1. Introduction

A detachment of the retina leads to a loss in vision of the affected parts and, if left untreated, usually results in a blind eye. Several different surgical methods have been developed to achieve reattachment of the detached retina and save vision. In 1970, pars plana vitrectomy (PPV) was introduced for the treatment of complicated types of retinal detachment. In the 1980s, the indications for vitrectomy in rhegmatogenous retinal detachment (RRD) were broadened to less complicated situations in which routinely scleral buckling procedures were employed and the term "primary vitrectomy" was introduced. Due to the increasing number of indications for PPV, surgeons nowadays are much more familiar with this technique and the number of primary vitrectomies has increased immensely throughout the world. However, it is unclear if PPV achieves better anatomical and functional results in retinal detachments that could also be treated with standard operating methods like scleral buckling surgery.
This study was conducted to analyse the results and complications of primary vitrectomy for RRD in a single institution over a 9-year period.

1.1 Rhegmatogenous retinal detachment

1.1.1 Retinal detachment

The retina, as a receptor and an effective transducer, is the most complex and one of the most important of the ocular tissues. It consists of 10 layers (starting from its inner aspect): the internal limiting membrane, the nerve fiber layer, the ganglion cell layer, the inner plexiform layer, the inner nuclear layer, the outer plexiform layer, the outer nuclear layer, the external limiting membrane, the photoreceptor layer of rods and cones, and the retinal pigment epithelium (RPE). The internal limiting membrane is nearest the vitreous cavity, while the outer surface of the sensory retina is apposite to the retina pigment epithelium and thus related to Bruch's membrane, the choroid, and the sclera. In most areas, the sensory retina and retinal pigment epithelium are easily separated to form the subretinal space. Steinberg et al' s [57] study demonstrated that no real anatomic junctions form between the cells of the two layers. But at the optic disk and the ora serrata, the sensory retina and the pigment epithelium are firmly bound together, thus limiting the spread of subretinal fluid (SRF).

Therefore, the term “retinal detachment” denotes separation of the neurosensory retina (NSR), i.e. the photoreceptors and inner tissue layers, from the underlying retinal pigment epithelium. It can occur when the forces of adhesion between the two layers are overwhelmed by different mechanisms. Regardless of the mechanisms, all types of retinal detachment have one characteristic in common, the accumulation of fluid in the subretinal space.

1.1.2 Types of retinal detachment

There are three main types of retinal detachment: Rhegmatogenous, traction, and serous or hemorrhagic retinal detachment. Rhegmatogenous retinal detachment (RRD) is the most common of the three major types, its primary characteristic is a full thickness break in the neurosensory retina. The second is traction retinal detachment. Traction retinal detachment occurs when the retina is pulled off the retinal pigment epithelium by traction forces in the absence of retinal breaks. The tractional forces are caused by a clinically apparent vitreal, epiretinal or subretinal membrane consisting of fibroblasts and of glial and retinal pigment epithelial cells. It is most common in proliferative retinal and vitreoretinal diseases, like proliferative diabetic retinopathy (PDR), proliferative vitreoretinopathy (PVR), retinopathy of prematurity, or ocular trauma. Serous or hemorrhagic retinal detachment is characterized by fluid or haemorrhage accumulation in the subretinal space in the absence of either retinal breaks or traction. The source of fluid is the vessels of retina, or the choroid, or both. This can occur in a variety of vascular, inflammatory or neoplastic diseases of retina, RPE and choroid [58] in which fluid leaks outside the vessels and accumulates in the subretinal space.

1.1.3 Prevalence, pathogenesis and risk factors of rhegmatogenous retinal detachment

As above mentioned, RRD is most common in retinal detachment, which is caused by a full-thickness retinal break with subsequent shift of intraocular fluid and liquified vitreous into the subretinal space. The annual incidence of RRD is 8-12.6 per 100,000 people [20, 22,59,60]. People aged 60 to 69 had the highest incidence (22.2/100,000), and a significantly higher incidence was found in males for traumatic detachment, but not for pseudophakic/aphakic and nontraumatic phakic detachment [59]. For each gender, there was a significant increasing trend with increasing age [60]. In comparison, the incidence of retinal detachment after cataract

surgery is 0.6-1.7% during the first postoperative year [66-68]. In Rowe et al's study, ten years after phacoemulsification and extracapsular cataract extrction, the estimated cumultive probability of retinal detachment was 5.5 times as high as would have been expected in a similar group of county residents not undergoing cataract surgery [60].

The precursors to rhegmatogenous retinal detachment are a retinal break, liquefied vitreous and tractional forces. The break is produced and held open by vitreous traction that allows liquefied vitreous to access the subretinal space [62]. Since the prevalence of retinal break was found to be 83 times that of retinal detachment [65], even if a full thickness break is present in the retina, a retina detachment will not occur if the vitreous is not at least partially liquefied and if the necessary traction is not present [63]. Vitreous syneresis, which culminates in posterior vitreous detachment (PVD), can produce all three precursors (a retinal break, liquefied vitreous and tractional forces) of RRD [64]. This is why in most instances an RRD is preceeded by a PVD.

The most important risk factors for its development are vitreoretinal adhesions in association with PVD, local ocular diseases such as retinoschisis and myopia, a history of RRD in the fellow eye, history of cataract or other intraocular surgery and ocular trauma [22,61]. The proportion of aphakic or pseudophakic patients with RRD has increased to 30% during the past decade [1], due to the increasing numbers of cataract operations performed.

1.1.4 Clinical features, examination and diagnosis

The major symptoms of RRD include flashes of light, floaters and visual field defects, loss of visual acuity in eyes with a detached macula and media opacities. Vitreous detachment causes flashes of light and floaters, and these are succeeded by a field defect if RRD occurs subsequent to break formation and subretinal fluid spreading. The main clinical characteristics of RRD are a full-thickness retinal break, variable degrees of vitreous traction and fluid accumulation in the subretinal space. The ocular anterior segment, vitreous and posterior segment must be examined in detail, including external examination, measurement of best-corrected visual acuity and IOP, slit-lamp examination of the anterior segment, examination of the posterior segment by binocular indirect ophthalmoscopy preferably with scleral

indentation, and non-contact or contact lens biomicroscopy. Ultrasound examinations are performed in the cases of opaque media. The detailed examinations contribute to find the retinal breaks, to assess the need for any pre-surgical treatment, to differentiate diagnosis of RRD, and to decide the choice of surgical method and the need of prophylatic treatment. RRD is diagnosed and differentiated from tractional and serous or hemorrhagic retinal detachment when a retinal break is present in eyes with retinal detachment.

1.1.5 Treatment

1.1.5.1 Principles of surgical management

RRD is one of the major blinding conditions and is considered one of a few ocular emergencies. Patients with RRD usually have a good visual potential and may regain good vision. If untreated, most RRD will progress to a complete detachment and result in loss of vision of the affected eye. Therefore, RRD should be treated correctly and without delay. Most patients with RRD need a major surgical operation, only a few patients with small detachment can be treated with minor procedures, e.g. cryotherapy or photocoagulation or both.

The principles for treatment of RRD are closing retinal breaks and relieving retinal traction by reversing its pathogenic procedure. When RRD is complicated by PVR, surgical reattachment becomes more complex owing to the development of additional traction forces.

1.1.5.2 Methods of surgery

The surgical management of RRD has evolved dramatically during the past decades. Pneumatic retinopexy and primary pars plana vitrectomy have been introducted and refined as alternative techniques to scleral buckling surgery. Therefore, to date, there are three major surgical methods for treatment of RRD-- scleral buckling, pneumatic retinopexy and PPV. Scleral buckling or pneumatic retinopexy are the most common and effective surgical techniques performed for uncomplicated situations – i.e. those with good visibility of the fundus, single breaks and/or a limited retinal detachment [2, 4], and no PVR or less than grade

C. In approximately 90–95% of patients with uncomplicated RRD, final retinal reattachment can be achieved with these techniques [1, 2].

1.2 Pars plana vitrectomy

1.2.1 Indications of primary pars plana vitrectomy

Pars plana vitrectomy, established in 1971 by Machemer [17], is a method originally served for complicated RRD – i.e. those with giant retinal tears, vitreous haemorrhage, breaks at the posterior pole or macular hole, proliferative vitreoretinopathy (PVR) [16,17,31], retinoschisis [27], and choroidal detachment [25,26]. However, as facilities for vitreous surgery have become more widely available and surgeons have become more experienced with this technique, the threshold for vitrectomy has fallen and the indication for PPV for retinal detachment widely overlaps that for scleral buckling. Therefore, PPV has now gained a tremendous popularity in recent years and is used increasingly for primary repair of less than very complicated RRD, such as RRD with multiple breaks in different position [12,19], unseen breaks [3,6,8] and RRD in pseudophakic/aphakic patients [3,5-7]. In some centres in the United Kingdom, PPV is the method of choice in up to 63% of all patients with RRD [24].

Furthermore, PPV has been extensively performed for management of recurrent retinal detachment [69,70], dislocated lens fragments [71-73], PDR, intraocular foreign bodies, posterior perforating injuries and endophthalmitis. [73]

1.2.2 Surgical technique

PPV can be performed under either local or general anaesthesia. A conventional 3-port PPV is used with the sclerotomies placed 3.5 to 4 mm posterior to the limbus, and the infusion is sited in the lower temporal quadrant. In primary PPV, the vitreous is removed, including the vitreous base using deep scleral indentation, and the causative vitreoretinal traction is permanently eliminated through the removal of vitreous gel. Subretinal fluid is usually aspirated through the existing breaks or through a drainage retinotomy, or is shifted into the vitreous cavity through the preexisting breaks with the injection of perfluorocarbon liquids

(PFCL), avoiding the possible hazards of external drainage. Breaks can be detected by scleral indentation and by unfolding the detached retina using PFCL. Breaks are treated with cryopexy or laser photocoagulation to induce scarring around the retinal breaks. The whole vitreous cavity is filled with air or a mixture of gas or silicone oil for prolonged internal tamponade. If necessary, an encircling band or local buckle is used, and combined cataract surgery is also performed in the patients with significant cataract.

1.2.3 Intraoperative complications

The risk of motility disorders, anisometropia or external infection caused by exoplants can be avoided in cases without scleral buckling. On the other hand, PPV carries its own risks and complications including iatrogenic retinal breaks, lens touch, choroidal or retinal detachment from the infusion fluid, retinal or vitreous gel incarceration in the sclerotomy, subretinal or vitreous haemorrhage, choroidal haemorrhage, subretinal PFCL, corneal oedema and hyphaema [6,7,11,12,28,74,119].

Of them, iatrogenic retinal breaks are the most common intraoperative complication and will probably not be eliminated even if the greatest care is taken. Its possible causes are accidental aspiration of retina with the vitreous cutter, increasing vitreous traction during vitreous cutting, traction on the vitreous base from the insertion of instruments through the sclerotomies, retinal incarceration and consequent trauma in the sclerotomies [6,11,12, 119]. In general, iatrogenic retinal breaks occur usually in the retinal periphery, if diagnosed and treated intraoperatively, the outcome of surgery is usually not affected.

The second most frequent intraoperative complications are lens touch and subretinal or vitreous haemorrhage. A lens touch is caused by vitrectomy instruments and often occurs during removing of the anterior peripheral vitreous. Retinal or vitreous haemorrhage result from the vessel trauma during surgery [12] and its precipitating factors include intraoperative hypotony and cryopexy [32]. Choroidal or retinal detachment from the infusion fluid and choroidal haemorrhages are rare. In contrast, the incidence of subretinal PFCL will probably increase with increasing use of PFCL.

1.3. Postoperative anatomic and functional results and prognostic factors

1.3.1 Postoperative anatomic results and predictive factors

The postoperative retinal reattachment is one of the primary surgical purposes; therefore, it is one of the most concerned points for the vitreoretinal surgeon and the affected patients. Since the first report by Klöti in 1983[23], many series of PPV have been published [3,6,7,10-15,18,19,21,29]. With increase of surgical experiences and rapid parallel developments in instruments and techniques of primary PPV, the final retinal success rate has reached over 90%. Reviewing the literatures in the past 10 years, the primary retinal reattachment has been achieved in 84-100% using PPV with or without scleral buckling, and the final success rate has reached 100% in eyes without occurrence of postoperative PVR [6,8,9,25,42,19,33,36]. However, the primary and final success rates were 64-94% and 85-100% in eyes with occurrence of postoperative PVR respectively [3,7,10,12,14,18,39,43,40,34,35,44]. Only a few reports stated that the final reattachment was 100% in eyes with low incidence (4% or less) of postoperative PVR [3,34,41]. Postoperative PVR seems to be a primary cause of retinal redetachment.

The factors affecting postoperative anatomic results include extensive detachment, large or posterior retinal break, preoperative choroidal detachment, intraoperative haemorrhage, vitreous haemorrhage, and presence of PVR [45,100,101]. The recent studies indicated that female gender, giant retinal break, creation of a relaxing retinotomy and gas tamponade significantly associated with retinal redetachment using PPV in eyes with complex retinal detachment [102,47]. Few reports have been published on prognostic factors of anatomic results using primary PPV treatment of rhegmatogenous retinal detachment.

1.3.2 Postoperative functional results and prognostic factors

With constant improvement of retinal anatomic results, the retinal functional results turn into the most important focus of surgeons' attention. In a series of studies, the final visual acuity of 0.4 or better has been achieved in 32-79%, [3,6-8,12,42,40,34,36] while the postoperative visual acuity have reached 0.5 or better in 40 or 48% patients. [18,39] Speicher et al. [35] recently

reported that final acuity of 0.5 or better were achieved in 80% of pseudophakic patients with macular involvement, and 0.67 or better in 88% of macular-on patients.

Predictive factors of final visual acuity have been published by several investigators. A better visual acuity recovery could be achieved in eyes with short history of visual loss, an attached macula, no presence of anterior chamber reaction, no PVR of grade B or greater, and better visual acuity preoperative [7,35,49,103]. Using multiple regression analysis Oshima and associates [49] found that preoperative visual acuity, intraocular pressure and duration of macular detachment were three best predictors of postoperative visual recovery in 47 patients with macular-off RRD. At the same time, they found that primary vitrectomy was more effective than scleral buckling for achieving early visual recovery in eyes with preoperative visual acuity of less than 0.1, intraocular pressure of less than 7 mmHg or macular detachment more than 7 days.

Moreover, the visual recovery in macular-off retinal detachments was studied in detail by other investigators [104-108]. Ross [105] and Burton [106] found that duration of macular detachment within the first week did not influence postoperative visual. There are no clinical trials analyzing prognostic factors of final visual acuity with primary PPV treatment of RRD.

1.4 Postoperative complications and risk factors

1.4.1 Postoperative complications

Postoperative complications published include increased ocular pressure in 17.9-48% [3,18,35], vitreous haemorrhage, recurrent retinal detachment [1,11,12], PVR [10-12], macular pucker [12], cataract formation, commonly sclerotic nuclear, or progression of an already existing cataract [12], new retinal breaks [41,42,55], corneal decompensation, PFCL droplets or epiretinal macular PFCL [99], endophthalmitis [115], visual field loss [116], and hypotony. The most important complications, which severely affect surgical anatomic and functional results, are recurrent retinal detachment, PVR, macular pucker and cataract formation.

Recurrent retinal detachment is usually caused by missed, reopened or not sealed, or new retinal breaks, or/and PVR [10-12,41,42,55]. The postoperative incidence of PVR and macular pucker reported are 5.1-20% [10-12,18,35] and about 6-16% [7,12,18,35] respectively. At postmortem examination, 30.6% and 34.9% of eyes after retinal detachment surgery have macular pucker and subclinical epiretinal membranes [93]. After PPV, more than 30% of phakic patients have development of nuclear cataract [28].

1.4.2 Risk factors for postoperative proliferative vitreoretinopathy

The development of postoperative PVR is still one of the major causes of failure in retinal detachment surgery, despite the current final retinal reattachment over 90% [31]. PVR is a complex process and has many similarities to those of the wound healing response with inflammation, migration and proliferation of a variety of cells [77-79]. To prevent PVR and improve the prognosis of retinal detachment surgery, it is necessary to determine the factors involved in its development.

Risk factors for PVR have been studied and identified by many investigators using multivariate analysis. These include the use of vitrectomy [81], preoperative vitreous haemorrhage [75,76], PVR at presentation, [75,80,81] aphakia, [76,82] large retinal breaks, [76,83] use of cryopexy, [81] duration of detachment, [76] the presence of choroidal detachment preoperatively, [80,81] horseshoe tear, [76,83] and the use of silicone oil [84,85]. Almost all risk factors for PVR are associated with intravitreal dispersion of retinal pigment epithelial cells or breakdown of blood-ocular barrier which are prerequisite to development of PVR [88]. In Girard et al's [80] retrospective study of PVR after retinal detachment surgery, the authors confirmed the effect of some factors, but did not consider the number of surgeries, aphakia, subretinal fluid drainage as predictors of PVR development.

Kon et al [86] prospectively studied the incidence and risk factors of postoperative PVR after primary vitrectomy. In that series, he found only aphakia and presence of preoperative PVR to be significantly associated with postoperative PVR after analyzing 12 preoperative and intraoperative variables. In addition, they proposed two mathematical models to predict the

possibility of developing postoperative PVR and showed that using this model it is possible to identify subjects at greater risk of PVR developing after primary vitrectomy [87]. However, they did not regard subretinal fluid drainage as predictor of postoperative PVR, as well as the size of retinal breaks. For these reasons, a more complete clinical study, revealing the predictors of postoperative PVR undergoing primary PPV treatment for RRD, should be done.

1.4.3 Risk factors for postoperative macular pucker

The term "macular pucker" usually refers to epiretinal membranes secondary to retina tears or detachment and vitreoretinal surgery [90,91]. Macular pucker may result in reduced visual acuity and/or metamorphopsia [90,91], and it is characteristic that the visual acuity slowly recovers after treatment with vitrectomy and epiretinal membrane removal [92]. To date only a few reports have been published on the risk factors for the development of postoperative macular pucker [94,95,118]. Uemura et al [94] indicated that retinal breaks greater than 3 disc diameters, vitreous haemorrhage and retinal cryotherapy were significantly associated with macular pucker. In Cox et al's [95] study, the risk factors for development of macular pucker included large retinal breaks, multiple retinal breaks and aphakia or pseudophakia. Membrane peeling is an effective surgical method for macular pucker, but is not without risk, such as intraoperative retinal tears and postoperative retinal detachment [96].