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Anatomic and Topographic Vitreous and Vitreoretinal Interface Features during Chromovitrectomy of A, B, C Stages of Proliferative Diabetic Vitreoretinopathy (P. Kroll's Classification of Proliferative Diabetic Vitreoretinopathy, 2007): Fyodorov's Eye Microsurgery Complex

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Abstract

Methods and results of the developed vitreous body imaging technique in proliferative diabetic vitreoretinopathy diagnostics using new contrast dye during operation. The P. Kroll's classification of proliferative diabetic retinopathy was modified after receiving new data about vitreoretinal interface structures during investigation using chromovitrectomy.

Keywords: vitreous, anatomy, diabetes, retinopathy, diagnostics chromovitrectomy

1. Introduction

Vitreous body is a clear, light-transparent eye part. The visualization of vitreous structures and their changes after and during pathological processes caused by diabetes did not provide yet. The purpose of this study was to study the possibility of developed vitreous body developed technique in proliferative diabetic vitreoretinopathy diagnostics.

Since 2010 chromovitrectomy with the original dye "Vitrecontrast" is developing for all intravitreal pathologies in the Fyodorov's Eye Microsurgery Complex. This method, called "vitreocontrastography", allows contrast and visualize all Worst J. described vitreous structures [1–9].

2. Materials and methods

The aim of this work was to study the anatomic and topographic specifics of the vitreous body (VB) and vitreoretinal interface (VRI) changes at different proliferative diabetic vitreoretinopathy (PDVR) stages.

The inclusion criteria of patients into the study corresponded to the traditional PDVR classification (A, B, C stages by P. Kroll et al., 2007 [10]), according to it, patients were divided into three groups.

The first group of patients included 52 patients (52 eyes) with diagnosed PDVR, stage A. 10 patients had diabetes mellitus II type, 6 out of them had insulin-dependent, 4 – insulin-related. Best-corrected visual acuity (BCVA) varied from 0.01 to 0.3; IOP varied within 12 mm–22 mm of mercury; the length of the eye-ball was 23 mm. and less. According to B-scanning, all patients had PVD with local fixations causing local tractional elevation 0.7–0.9 high; 30 patients had hemophthalmia.

In the second group 47 patients (47 eyes) with PDVR, stage B were followed up. Diabetes mellitus I type was diagnosed in 16 patients; diabetes mellitus was diagnosed in 31 patients, 14 of them had insulin diabetes. In this group, the BCVA varied from fingers at face to 0,1 non-correctable; IOP varied within 12 mm–22 mm of mercury; the length of the eyeball was 23 mm and less. According to B-scanning, all patients had PVD with local fixations causing tractional retinal detachment 1,2–1,7 high, 34 patients had hemophthalmia.

In the third group 32 (32 eyes) with PDVR, stage C was followed up. Fourteen patients were diagnosed with diabetes mellitus type I; 18 patients had diabetes mellitus type II, 14 out of them had had insulin-related diabetes. BCVA left pr. certae – 0.03 non-correctable; IOP varied 14 mm–20 mm of mercury. B-scanning found PVD in all patients, the tractional retinal detachment was up to 2,2–2,7 mm. Hemophthalmia was in 18 cases.

All the patients had 25 G vitrectomy with the Constellation Vision System (Alcon, USA) under the operational microscope Topcon OFFISSOMS 800 (Japan). The viscocontrastophy method was used to contrast the structures.

The distinctive feature of the vitrectomy performed within this study was contrasting VB structures for the intra vitam imaging of cisterns and canals, the assessment of their integrity, and anatomic and topographic specifics at each stage of the disease.

For this purpose, 3 ports at 4.00, 14.30, and 9.30 o'clock positions were installed pars plana 4 mm from the limbus. 0.1–0.2 ml of vitreocontrast suspension was injected sequentially through each of the installed ports into the vitreous body with a 30 G needle in order to contrast retrociliary and equatorial cisterns.

After contrasting the VB structures and video recording of their specific anatomical and topographic arrangement, an irrigation cannula was installed, an infusion solution was supplied into the vitreous cavity, and a median vitrectomy was performed. In the course of the vitrectomy, sequential isolated removal of VB cisterns was possible. At the next stage, by repeated contrasting, VB cortical layers were sequentially visualized followed by their removal until the surface of the retinal ILM was exposed. Then, retinal ILM was contrasted and its peeling in the macular zone was performed. Peeling was done by shaping ILM petals, followed by their partial removal with a vitreotome needle in a shave mode, and leaving the ILM in the foveolar zone in order to prevent the development of neuroepithelial atrophy in the long-term postoperative period.

The results of the studies proved the fact that under contrasting VB structures, in the first group, retrociliary and equatorial cisterns were preserved. The contrasted structures fully corresponded to their normal architectonics. The wall of the discovered structures was preserved, the boundaries were clear, and the contrasting composition did not go beyond the cisterns in 36 (97%) cases (**Figure 1**).

Figure 1.
Normal architectonics of retrociliary and equatorial cisterns in PDVR, stage a (the first group of patients).

Figure 2.
The cortical layer on the retinal surface after vitrectomy for PDVR, stage a (the first group of patients).

During central vitrectomy, VB was completely removed without cortex contrasting. After complete VB removal in all the cases, the retina was attached, no cortical layers or residual fibers were visualized on its surface. After repeated staining of the retinal surface with the suspension, a thin layer of fibers was visualized (**Figure 2**).

In 94% of cases it had a similar configuration and took the central zone of the eye fundus limited by vascular arcades. In other cases, this thin layer took the entire extent of the retina up to the extreme periphery. We managed to remove the contrasted layer from the retinal surface by endovitreal forceps in 24 patients. In 28 patients, it had a very loose and fibrous structure and was quite tightly fixed to the ILM along its entire length and to remove it partially from the retinal surface was possible only by Tano scraper (**Figure 3**).

To remove it in a single layer in the macular region was not possible. In all the cases it was removed only in a single block with ILM. The foveolar zone was left intact to prevent the development of retinal neuroepithelia atrophy (**Figure 4**).

Figure 3.
Thin vitreous layer in the central zone limited by vascular arcades after putting the suspension on the retinal surface under PDVR, stage a (the first group of patients).

Figure 4.
The removal of the cortical layer soldered with ILM keeping the foveolar fixation in PDVR patients, stage a (the first group of patients).

It is necessary to note that the application of the developed technique of VB imaging (in comparison with the reference classification) made it possible to identify the new stage of PDVR defined by us A-1.

The classification features of this stage are:

- Full visualization of the vitreous and the VB layer attached to it at the background of ophthalmoscopically unchanged ILM;
- Full contrasting of the main VB structures (bursa-like cavities) cisterns with clear boundaries 1,5–1,7mm and 0,2–0,3 mm wide, the surface is preserved (the contrasting agent does not go beyond the boundaries)
- Lack of the fixation of posterior cortical layers to the retinal surface;
- Tight adhesion of VB layers to ILM;

- Vitreous layers in the central zone of VB layers in the central area of VRI vascular arcades.

It should be noted that the last classification sign (as a suggested PDVR stage A – 1) is presented by new scientific facts. In 70% of the cases this layer can be quite easily separated from the retina by the forceps (average level of adhesion), in 30% the VB layer is characterized by a high level of adhesion with the possibility of their partial removal (**Figure 5**).

According to basic classification [10], stage A is characterized by proliferative changes of VB and retina especially around the optic disk and posterior cortical layers. The application of the developed VB imaging technique made it possible to design the following classification signs of the A-2 stage:

- The presence of well visualized bursa-like cavities in VB 1.5–1.7 mm long and 0.3–0.5 mm wide with equal clear boundaries, the walls of the cavities are preserved;
- Cortical layers have areas of fixation to the VB. They are removed only by intraoperative PVD induction (in 40% of the cases) or cannot be completely removed, staying fixed in the places of firm contact with the retina;
- On the retinal surface in the VRI zone a multilayered (in 94% of cases 2–3 layers) cortical layered with vitreoschisis areas;
- VB layer adjacent to the retina can be completely removed in 30%, partially in 50% of cases. In other cases, it is characterized by the firm degree of adhesion to the retina;
- In the macular zone, in 80% of cases this layer has such firm adhesion to the ILM that can be removed only in a single block with ILM;
- In the periphery, true PVD is visualized.

Figure 5.
Cortical VB layer that cannot be mechanically removed intraoperatively.

Thus, at stage A-2 the tractional element develops in the areas of VB splitting (but not its complete posterior detachment) that eventually causes a tractional retinal detachment. At this stage, local tractional detachment localizes in the periphery in 85% of cases.

The results of the anatomic and morphological assessment of the 2-nd group patients showed that during vitreocontrastography retrociliary and equatorial cisterns had fully preserved architectonics, unchanged wall, and clear boundaries. In most cases (95%) there is no exit of the contrast agent, and only in 5% of the cases, the structure was disrupted (**Figure 6**).

After central vitrectomy and removal of contrasted VB structures, the cortical layers were sequentially stained. At the same time, in 96% of cases, the VB layer extending to the region of vascular arcades and removed as a single layer was visualized. After repeated contrasting, another VB layer was visualized in 63% of the patients. It was also attached to the retina up to the zone of the vascular arcades. In 41% of the patients, the area of this layer was limited by the macular zone. Thus, VB cortical layers is a multilayered structure consisting of several formed layers, each of which has a certain topography and fixation (**Figures 7–9**).

The discovered VB layers do not get to the peripheral retina being firmly fixed in the zone limited by vascular arcades. Besides, in this group patients' true PVD was discovered in 94% and only in the periphery. After the removal of cortical layers in the central zone and the retinal surface visualization as well as after repeated staining with the suspension, in all the cases a thin vitreous layer firmly fixed to the ILM surface was visualized on the retinal surface (**Figure 10**).

This layer's mechanical removal was complicated and possible only partially because of its insufficient thickness and its loose and unformed structure. Besides, in the macular zone, this layer removal separately from ILM was not possible (**Figures 11, 12**).

According to basic classification [10] stage B is characterized by the shrinkage of the posterior vitreous cortical layer that leads to its tractional detachment in the areas of VB fixation to the retina. Proliferative and tractional changes in the temporal lobe (along the upper and/or lower vascular arcades) without the engagement of the macular zone are related to stage Bt proliferative changes of VB and retina especially around the optic disc and posterior vitreous cortical layers.

Figure 6.
Fully preserved architectonics, unchanged wall, and the clear boundaries of cisterns under PDVR, stage B (2-nd group of patients).

Figure 7.
Splitting of cortical layers (vitresochisis) extending to vascular arcades in PDVR, stage B (2-nd group of patients).

Figure 8.
Splitting of cortical layers (vitresochisis) extending to vascular arcades in PDVR, stage B (2-nd group of patients).

The application of the developed VB imaging technique made it possible to design the following classification signs of stage B:

- The presence of bursa like cavities 1.5–1.7 mm high and 0.3–0.5 mm wide with equal clear boundaries well visualized in VB, the walls of the cavities are preserved;
- Cortical layers in the central zone have a lamellar structure including up to 5–7 vitreous layers forming numerous vitresochisis zones that cause tractional retinal detachment 1.1 to 2.2 high in different segments while using vitreous layers in vitresochisis zones as a substrate. Along with the vitreous layers, neovascularization proliferates and cellular proliferation occurs forming a typical picture of eye fundus changes;

Figure 9.
Splitting of cortical layers (vitresochisis) extending to vascular arcades in PDVR, stage B (2-nd group of patients).

Figure 10.
Preretinal VB layer extending to vascular arcades after repeated contrasting under PDVR, stage B (2-nd group of patients).

- VB layer adjacent to the retina may be partially mechanically removed. In 80% of cases it stays in the places of firm fixation to the retina;
- In the macular zone, in 80% of cases, this layer can be removed in a single block with ILM.

In general, it is necessary to say that during the preoperative period and during the surgical intervention, PDVR hemorrhagic manifestations do not complicate the performance of sequential (lamellar) vitreocontrastography. Besides, the VRI condition makes it possible to study the exact topography of each vitreous layer formed in the course of the pathological process (collagen crosslinking), vitresochisis zones with the possibility of their exact measurement, configuration sizes, the localization of the fixation points to the underlying vitreous layers. Vessels, and retinal surface.

The results of the anatomic morphologic assessment of the 3-d group showed that during vitreocontrastography all the retrociliary and equatorial cisterns

Figure 11.
Removal of the layer soldered with ILM under PDVR, stage B (2-nd group of patients).

Figure 12.
Removal of the layer soldered with ILM under PDVR, stage B (2-nd group of patients).

had fully preserved architectonics, unchanged wall, and clear boundaries (**Figure 13**).

After central vitrectomy, in the zone limited by vascular arcades, a fibrovascular membrane with multiple zones of the fixation to the retina and causing tractional retinal detachment was visualized. In 11% of the cases, this structure had a multi-layered structure. However, in other (89%) cases we failed to perform layer-by-layer contrasting and to identify the zones of layers attachment (**Figures 14, 15**).

According to the basic classification [10] stage B is characterized by a tractional retinal detachment that extends to the macular zone. And stages from C1 to C4 are identified by the number of detached macular quadrants.

Developed VB imaging technique made it possible to develop the following classification signs of stage C:

- The presence of well-visualized bursa like cavities 1.5–1.7 mm high and 0.3–0.5 mm wide with equal clear boundaries in VB, the walls of the cavities are preserved;

Figure 13.
Preserved anatomy and topography of retrociliary and equatorial cisterns in PDVR, stage C (3-d group of patients).

Figure 14.
Multi-layered fibrovascular membrane that has numerous zones of fixation to the retina and causes tractional retinal detachment in the region limited by vascular arcades under PDVR, stage C (3-d group of patients).

- In 18% of cases, VB partial destruction is visualized. It is manifested in the elongation of bursa like structures (cisterns) up to 2.0–2.5 mm, their disrupted walls, and the exit of the contrast beyond the cavity boundaries;
- VB cortical layers have fibrosis, and in 80% of cases, are not differentiated. Besides, in the central zone, under the possibility of its visualization, stratified cortical layers are identified (thicker than at the previous stage, no more than 2–3 layers);
- In the central zone, VB has a firm attachment to the retinal ILM.

Figure 15.
Multi-layered fibrovascular membrane that has numerous zones of fixation to the retina and causes tractional retinal detachment in the region limited by vascular arcades under PDVR, stage C (3-d group of patients).

When discussing the presented results, it is necessary to single out four main positions. The first one deals with the PDR basic classification choice. In this regard, we should note that some classifications proposed before do not take into account the role of the vitreous in the development of changes under diabetes. They mostly address retinal vascular changes and are usually based on ophthalmoscopic data that predominantly reviews the relevance of these classifications for the laser treatment tactics [citation according to 402]. The classification offered by P. Kroll et al. [10] is not that much based on PDR classification characteristics but rather on those of PDVR that determined its choice for the aims of this work. It should be mentioned again that our analysis of classification signs under different PDVR stages provided for the application of the developed VB imaging technique based on the original method of vitreocontastography.

The second position defines the main aspects of PDVR pathogenesis from the perspective of anatomic topographic changes of the vitreous structure. In this regard, the first thing that draws attention is quite clear delineation into anatomically preserved pre-equatorial vitreous section and pathologically changed cortical layers, and the VRI zone. In all the cases irrespective of the stage of the disease retrociliary and equatorial cisterns preserved their changed cortical layers, and there was no exit of the contrasting agent deeper than the stained structures. Another interesting fact is that under the unchanged anatomy of the vitreous structures, the suspension localizes only in the cisterns and does not reach cortical layers on the retinal surface. This circumstance may explain the fact that preserved cisterns prevent the circulation of inflammatory and VGF factors and their occurrence in the anterior segment of the eye-ball.

It is also important to note that, in the ILM zone, the thinnest VB layer lining this area, reaching vascular arcades, and having tight adherence to ILM was found for the first time. This layer was discovered after multiple contrasts of cortical layers that again confirm their stratified structure and the ability to split. Such anatomic localization of the vitreous layer and pathological changes in the area of vascular arcades may be explained by PDRV development pathogenic specifics. Such anatomic localization of the vitreous layer and pathologic changes in the area of

vascular arcades can be explained by the pathogenic changes of PDVR development. The trigger mechanism in PDVR is known to be vascular permeability disorder, more often in the zone of vascular arcades, which leads to the release of inflammation factors, VGF, PGF. This probably provokes the tight fixation of VB preretinal layer to the ILM directly in the zone limited by vascular arcades. This is the discovered VB layer that plays a leading role in the development of following changes under the disease progression. Propagating to the macular zone and being tightly fixed to the ILM, these VB changes condition macular edema development, especially, due to the tangential tractions. They are the risk factor for the development of further proliferative changes.

Besides, due to the abnormal PVD in the zone limited by vascular arcades further changes of cortical layers take place by sort of crosslinking (adhesion) of vitreous fibers, and as a result, they turn into numerous multilayered vitreoschisis zones tightly fixed to the retina. These structure layers are the risk factors of neovascularization and further proliferation with the formation of fibrous membranes with the course of time. These anatomic specifics explain tractional retinal detachment development during the progression of VB proliferative changes that also have a specific topography.

The third position is connected to the results of our comparative analytical assessment of PDVR clinical diagnostic efficiency using the developed technique of VB imaging and the traditional classification (**Tables 1–3**). The data presented in the tables prove to the principally higher level of anatomic and morphologic diagnosis at different PDVR stages using the new VB imaging technique (based on the original method of vitreocontrastography) that, in our opinion, is related to the following general weaknesses of the traditional classification:

VB imaging technique	Traditional classification	Main weaknesses of the traditional classification
Definition of the <i>new stage</i> –A-1: 1. Anterior cortical layers are preserved. 2. VB structures are preserved (cisterns). 3. The retina is fully attached without the visible ophthalmological changes of the vitreous and retina. 4. VB layer with certain topography (taking the central area of the eye fundus). <i>Stage A-2:</i> 1. Anterior cortical layers and VB structures are preserved 2. In the central zone 2–3 layered VB cortical layer is 3. preserved. The layers are formed by vitreoschisis zones 4. On the retinal surface VB layer firmly fixed to the ILM in the macular zone is contrasted.	Characterized by proliferative changes of VB and retina especially around the optic disc and VB posterior cortical layers.	1. Based on the ophthalmoscopy data. 2. Optically transparent media are required. 3. Cannot be performed under hemophthalmia and vitreous opacification (or in such a case should be based on B-scanning data). 4. Based only on the assessment of the vitreous and retinal changes visible with the use of ophthalmoscopy (judging by pathogenesis, epiretinal membranes become visible only at the fibrosis stage) 5. Anterior and central structures are not assessed.

Table 1.
Results of the comparative analytical assessment of the main classification signs of PDVR, stage a found using the developed VB imaging technique and traditional classification (Kroll et al. [10]).

VB imaging technique	Traditional classification	Main weaknesses of the traditional classification
<ol style="list-style-type: none">1. Anterior vitreous cortical layers are preserved.2. In the central zone, there are cortical layers with numerous vitreoschisis zones causing tractional retinal detachment 1.7–2.2 mm high.3. Normal PVD is at the retinal periphery. In the central zone, there is abnormal PVD with numerous vitreoschisis4. zones.	Shrinkage of VB posterior cortical layers in the places of VB fixation to the retina results in retinal tractional detachment.	<ol style="list-style-type: none">1. The assessment is possible only under transparent media by ophthalmoscopy or (under hemophthalmia) should be based on b-scanning data that is not indicated in the classification.2. Takes into account retinal detachment localization and height but the analysis of VB changes with the account of the localization of vitreoschisis zones is not possible.3. Only irreversible changes (tractional retinal detachment) is possible.4. Only (fibrosis) changes of the vitreous (epiretinal membranes) visible by ophthalmoscopy can be seen5. There is no analysis of the layer-by-layer changes of the posterior cortex and VRI as the main areas of the pathological process.

Table 2.
Results of the comparative analytical assessment of the main classification signs of PDVR, stage C, found using the developed imaging technique and according to the.

VB imaging technique	Traditional classification	Main weaknesses of the traditional classification
<ol style="list-style-type: none">1. Anterior cortical layers and VB structures are intact.2. Partial destruction of VB structures manifested in the disrupted integrity and changed sizes of some its sizes.3. Vitreoschisis areas in the central zone are not visualized due to fibrous changes in VB cortical layers.4. After the removal of fibrous membranes in the central zone, VB layer tightly fixed to the ILM of the retina is visualized.	Tractional retinal detachment covers the macular zone. According to the number of detached macular from C1 to C4 stages are identified.	<ol style="list-style-type: none">1. Evaluate the final result of pathological changes (tractional retinal detachment area by segments), VB changes are not included into the analysis.2. Practically does not provide data about the pathological process pathogenesis related to the retinal detachment configuration and topography.

Table 3.
Results of the comparative analytical assessment of classification signs of PDVR, stage C found using the developed imaging technique and according to the traditional classification (Kroll et al. [10]).

- Classification signs are based on ophthalmoscopy data (assessment of VB and retina changes seen only by ophthalmoscopy);
- There are sufficient limitations related to the transparency of optical media (in particular, under hemophthalmia and vitreous opacification, B-scanning data is required;
- There is no assessment of anterior and central vitreous structures;

- Lack of the visualization of layer by layer posterior vitreous cortex and VR interface in general, the structures of which are recognized as the main areas of the pathological process development under PDVR [11, 12];
- Classification signs are based on the assessment of irreversible changes (localization and the height of tractional retinal detachment) without taking into account VB changes related to vitreoschisis zones.

The fourth position defines the cumulation of PDVR classification anatomic morphological signs (CAMS) developed using the original VB imaging technique with the position of vitreoretinal surgery improvement (**Table 4**).

The data presented in **Table 4** makes it possible to formulate the following main areas of surgical intervention improvement under PDVR that is supported by the application of the developed VB imaging technique on the basis of the original vitreocontrasting method:

1. Maximum full visualization of all the pathological changes including the area of VB layer (CAMS - 1,2,3,8);
2. Maximum possible (without accompanying iatrogenic retinal damages) removal of the VB layer on the retinal surface as a prognostic factor of the pathological process severity increase (CAMS-6,7);
3. In the cases of the partial removal of the layer firmly adhered to the retina, it is viable to correct these retinal zones by selective, pathogenetically based endolazocoagulation or by endovitreal tamponade (either the gas-air one or the silicon one). Anti VGF therapy to prevent hemorrhagic complications (CAMS – 6,7) is also indicated;
4. In the cases of visible tractional component and the VB layer firm fixation to the ILM in the macular zone, retinal ILM peeling is advisable to remove the traction component (CAMS – 4,5).

Thus, the application of the developed VB imaging technique (based on the vitreocontrastography) in patients with PDVR provides a principally new approach

##	Classification anatomic morphological sign	A-1	A-2	B	C
1.	Visualization of VB structures (cisterns, cavities)	+++	+++	+++	+++
2.	Visualization of VB cortical layers with the possibility of their complete removal only in the periphery	+++	+++	+++	+++
3.	Partial VB destruction (structural integrity is disrupted)	—	—	+	++
4.	The presence of stratified cortical layers with vitreoschisis zones	+	+	++	+++
5.	Tractional retinal detachment manifestation	—	+	++	+++
6.	The adhesion degree of the VB layer adjacent to the retina	+	++	+++	+++
7.	The adhesion degree of the VB layer in the macular zone	+	++	++	+++
8.	Visualization of true PVD in the retinal periphery	+	+	++	+++

Sign: “-” – no sign, “+” – the sign is insignificant; “++” – the sign is moderate; “+++” – the sign is distinctly manifested.

Table 4.
Classification of PDVR anatomic and morphological signs developed on the basis of the original VB visualization technique.

to clinical diagnostic research based on the development of anatomic and morphological signs (imaging of VB structures and cortical layers (including on the retina), the VB adhesion level, etc). and characterized by principal advantages comparing to PDVR traditional classifications. In general, on the basis of the given recommendations, this makes it possible to increase the level of vitreoretinal surgery efficiency.

The above given positions are illustrated by the following clinical case.

The clinical case:

Patient F-va, 52 years old, medical record #1469012, diagnosis – PDVR, hemophthalmia, condition after transpupillary retinal laser coagulation. Hemophthalmia. Visual acuity – 0.03. IOP 16 mm. of mercury. Anterior posterior axis – 22.8 mm. The main stages of diagnosis and treatment are presented in **Figures 16–23**.

The first stage was the step-by-step consistent contrasting of vitreous structures (**Figure 16**). Thus, the presence of nontransparent optic media does not influence the quality of the imaging technique of complex VB structures and gives the opportunity to build the three-dimensional image of the topographic anatomy of VB structures.

After the vitrectomy, eye fundus imaging with the assessment of its pathological changes was performed. Without vitreocontrastography, vitreous cortical layers are not visualized on the eye fundus, no major pathological changes are seen, and the

Figure 16.
a – Contrasting of vitreous cisterns at the backdrop of hemophthalmia does not influence the quality of vitreocontrastography. The contrasted vitreous cavity with clearly outlined boundaries, preserved walls (red arrow), patient F-va, medical record # 1469012. b – Contrasting of VB structures. Contrasted vitreous cavities (cistern according to J.Worst) with clear boundaries are visualized, no exit of a contrasting agent, possibility to perform a vitreocontrastometry (changes of sizes) (black arrow), patient F-va, medical record #1469012. c – Contrasting of vitreous structures. Partial destruction of VB (blue arrow). changes of the cavity (cistern) clear boundaries, no exit of a contrasting agent, patient F-va, medical record #1469012.

eye fundus looks quite good to complete the surgery. However, the further application of VRI contrasting made it possible to visualize a cortical VB layer on the retinal surface. Besides, vitreocontrastography made it possible to assess the topographic anatomy (boundaries, area, relation to other anatomic structures) of the visualized layer (**Figures 17–19**). Since there is no cito and phototoxicity of the contrasting suspension, these manipulations are not limited by time. At the next stage, the attempt of the discovered VB layer mechanical removal with the concurrent assessment of its adhesion to underlying tissues is made (**Figure 20**). The role of this very layer in the pathological process, and in the support and development of its complications, is expressed in the development of hemorrhagic complications during the attempt to remove the cortical layer in the places of its tight fixation to the retinal ILM and (or) to the vessels (**Figure 21**).

The highest level of the contrasted layer adhesion is observed in the macular and paramacular zone (**Figure 22**).

At this stage of the process, the cortical layer can be removed from the retinal ILM surface in the macular and paramacular zone both as a separate layer and in a single block with retinal ILM. After the VB layer removing from the ILM surface in the macular and paramacular zones, retinal ILM is contrasted. If on the ILM surface there is the residual VB layer, its thickness is assessed, and the need in ILM peeling is reviewed. In this case, in order to maximally eliminate the tractional component

Figure 17.
Putting the contrasting agent on the retinal surface (patient F-va, medical record #1469012).

Figure 18.
Removal of the contrasting suspension excess by aspirational canula (patient F-va, medical record #1469012).

Figure 19.
Visualization of VB cortical layer on the retinal surface (patient F-va, medical record #1469012).

Figure 20.
Removal of the contrasted VB layer from the retinal surface by endovitreal forceps (patient F-va, medical record #1469012).

and to prevent the development of neuroepithelial atrophy in the long-term follow-up period, the ILM was removed in the paramacular zone without affecting the macular zone. The VB contrasted layer was removed from the retinal surface as much as it was possible leaving the areas of tight fixation to ILM, vessels, and optic disc to prevent hem. Due to the adhesion of the contrasting suspension particles to the VB fibers, this layer becomes more formed, denser and well visualized, which makes this delicate process easy to manage and control. Retinal endolaser coagulation was carried out selectively, in the areas of this VB layer dense fixation to the retinal ILM, to the vessels, in the zones where this layer mechanical removal is impossible, and in the neovascularization zones. The tamponade of the vitreous cavity with the air completed the surgery.

Neither in the early nor in the late postop period, the patient had complications. Two years after the surgery, visual acuity – 0.7; IOP 16 mm of mercury, the photo of the eye fundus is presented in **Figure 23**.

The clinical case:

Patients P 49 years old.

Female: Diabetes mellitus type 2, noninsulin-dependent. Glycemia level 8–9 mmol/l.

Diagnosis: Proliferative diabetic retinopathy. Tractional retinal detachment 2,2–2,5 mm.

Figure 21.
a, b. the photo of the VB layer fixation place to the retinal ILM (black arrow), patient F-va, medical record #1469012. c, the development of hemorrhagic manifestations under the attempt to remove the VB cortical layer in the places of the tight fixation to the ILM (patient F-va, medical record #1469012).

Figure 22.
During the removal of the contrasted VB layer from the retinal surface, its tight fixation to the retinal ILM is seen in the macular zone (indicated by the black arrow). In the indicated zone VB layer mechanical separation is complicated (patient F-va, medical record #1469012).

Visual acuity 0,06, IOP 19 mm. of mercury. APA 22,1 mm.
B scan: Strong destruction of the vitreous body, PVD causing tractional retinal detachment 2,2–2,5 mm high.

Figure 23.
Photo of the eye fundus 2 years after the surgery (patients F).

According to the ophthalmological picture, this stage corresponds to stage 2 by Kroll classification.

Vitreocontrastography.

Visualization of vitreous structures.

The first stage of the vitreocontrastography is step-by-step staining of vitreous structures. This investigation can be carried out in any of relevant quadrants.

In this example, cavities (cisterns by J. Worst) filled with the dye are visualized. Stained cavities have clear borders, unchanged size, suspension vitreocontrast did not go beyond the cavities.

It is possible to do vitreocontastometry with the identification of the sizes of stained cisterns (**Figure 1**).

Figure 24.
Vitreocontrastography. The preserved cisterns of the vitreous body with clear-cut borders are visualized. The measurement of stained structures is possible.

Haemorrhagic and neurotrophic complications (**Figure 24**).

The next step is the central vitrectomy with the removal of all stained endovitreal structures. After that, the possibility to investigate the cortical layers of the vitreous body by vitreocontrastography is given.

The staining composition is applied to the cortical layer of the vitreous body (**Figure 25**).

The use of vitreocontrastography in the course of the vitreoretinal surgery makes it possible to execute the step-by-step lamellar removal of vitreous cortical layers with the precise visualization of their topography (**Figure 26a–d**).

The intraoperative image of the eye fundus after the removal of one vitreous cortical layer (**Figure 27**).

Vitreous body visualization using vitreocontrastography method. Applying of suspension Vitreocontrast (**Figure 28**) makes it possible to visualize the next cortical layer of the vitreous body (**Figure 28**). After staining it is possible to remove the isolated vitreous cortical layer both by vitreotome needle (**Figure 28**) and endovitreal forceps (**Figure 28a, b**) (**Figures 29 and 30**).

To evaluate the topographic anatomy of the second layer of the vitreous body and to identify the places of its fixation to underlying tissues for its separation and removal we used the endovitreal forceps (**Figure 31a and b**).

After the intraoperative dissection and the delicate removal of the second layer of the vitreous body, the underlying layers of the vitreous body remain transparent and practically are not visualized. Intraoperatively, it is possible to evaluate only irrepressibly changed areas of the vitreous body (**Figure 31**).

During the vitreocontrastography, the dye was applied for the second time for further intraoperative diagnostics (**Figures 32 and 33**).

After this stage of vitreous staining, another cortical layer of the vitreous body is visualized (**Figure 34a–d**).

In the course of the third vitreous layer removal, its tense fixation to the retinal ILM in the macular area was discovered. The removal of the discovered layer separately is impossible (**Figure 35**). Under the accurate dissection of this layer in

Figure 25.
Visualization of the topographic anatomy of cortical layers. Staining of the first layer of the vitreous body.

Figure 26.
Removal of the stained layer of the vitreous body. When the vitreotome needle has used the particles of the dye do not change the degree of adhesion making it possible to remove the vitreous body consistently strictly within the limits of one layer. The lack of the shaking effect facilitates surgical procedures.

Figure 27.
One layer of the vitreous body is removed. Visually accessible changes of the vitreous body are visualized in the form of the proliferative tissue niduses that cause tractional retinal detachment (black arrows). In the macular zone puckers can be seen (blue arrow). the visualization of other pathological changes is hampered.

Figure 28.
Applying suspension vitreocontrast on the retinal surface.

the macular zone, it showed a very high level of adhesion, and its removal without ILM is impossible in this zone.

In the macular zone, the removal of this layer is possible only as a single block with retinal ILM (**Figure 35**).

Figure 29.
Visualization of the second layer of the vitreous body.

Figure 30.
Isolated step-by-step removal of the second stained layer of the vitreous body by the vitreotome needle.

To prevent the development of neuroepithelium atrophy in the long-term follow-up period ILM segment is not removed in the macular zone (**Figure 36**).

The changes of ILM physical properties in the course of staining make any manipulations with retinal ILM easily performed, manageable, and well visualized.

Thus, during vitreocontastography and practical lamellar intraoperative dissection of the structures and layers of the vitreous body, it is possible to

Figure 31.
A—Isolated lamellar intraoperative dissection of the second cortical layer of the vitreous body. b—Identifying the places of the second vitreous layer fixation to the underlying tissues (designated by the black arrow).

Figure 32.
The image of the eye fundus after the removal of the second layer of the vitreous body. The underlying cortical layers are transparent (blue arrows), only the changed areas of the vitreous body are visualized (black arrows), some insignificant amount of the staining suspension on the surface (red arrows).

Figure 33.
The second application of the dye to identify the topographic anatomy of underlying tissues.

a

b

c

d

Figure 34.
Cortical layers visualizing.

Figure 35.
The lamellar removal of the stained layer from the retinal surface is impossible in the macular zone due to the high level of adhesion between the cortical layers and ILM (blue arrows).

Figure 36.
In the course of the removal of the vitreous layer as a single block with ILM we refrain from performing this manipulation (blue arrow).

Figure 37.
Foto of the eye fundus 2 years after surgery.

visualize numerous areas of vitreoschisis that are the substrate for the process of proliferation and the growth of neovessels (**Figure 37**).

3. Conclusion

Developed method of vitreocontrastography during vitrectomy allowed to find and describe new structures and interactions in VRI. It is shown that vitreococn-
trastography method is very simple, safe, and effective for the ultrathin and trans-
parent eye structures visualization. Due to vitreocontrastography new classification
of PDVR was proposed.

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