Int Ophthalmol (2019) 39:1695–1701
https://doi.org/10.1007/s10792-018-0988-x

ORIGINAL PAPER

Controlled drainage of subretinal fluid during scleral buckling surgery for rhegmatogenous retinal detachment: the pigment stream sign

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Received: 11 December 2017 / Accepted: 6 July 2018 / Published online: 10 July 2018

Abstract
Purpose To describe the macroscopic characteristics of the subretinal fluid (SRF) and its spilling modality during evacuative puncture in scleral buckling (SB) surgery for rhegmatogenous retinal detachment.
Methods We retrospective reviewed all the SB surgeries performed over a period of 26 months at the University Eye Clinic of Trieste, Italy. We selected a cohort of 102 patients in which SRF drainage by means of evacuative puncture was performed. A high-definition video was recorded during the whole duration of the procedures, and the macroscopic characteristics of the SRF leakage were assessed.
Results Pigmented dark-brownish deposits spilling in the fluid outcoming from the evacuative puncture was observed during the surgeries. In all cases, this macroscopic feature was detected during the late phases of the drainage. Moreover, indirect ophthalmoscopic evaluation showed the almost complete SRF drainage and a flattened retina at that moment.
Conclusions The pigment stream sign, easily detectable by the surgeon, allows to understand, during the evacuative puncture, when the SRF has been drained almost completely and that the drainage procedure is therefore close to the end.

Keywords Rhegmatogenous retinal detachment · Scleral buckling surgery · Subretinal fluid drainage · Pigment stream sign · Evacuative puncture

Introduction

Scleral buckling (SB) is an effective surgical technique for rhegmatogenous retinal detachment (RRD) repair. This procedure is widely adopted, and an anatomical success rate of 82–95% has been reported [1–4].

Despite alternative methods for retinal detachment (RD) repair, such as pars plana vitrectomy, pneumatic retinopexy or temporary inflatable balloons, SB still remains a valuable procedure in many instances and it should continue to be a part of the RRD surgery [5]. The aim of SB surgery is the closure of the break. Once the break is closed, the SRF is rapidly absorbed within a few hours or days according to the amount and density of SRF [6, 7].

Presented in part at the 15th EURETINA Congress - Nice 2015.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10792-018-0988-x) contains supplementary material, which is available to authorized users.

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SB surgery without evacuative puncture may be effective in many cases [8]. In the non-drainage surgeries, the most common causes of failure are ineffective indentation, inadequate segmental and/or encircling buckle positioning, vitreous traction, radial folds formation and the "fishmouthing" phenomenon. In addition, the lack of SRF reabsorption can stimulate proliferative vitreoretinopathy (PVR) especially if additional retinopexy treatments (laser and/or cryoretinopexy) are performed [9]. For these reasons, several retinal surgeons prefer to perform the drainage of the SRF in a high percentage of SB surgery for uncomplicated RD [10–12].

The SRF drainage is particularly useful when a great amount of SRF makes the buckle indentation not high enough to close the break, especially with severe vitreoretinal traction on the break. Drainage procedure is one of the most delicate and critical steps during episcleral surgery due to the risk of intraoperative complications such as vitreoretinal incarceration, retinal perforation, subretinal hemorrhage, eye hypotony and choroidal detachment [12, 13].

Site of SRF drainage is performed according to the configuration of RD. Several factors must be considered in deciding drainage site such as the distribution of subretinal fluid, the location of retinal tears, the location and configuration of the buckle, the vascularity of the choroid and the ease of site exposure. The ideal location of the drainage site is just above or below the lateral rectus muscle because the major choroidal vascularization is avoided and the sclera exposure is excellent. Drainage procedure is useful in order to facilitate precise localization of retinal breaks at the scleral level, to close retinal tears, to allow the attachment of the retina at the level of the buckle, to optimize the retinopexy procedures and to reduce intraocular pressure allowing scleral indentation more effective. A good drainage of the SRF reduces the amount of cryotherapy applications and consequently the risk of vitreous pigment dispersion and vitreoretinal traction. Moreover, SRF drainage creates space inside the eye to inject gas tamponade if necessary.

Several techniques for SRF drainage have been described. Schepens first described a method for controlled drainage of SRF which has been used widely and successfully during SB surgery [14]. Other techniques reported in the literature include the 25-gauge needle drainage (Charles' technique), the suture needle drainage, the argon laser choroidotomy, the modified needle drainage using a 26-gauge needle and the drainage technique through scleral pocket with incision radial or parallel to the limbus [9, 14–19].

The monitoring of SRF spilling and its macroscopic characteristics allows the surgeon to identify possible complications before they threaten outcomes, and facilitate the nearly complete drainage of SRF, until the retina is flat or almost close to being flat.

The aim of this study was to evaluate the macroscopic characteristics of the SRF while spilling from the external evacuative puncture in order to recognize recurrent and ease detectable features that may help the surgeon to obtain a controlled and therefore safe drainage during SB surgery.

Materials and methods

This retrospective observational study was carried out at the University Eye Clinic of Trieste, Italy. The study adhered to the tenets of the Declaration of Helsinki and informed consent was obtained from all subjects.

A total of 102 patients who underwent SB surgery with drainage puncture for primary RRD between January 2015 and March 2017 were included in the study.

All procedures were performed by a single and experienced surgeon (DT). All surgeries were digitally recorded as standard procedure.

We included patients with primary RRD and PVR less than or equal to C1 who underwent SB surgeries with SRF drainage. We quantified the pre-op SRF considering the mean extension of the retinal detachment. In our cohort study, it was 5.1 ± 2.3 clock hours. The drainage was performed because the amount of SRF, even after a 2-day double patching, was evaluated excessive to obtain a buckle indentation high enough to safely close the retinal break.

Patients with retinoschisis or who had previously undergone RRD surgery were excluded from the study. In all patients, local anesthesia was used and the standard technique of SB retinal detachment surgery was followed. The decision of encircling buckle or segmental buckle was made based on the size, number and location of the retinal tear. Indirect ophthalmoscopy (IO) evaluation was used intraoperatively to identify and localize all breaks, as well as to localize the SRF drainage site according to the extent of retina elevation and the retinal tears position. Thus, the

drainage was performed considering the highest retina elevation, preferably far from the vorticose veins of the choroid.

During surgery, drainage puncture was performed as described below. A flat diathermy probe was used in order to avascularise the scleral area and to reduce the risk of bleeding. A radial sclerotomy was performed using a 15°, and a thin sharp cauterization tip was used to enter the choroid and to reach the subretinal space. The depth of the incision was carefully observed with higher magnification until the spilling of SRF occurred. During all evacuative procedures, a progressive indentation of the eye was maintained to ensure an appropriate intraocular pressure and to allow the drainage of as much SRF as possible. The indentation maneuver was performed, if possible, at the primary retinal tear to close it during the drainage allowing to obtain a continuous and homogeneous drainage of SRF. In this way, the dangerous alternating pressure and depression of the eyeball was avoided. At the end of the drainage, the scleral incision was closed with a non-absorbable nylon 5–0 suture.

In order to analyze the precise timing of SRF leakage and to assess the macroscopic features of the SRF, a video camera included in the surgical microscope (OPMI Lumera 700, Carl Zeiss, Germany) was used to record a high-definition video of all surgeries (Online Resource 1).

Later, all the recorded videos were evaluated by two trained doctors. In many evacuative procedures, dark-brownish pigment deposits in the SRF spilling from the sclerotomy were observed. This feature, called pigment stream sign, was easily detectable by the surgeon during the drainage, and the recorded video has allowed to notice the exact moment in which it occurred.

The evacuative procedure was divided in different phases as follow (Fig. 1):

- Phase 1: from the beginning of the external evacuative puncture (T_0) to the appearance of pigment deposits in the drained fluid (T_1);
- Phase 2: from the appearance of pigment clusters in the drained SRF (T_1) to the end of pigment leak in the drained SFR (T_2);
- Phase 3: from the end of the pigment deposits spilling (T_2) and the end of SRF leakage (T_3).

Statistical analysis

All statistical analyses were performed using the SPSS software (version 17.0, SPSS, Inc.). Data were described with means and standard deviations for parametric variables, or with medians and interquartile ranges if data displayed a skewed distribution. The Mann–Whitney U test was used for evaluate the difference between groups. The difference between categorical variables was investigated using the Chi-squared test.

P values lower than 0.05 were considered to represent statistically significant differences.

Results

In all 102 cases, the drainage of SRF was obtained with one single evacuative puncture. No intraoperative complications related to the external drainage procedure occurred.

Overall, 84 patients (82.4%) achieved primary anatomical success. Eighteen patients (17.6%) required further surgery because of persistent retinal detachment; of these, 13 patients (72.2%) underwent pars plana vitrectomy, whereas five patients (27.8%) were treated with pneumatic retinopexy.

Among the whole studied cohort, 22 (21.6%) videos resulted not properly evaluable; consequently, they were excluded from the analysis.

In 80 (78.4%) SB surgeries, the spilling of pigmented deposits in the fluid outcoming from the

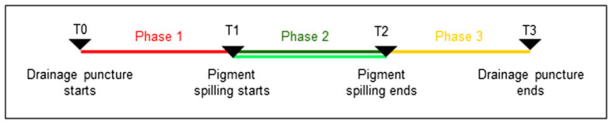

Fig. 1 Timeline of the evacuative procedure. T_0, the beginning of the evacuative puncture; T_1, the appearance of pigment deposits in the drained fluid; T_2, the end of pigment deposits spilling; T_3, the end of subretinal fluid leakage

evacuative puncture was observed. In these cases, the mean duration of the entire drainage process was 13.68 min (SD ± 4.47 min).

The time of each phases of the evacuative procedure was carefully evaluated (Fig. 2). On average, the duration of Phase 1 was 8.88 min (SD ± 4.97 min). The median duration of Phase 2 was 22 s (interquartile range 14.7–88 s). The mean time of Phase 3 was 56 s.

In 40 evacuative procedures (group 1), Phase 2 was inferior to 22 s, while in 40 of them (group 2) was superior or equal to 22 s. In group 1, the mean duration of Phase 3 was 6.1 min (SD ± 5.2 min), while in group 2 the median duration of Phase 3 was 0.4 min (interquartile range 0.26–0.81 s); the difference between the two groups was statistically significant ($p = 0.024$) (Fig. 3).

A Chi-squared test was performed to examine the relation between group 1 and group 2. The relation between these groups was significant, $\chi 2$ (2, $N = 80$) = 24.4, $p < 0.01$ (Fig. 4).

Discussion

Drainage is one of the most important debates in SB surgery for RRD.

Some authors believe that most cases of RRD can be managed without drainage of SRF, whereas others believe that drainage is a crucial aspect of the procedure [8–12]. Indeed, several study reported that the persistence of SRF postoperatively does delay anatomical and visual recovery [20, 21].

The drainage of SRF is a useful procedure favoring retinal detachment repair during SB surgery, contributing to flat the detached retina by decreasing the SRF.

Numerous techniques for the drainage of SRF have been reported, including the conventional method using sclerotomy, diathermy and perforation of the choroids, the needle drainage, the external laser choroidotomy and the needle suture [9, 14–19].

However, the drainage of SRF is a surgical maneuver correlated with possible intraoperative severe complications such as retinal incarceration, subretinal hemorrhage, choroidal detachment and loss of vitreous [12, 13].

The most delicate step of the drainage procedure is monitoring the amount of SRF that has been drained in order to reduce the risk of the above mentioned complications.

Typically, drainage is monitored externally, with only initially or intermittent use of IO to assess drainage progression, retinal flattening and possible complications [11, 15, 22, 23].

With external monitoring, a developing drainage complication may deteriorate prior to being recognized. External signs of drainage complications include premature cessation of SRF spilling, indicating possible retinal incarceration, or bleeding from the

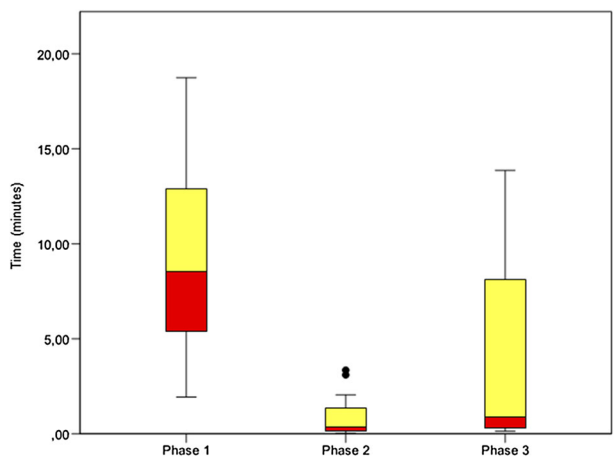

Fig. 2 Graph shows the time of each phases of the evacuative procedure. Phase 1: from the beginning of the external evacuative puncture (T_0) to the appearance of pigment deposits in the drained fluid (T_1). Phase 2: from the appearance of pigment clusters in the drained SRF (T_1) to the end of pigment leak in the drained SFR (T_2). Phase 3: from the end of the pigment deposits spilling (T_2) and the end of SRF leakage (T_3)

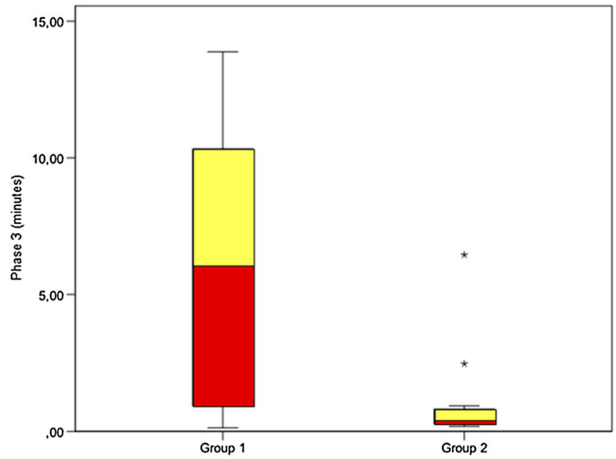

Fig. 3 Graph shows the time between the end of pigment deposits spilling and the end of the subretinal fluid leakage (Phase 3). Group 1 represents the procedures in which Phase 2 was inferior to 22 s. Group 2 represents the procedures in which Phase 2 was superior or equal to 22 s. The mean time of Phase 3 was higher in group 1 compared to group 2 ($p = 0.024$)

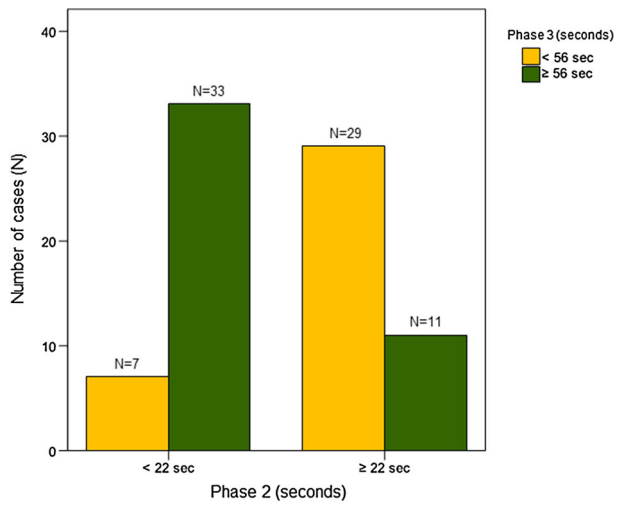

Fig. 4 Bar chart shows the number of cases during Phase 2 and Phase 3 using different threshold values (Phase 2: 22 s, Phase 3: 56 s). *N* was 7 in Phase 2 $<$ 22 s and Phase 3 $<$ 56 s; *N* was 33 in Phase 2 $<$ 22 s and Phase 3 $\geq$ 56 s; *N* was 29 in Phase 2 $\geq$ 22 s and Phase 3 $<$ 56 s; *N* was 11 in Phase 2 $\geq$ 22 s and Phase 3 $\geq$ 56 s. The relation between these groups was significant ($p < 0.01$). *N*, number of cases

drainage site, indicating possible choroidal, subretinal or vitreous hemorrhage.

Petterson et al. described a technique for continuous monitoring of SRF drainage using IO during the whole duration of the procedure [24]. In this way, as soon as the drainage process is proven, the surgeon uses the IO to observe the entire duration of SRF leakage and to check for imminent complications.

If an external monitoring is adopted, especially in case of media opacities such as corneal edema as well as crystalline lens opacities, one of the main concerns is the amount of SRF to be drained. During the drainage procedure, the surgeon is not aware about the remaining SRF to be drained. In the meanwhile, the eye becomes soft and an indentation maneuver is strongly suggested to maintain an adequate intraocular pressure. As it is not possible to drain too much fluid in order to avoid excessive ocular hypotony and eye deformation due to indentation, it could be very useful to recognize a sign of imminent drainage stop.

An indicator of drainage ending is the appearance of pigmented deposits in the subretinal fluid. This sign has been described in the literature including surgical textbooks and websites [25, 26]; however, to our knowledge the relation between the duration and the amount of pigment deposits spilling and the end of SRF leakage has never been evaluated. In the present study, we observed that the spilling of pigmented deposits in the fluid outcoming from the evacuative puncture is a common aspect during our surgical procedures. Among these cases, a strong correlation between the pigment clusters leak and the end of SRF leakage was found. In particular, it has been observed that if the pigment leaks continuously during the

drainage and becomes progressively more abundant (longer phase 2), the SRF drainage is close to the end (shorter phase 3). Conversely, if the pigment spills for a short time (shorter phase 2), the SRF leaks abundantly from the drainage site (longer phase 3) indicating that the evacuative procedure is not close to the end.

Intraoperative flat retina was defined as the complete dry reattachment of the retina, without any areas of residual SRF. IO fundus evaluation showed a complete flat retina and closed retinal tears in Group 2, while some areas of residual SRF were observed in Group 1.

The pigmented granules in the drained SRF are an indirect sign of the progressive adhesion of the retina on the underlying retinal pigmented epithelium (RPE). Indeed, copious amount of pigmented precipitates tends to appear in the later phases of the drainage puncture when the SRF is almost completely drained, as confirmed by intraoperative IO evaluation.

Our study shows that the continuous and progressively increasing leak of pigment deposits in the SRF is an important sign during the evacuative puncture indicating the forthcoming end of the drainage procedure. The pigment stream sign, when present, is easily detected by the surgeon during the drainage procedure and is useful to understand the approaching end of SRF leakage.

Compliance with ethical standards

Conflict of interest Chiara De Giacinto declares that she has no conflict of interest. Marco Paoloni declares that he has no conflict of interest. Alberto Armando Perrotta declares that he has no conflict of interest. Marco Pastore declares that he has no conflict of interest. Rita Piermarocchi declares that she has no conflict of interest. Daniele Tognetto declares that he has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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