrasound and/or UBM, but they were completely imaged by PIB, and their pathological results were all choroidal melanoma (Figure 6).

Compared with the intraoperative or pathological results, there were 19 cases missed diagnosis, misdiagnosed or difficult-to-diagnose by conventional ultrasound or UBM, including 4 cases of long-standing RD difficult to diagnose, 4 cases misdiagnosed (3 cases of vitreous organic membrane traction misdiagnosed as RD, 1 case of RD combined with intumescent cataract misdiagnosed as anterior vitreous opacity) and 11 cases incompletely observed or miss diagnosed (the anterior vitreous organic membrane was not detected in 1 case of PHPV, anterior vitreous hemorrhage was not detected in one case of PHPV, and 9 cases of intraocular tumor were incompletely observed). So, in this study, the accuracy rate of conventional ultrasound or UBM were 56.82% (25/44), which was significantly lower than that of PIB (100%; Figure 7) The sensitivity of PIB and conventional ultrasound or UBM were 100% and 56.82%.

Fifteen patients with RD diagnosed by PIB underwent vitrectomy and silicone oil tamponade. Among them, the surgery of ten patients were combined with lens extraction and intraocular lens implantation, including 8 cases with lens opacity, 1 case with lens opacity and swelling and 1 case with lens posterior capsule rupture. Among the 5 patients with choroidal detachment, 4 had rhegmatogenous RD combined

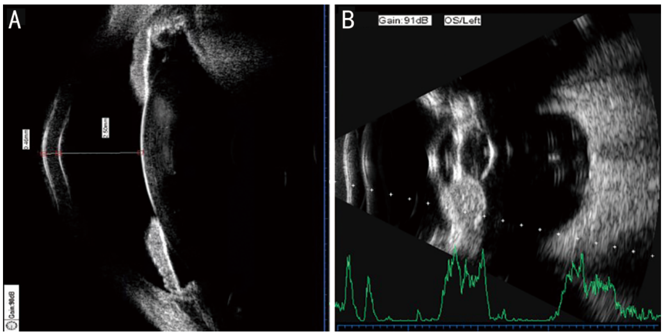

Figure 5 Incomplete observation case of ciliary body tumor A: Incomplete observation by ultrasonic biomicroscope; B: Complete observation by Pano-immersion B-scan ultrasonography.

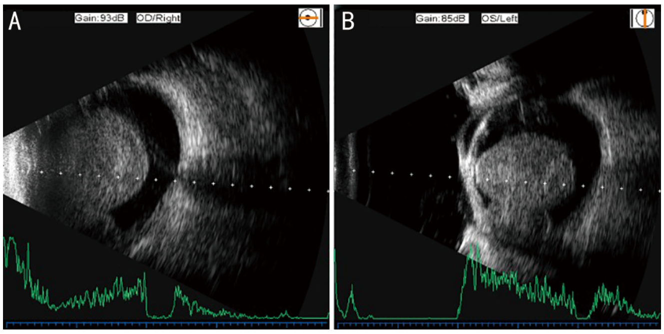

Figure 6 Incomplete observation case of choroid tumor A: Incomplete conventional B-ultrasound observation; B: Complete observation by Pano-immersion B-scan ultrasonography.

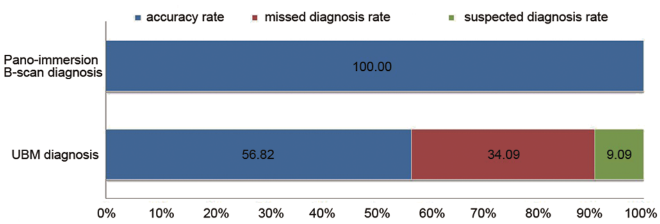

Figure 7 Comparison of the diagnostic value between the ultrasonic methods according to the surgical results.

with choroidal detachment and underwent vitrectomy with silicone oil tamponade; one had uveal effusion syndrome and his surgery was combined with posterior sclerectomy to support transscleral drainage. Twelve patients with PHPV underwent vitrectomy combined with lens extraction and intraocular lens implantation. Four patients with vitreous opacity and/or organic membrane traction underwent vitrectomy. Eyeball enucleation was performed in 9 patients with space-occupying lesions. Among them, there were 2 cases of iris and ciliary body melanoma, 1 case of ciliary body melanoma and 6 cases of choroidal melanoma.

DISCUSSION

Ultrasonography is a very useful tool for an accurate examination of the retina when fundus examination cannot be performed due to opacity media, a situation that is common in case of posterior vitreous detachment (PVD) associated with vitreous hemorrhage preventing to correctly examine the retina.

RD, PHPV, intraocular tumors and other common fundus diseases can be diagnosed by routine ocular examination and conventional ultrasound or/and UBM when the refractive medium is clear, the lesion size is relatively limited and the lesion is not complex, and in most cases we can conclude accurate diagnosis after the combination of optical coherence tomography (OCT), fundus fluorescein angiography (FFA), indocyanine angiography (ICG), *etc*[12-13]. When the refractive medium is unclear or the refractive pathway is blocked, such as severe cataract, pupil membrane closure, severe vitreous opacity and so on, the above examinations cannot be carried out and ultrasound is necessary to assist in diagnosis[2].

During ultrasound examination, various practical difficulties can be encountered: 1) The ultrasonic features of the lesions are complex and difficult to diagnose. In this study, 4 cases of long-standing RD were hard to diagnose: Conventional ultrasound showed thick and uneven membrane-like echoes, which could not be distinguished from vitreous proliferative membrane. On the other hand, 4 cases of vitreous proliferation were misdiagnosed as RD because the ultrasonographic findings were similar. Besides, all patients with PHPV in this study showed stiff membranous echoes of different lengths connecting to the optic disc in conventional ultrasound, and the diagnosis of PHPV through conventional ultrasound requires a wealth of clinical experience and cannot be clearly classified. Some cases (Cases 3, 15) were easily to be missed diagnosis when combined with anterior vitreous hemorrhage and vitreous organic membrane formation. 2) Intraocular tumors with special sizes and location. Of such 9 patients in this study, three cases were tumors of ciliary body or iris ciliary body, and the conventional diagnostic method was UBM[14-15]. However, their tumors were so large that beyond the exploration depth of UBM, and hence, the observation of lesions was incomplete. As for the other six patients, their lesions were located in choroid, and the diagnostic methods were mainly conventional ultrasound, but in this study, the tumor was located in front of the vitreous equatorial part, which was the blind area due to the ultrasonic near-field effect, so the observation was incomplete. For tumors located behind the vitreous equatorial part, one ultrasonic section diagram was not enough to observe if the tumor was too large. Because the PIB can eliminate the influence caused by ultrasonic near-field effect, the intraocular tissue can be comprehensively observed and panoramic imaging can be carried out for biometric measurement or detail observation. Therefore, in this study, PIB was used to distinguish complex RD, PHPV and intraocular tumors which were difficult to be diagnosed by routine examination, and then we explored its clinical practical value.

Clinically, RD, vitreous proliferative membrane and PHPV belong to vitreous membrane-like lesions, and conventional ultrasound is helpful for diagnosis[2,16]. In this study, it was difficult to make an accurate diagnosis of RD by conventional ultrasound, because the detached retina was rough and even adhered to a cord shape due to long-standing RD, and there were dense punctate echoes and abnormal membrane due to a history of vitreous trauma, and also the scope of observation was sometimes limited. However, by using PIB, the whole membrane presenting "Y" or even "T" can be observed, and the distal attachment position can be clearly detected so as to make an accurate diagnosis. For example, the vitreous proliferative membrane misdiagnosed as RD was also corrected because PIB detected the distal end of the membrane was not connected to the eyeball. Meanwhile, abnormal lens (opacity, lens posterior capsule rupture, and expansion) can be detected by this method, so as to correct the diagnosis, design the surgery procedure and evaluate the difficulty of operation.

PHPV is a rare clinical entity that presents with leucocoria, microphthalmos, and cataract. It is mostly unilateral, just as all the PHPV patients in this study. PHPV are divided into anterior type, posterior type and mixed type, and their main manifestations are echo changes of lens posterior capsule, proliferation in anterior optic disc and cords between lens and optic disc, respectively. Most often, patients have some element of both anterior and posterior PHPV[17]. However, it is common to miss the diagnosis of anterior PHPV and neglect thin vitreous proliferative cords. In this study, all the PHPV cases with difficulty in diagnosis presented with short, thin and rigid membrane-like echoes attached to the optic disc. PIB have detected not only the complete membrane, but also the position of the membrane front attachment and the lens morphology, so as to make a comprehensive and accurate diagnosis. According to PIB, all the cases were diagnosed as the mixed type.

Ultrasound is a routine method to the diagnosis of intraocular tumors[18]. For experienced physicians, it was not difficult to correctly diagnose the nine patients in this study by conventional ultrasound and/or UBM, despite of the observation was incomplete. For the purpose of comprehensive observation, the above cases might be examined with the aid of CT or MRI[19]. But the fundus structure is complex and delicate, so conventional CT or MRI has lower resolution and higher cost for ocular observation. However, PIB, with the assistance of the existing ultrasonic equipment and the eye cup used in UBM examination, can eliminate the influence of near field effect and image the whole eyeball, which can completely observe the size, shape, location and relationship with the surrounding tissues of the tumor. So, this method can improve the diagnostic accuracy without increasing the examination cost.

The following rules can be summarized through this study: 1) For cases with RD, the whole detached retina, especially the distal attachment position can be observed, and the lens morphology can be detected by PIB. Cases with vitreous proliferative membrane misdiagnosed as RD can be corrected by PIB with the membrane-like echo without attachment to the eyeball.

2) For cases with PHPV, PIB can help to observe the nanophthalmos of the affected side, the relatively short axial length, and a conical or funnel-shaped hyperechoic mass connected from the anterior segment to the optic papilla in the vitreous anechoic area.

3) For cases with intraocular tumor, the advantage of PIB is that the position, size, morphology and relationship with surrounding tissue of the tumor can be observed comprehensively by adjusting the eye positions and changing the direction of probe simultaneously.

Among the 44 difficult cases in this study, compared with the intraoperative results or/and pathological results, conventional ultrasound or/and UBM examination showed difficulties to diagnosis in four cases, misdiagnosis in four cases, missed diagnosis in two cases and incomplete observation in nine cases. In contrast, the accuracy rate and sensitivity of PIB were 100%, which provided an important information for the design of treatment plan.

The limitation of this study was that the data were analyzed retrospectively and the types and number of difficult cases were limited. Further research requires a larger sample size and more disease types to confirm the results. To sum up, PIB can successfully detect the clinical features of complex RD, vitreous proliferation, PHPV and intraocular tumor without adding ophthalmic any equipment. Additionally, its diagnosis accuracy is high, and this method is proved to be a safe and effective ocular examination. Hence, for the cases with diagnostic difficulties in routine examination, PIB can help to solve some thorny problems, and has the value of clinical promotion.

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