INTRAOPERATIVE CHOROIDAL DETACHMENT DURING 23-GAUGE VITRECTOMY

RYAN M. TARANTOLA, MD,* JAMES C. FOLK, MD,* SHAIVAL S. SHAH, MD,*
H. CULVER BOLDT, MD,* MICHAEL D. ABRÀMOFF, MD,*† STEPHEN R. RUSSELL, MD,*
VINIT B. MAHAJAN, MD, PHD*‡

Purpose: To review intraoperative choroidal detachments during 23-gauge vitrectomy and examine possible mechanism(s) involved.

Methods: A retrospective consecutive case review of 23-gauge vitrectomies was performed. Main outcomes included choroidal detachment incidence, location, extent, relation to infusion cannula, and postoperative course. Laboratory study of human donor eyes was conducted by placing 23-gauge cannulas at various angles through the pars plana and injecting viscoelastic material after cannula retraction.

Results: Among 338 consecutive 23-gauge vitrectomy cases, 12 (3.55%) intraoperative choroidal detachments occurred. These included 6 (1.77%) serous detachments, 4 (1.18%) limited hemorrhagic detachments, and 1 case each of gas and silicone oil during an exchange. In four of six serous detachments and three of four hemorrhagic detachments, the detachment originated from the infusion cannula site. Intraoperative infusion cannula retraction (5 of 12 cases) and blockage (2 of 12 cases) caused transient hypotony. All cases of serous, hemorrhagic, and gas detachment resolved without intervention. Cannulas were placed at various angles to the sclera in human donor eyes. Choroidal detachments were produced injecting viscoelastic material through obliquely placed cannulas after 1 mm of retraction.

Conclusion: Infusion cannula retraction is an important mechanism and risk factor for the development of intraoperative choroidal detachment during 23-gauge vitrectomy. Precautions to prevent retraction and intraoperative repositioning may help avoid this complication.

RETINA X:1–9, 2011

Serous choroidal detachment (SCD) and hemorrhagic choroidal detachment (HCD) are complications that occur during or after intraocular surgery.[1–5] The mechanism of SCD includes both hypotony and inflammation, which lead to an increased tendency for fluid accumulation in the suprachoroidal space. Serous choroidal detachment can also occur in the setting of intraocular tumors,[6,7] nanophthalmos,[8] ocular inflammatory conditions,[9] carotid-cavernous fistula,[10] and panretinal photocoagulation,[11] secondary to certain medications,[12] and spontaneously.[13] In HCD, the postulated mechanism is initial hypotony, with or without a preceding serous choroidal effusion, resulting in stretching and rupture of a long or short posterior ciliary artery.[14–16] Hemorrhagic choroidal detachment is most commonly encountered during or after cataract extraction,[17] glaucoma filtering surgery,[18] penetrating keratoplasty,[19] and vitrectomy.[20,21] Hemorrhagic choroidal detachment may also occur secondary to trauma,[22,23] choroidal neovascular membranes, laser photocoagulation,[24] Valsalva,[25] or blood clotting abnormalities.[26] Involvement can vary from limited peripheral hemorrhage with spontaneous resolution to massive bleeding with retinal apposition and expulsion of intraocular contents. Surgical drainage of both SCD and HCD is indicated in certain instances, and the appropriate timing is controversial.[2,5]

From the *Vitreoretinal Service, Department of Ophthalmology and Visual Sciences, University of Iowa, Iowa City, Iowa; †Iowa City VA Medical Center, Iowa City, Iowa; and ‡Omics Laboratory, University of Iowa, Iowa City, Iowa.

Supported by the Research to Prevent Blindness.

The authors have no conflicts of interest to disclose.

Reprint requests: Vinit B. Mahajan, MD, PhD, The University of Iowa Carver College of Medicine, 200 Hawkins Drive, Iowa City, IA 52242; e-mail: vinit-mahajan@uiowa.edu

Recent advancements in microsurgical instrumentation have led to the increased use of small-gauge vitrectomy.[27–32] In standard 20-gauge vitrectomy, the conjunctiva is dissected, sclerotomy incisions are made at a 90° angle to the sclera with a microvitreoretinal blade, the infusion is sutured to the sclera, and the sclerotomies are sutured at the conclusion of surgery. In comparison, 23-gauge vitrectomy sclerotomies are created using trocars to place cannulas across the conjunctiva, sclera, and pars plana. Insertion of the trocar at an oblique angle rather than a 90° angle creates a beveled wound with increased length, improved wound apposition, and a greater likelihood of sealing without suture placement and likely reduces the risk of endophthalmitis and postoperative hypotony.[33–37]

In discussions with colleagues at our own and other institutions, it has been suggested that the frequency of intraoperative SCD and HCD increased with the introduction of 23-gauge vitrectomy. We observed many of these choroidal detachments developing intraoperatively at the site of the infusion cannula with visible cannula retraction beneath the choroid or associated with an infusion cannula blocked by vitreous. In these clinical and laboratory studies, our aim was to determine the incidence of intraoperative SCD and HCD during 23-gauge vitrectomy, elucidate the responsible mechanism(s), and examine approaches to prevent this complication.

Methods

The study protocol was approved by the Institutional Review Board for Human Subjects Research at the University of Iowa, and the study adheres to the tenets set forth in the Declaration of Helsinki. Operative reports, surgical logs, and charts from a consecutive group of surgical patients who underwent 23-gauge vitrectomy were retrospectively reviewed. Any patient with <3 months of follow-up was excluded. Statistical analysis was performed using SAS Version 9.1 (SAS, Inc, Cary, NC).

Surgical Technique

Vitrectomies were performed with retrobulbar anesthesia under monitored anesthesia care. Periorbital skin and eyes were prepped with 5% povidone–iodine (Betadine; Purdue Fredrick Co, Norwalk, CT). All cases were performed using a single-step transconjunctival 23-gauge trocar cannula system (Alcon Laboratories, Inc, Fort Worth, TX). Approximately 10% of cases used the newer Alcon spear-shaped lancet. Our impression was that the wound construction technique was unchanged. Angled trocar incisions were created 3 mm and 3.5 mm posterior to the limbus in pseudophakic and phakic eyes, respectively. Incisions were created using a biplanar insertion of the trocar with a 15° to 45° initial insertion angle dependent on individual surgeon preference. Cannulas were placed through the pars plana in the superotemporal, superonasal, and inferotemporal quadrants, with the infusion line attached to the inferotemporal cannula. Appropriate placement of the infusion cannula in the vitreous cavity was visually confirmed before initiating infusion. The infusion cannula was stabilized with steri-strips to the surgical drape but was not sutured. A core vitrectomy was performed in all cases. Additional surgical techniques were used as needed to address the abnormality present. In most cases, scleral depression was used to assist removal of the peripheral vitreous. At the conclusion of each case, the peripheral retina was examined using scleral depression to evaluate for any retinal abnormality, and laser was routinely applied posterior to sclerotomy sites and to any identified retinal breaks. After cannula removal, sclerotomy sites were evaluated to detect leakage and sutures were placed as necessary.

Laboratory Investigations

Three 23-gauge trocars were used to insert cannulas in recently harvested human autopsy eyes. The cannulas were inserted 3.5 mm posterior to the limbus at 90°, 45°, and 15° angles in a manner identical to that performed during surgery. The anterior segment was then dissected at the limbus removing the cornea and lens, leaving the iris root intact, and a Weck-cel vitrectomy was performed. Cannula placement was examined, and the internal location was noted. In some eyes, the cannula was retracted 1 mm. Viscoelastic material was then injected, and its location was noted. Subsequently, gross and microscopic examination was performed to determine the location of deposition and impact on ocular tissues.

Results

Clinical Results

Twelve cases (3.55%) of intraoperative choroidal detachment occurred among 338 consecutive 23-gauge vitrectomy cases. These 12 choroidal detachments contained serous fluid in 6 (1.77%), blood in 4

Table 1. Choroidal Detachment Incidence

Choroidal Detachment	Number	Percentage
Serous	6/338	1.77
Hemorrhagic	4/338	1.18
Gas	1/338	0.3
Oil	1/338	0.3
Total	12/338	3.55

Table 2. Choroidal Detachment Cases

Patient	Age	Sex	Indication	Choroidal Detachment	At Cannula Site	Hypotony	Cannula Status	Pre- and Postoperative Visual Acuity	Follow-up Duration (Months)	Risk Factors
1	71	M	Epiretinal membrane	Serous	Yes	Yes	Retracted	20/100; 20/40	4.5	None
2	63	F	Epiretinal membrane	Serous	Yes	Yes	Retracted	20/70; 20/40	10	None
3	71	M	Stage II macular hole	Serous	No	No	Neither	20/80; 20/25	6	High myopia, previous SB
4	79	F	Epiretinal membrane	Serous	Yes	No	Neither	20/50; 20/40	3.5	None
5	62	M	Stage IV macular hole	Serous	Yes	Yes	Retracted	20/200; 20/50 with cataract	3	None
6	88	M	Retinal detachment, AMD with geographic atrophy, cataract	Serous	No	No	Neither	20/50; 20/100: SO	3	Retinal detachment, advanced age
7	59	M	Stage IV chronic macular hole, cataract	Hemorrhagic	Yes	Yes	Blocked	20/400; 20/300	3	None
8	60	M	Vitreous opacities	Hemorrhagic	Yes	Yes	Retracted	20/30; 20/25	5	None
9	77	F	Chronic retinal detachment, Grade C-12 PVR, macular hole, cataract	Hemorrhagic	Yes	No	Neither	Light perception; 20/300 (aphakic)	11	Retinal detachment, SB placement, high myopia
10	59	F	Stage II macular hole	Hemorrhagic	No	Yes	Blocked	20/40; 20/25	3	None
11	73	M	Retinal detachment	SF_6	Yes	No	Retracted	Hand motion; 20/50	3.5	None
12	57	M	Retinal detachment with PVR, cataract	SO	Yes	No	Probable retraction	Hand motion; 20/40	4	None

F, female; M, male; PVR, proliferative vitreoretinopathy; SB, scleral buckle; SF_6, sulfur hexafluoride; SO, silicone oil; AMD, age-related macular degeneration.

(1.18%), sulfur hexafluoride (SF_6) in 1, and silicone oil in 1 (Table 1). All choroidal detachments were noted intraoperatively at varying times, including during the core vitrectomy, after peripheral vitrectomy, and during infusion of gas/oil during exchange. Eight male and four female patients were affected. The mean age of patients with choroidal detachment was 68.3 ± 9.8 years. The surgical indication for vitrectomy was macular hole in four eyes, retinal detachment in four eyes, epiretinal membrane in three eyes, and vitreous opacities in one eye. All patients had at least 3 months of follow-up, with a mean postoperative follow-up duration of 5.0 ± 2.8 months. Mean visual acuity was improved at most recent follow-up in all but 1 patient (Table 2). This patient (Patient 6) has deferred silicone oil removal from the vitreous cavity because of declining health.

The location and extent of the choroidal detachments were diagrammed along with cannula location

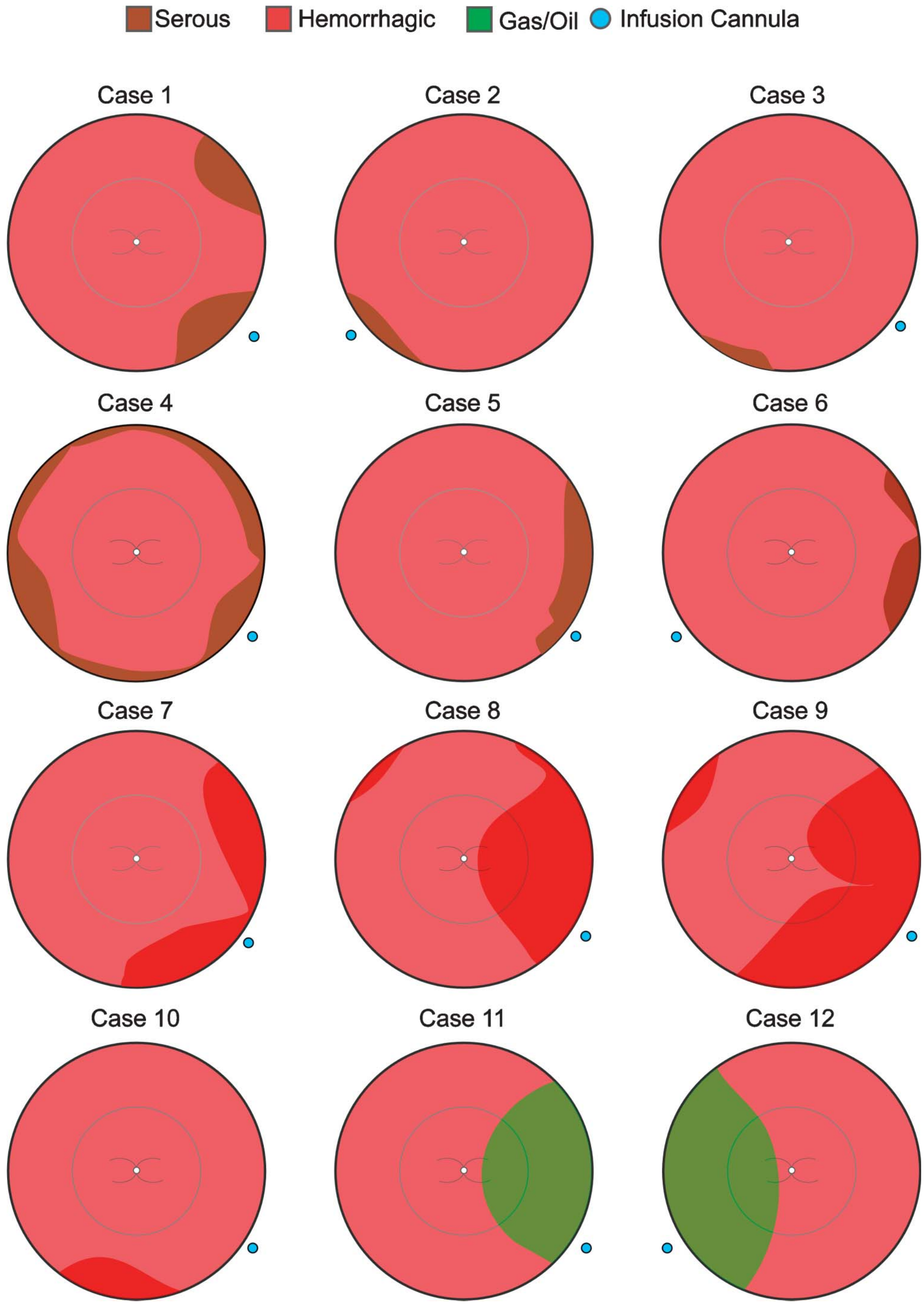

Fig. 1. Choroidal detachment maps. Fundus diagrams of intraoperative choroidal detachments are shown. Serous choroidal detachments are shown in brown. Hemorrhagic choroidals are in red. Sulfur hexafluoride and silicone oil choroidals are in green. The blue circle is the site of the infusion cannula, which correlated with the site of choroidal detachment in 9 of 12 patients.

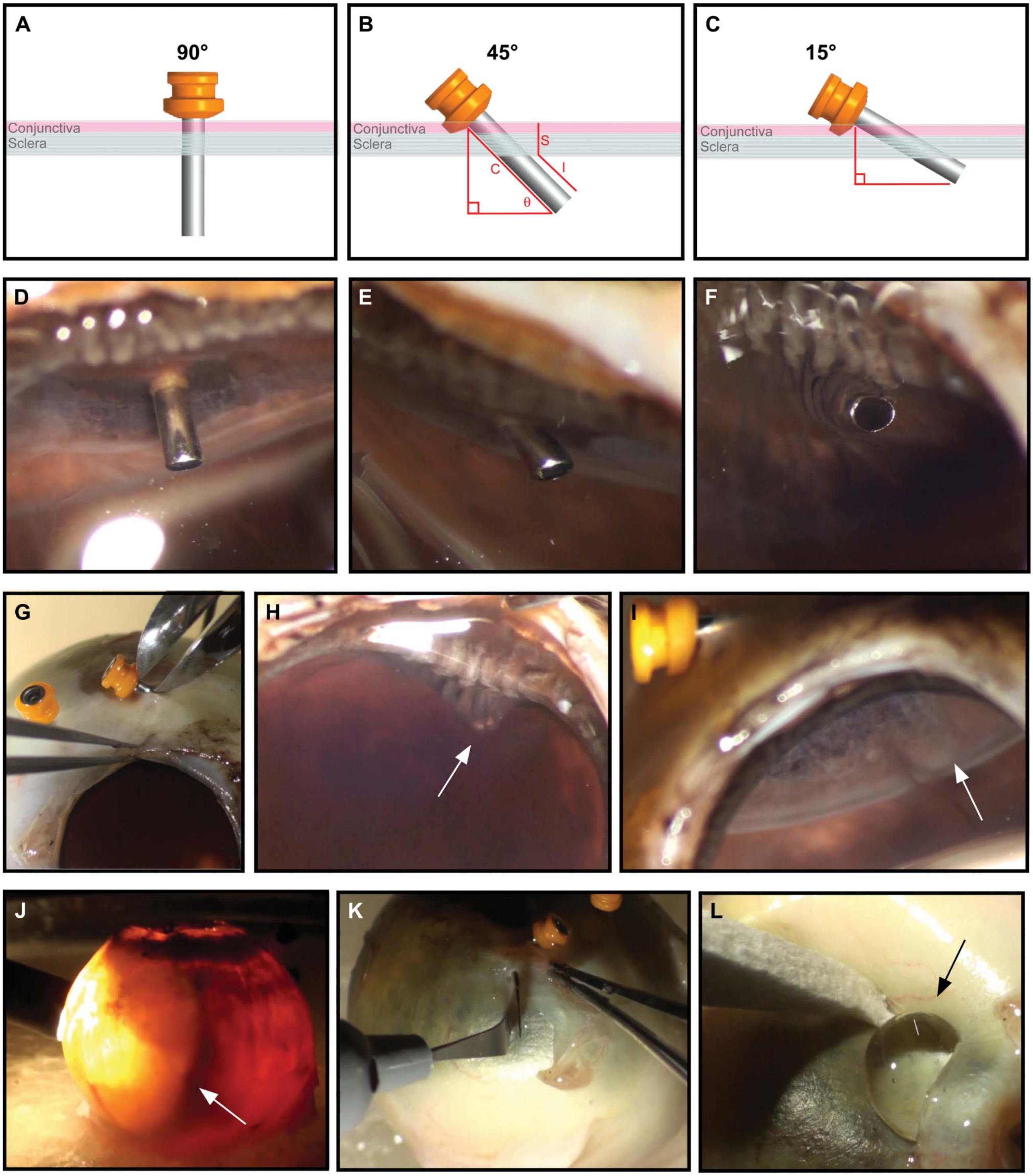

Fig. 2. Choroidal detachment in human autopsy eyes. **A–C.** Schematic showing 23-gauge cannulas inserted at insert cannulas at 90°, 45°, and 15° and calculation describing length of exposed internal cannula (I), total cannula length (C), conjunctival–scleral thickness (S), and wound angle(θ) such that $I = C - (S/\sin\theta)$. **D–F.** Intraocular view of 23-guage cannulas. **G.** External view after 15° cannula was retracted <1.0 mm. **H.** Internal view after the 15° cannula was retracted; note that the cannula tip is hidden under the pars plana. **I.** Intraocular view showing immediate choroidal detachment after injection of viscoelastic material through the 15° cannula. **J.** Transillumination of the globe reveals the area (white) of choroidal detachment. **K** and **L.** A scleral cut down confirms the presence of viscoelastic material in the suprachoroidal space.

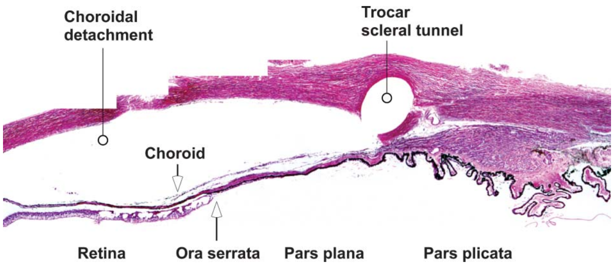

Fig. 3. Histology in the region of the experimental choroidal detachment demonstrates detachment of the choroid from the sclera adjacent to the location of the cannula tunnel.

(Figure 1). None of the SCD extended further than 3 mm posterior to the pars plana, and none reached to the equator. Four of 6 detachments were limited to <3 clock hours, 1 was 6 clock hours, and 1 was 12 clock hours in extent. All cases of HCD were limited and did not result in retinal apposition or expulsion of intraocular contents. Two cases of HCD extended below the macula as did the case of suprachoroidal SF_6 and silicone oil. In four of six SCD cases and three of four HCD cases, the detachment originated from the infusion cannula site. In both the SF_6 and the silicone oil detachments, the detachment originated from the infusion site.

Infusion cannula retraction and subsequent hypotony was noted in 3 of 6 cases of SCD (Patients 1, 2, and 5). In the remaining 3 cases of SCD (Patients 3, 4, and 6), no infusion cannula retraction or hypotony was noted. However, Patients 3 and 6 each had multiple risk factors for SCD, including high myopia, previous scleral buckle placement, and retinal detachment, and in Patient 4, the detachment originated from the infusion site, suggesting that there may have been unrecognized infusion cannula retraction. Infusion cannula retraction and subsequent hypotony was noted in 1 of 4 cases of HCD (Patient 8). In 2 other cases of HCD (Patients 7 and 10), the infusion cannula was blocked with vitreous, resulting in hypotony. In the final case of HCD, no infusion cannula retraction or hypotony was noted (Patient 9). However, this patient had multiple risk factors for HCD, including advanced age, scleral buckle placement, high myopia, rhegmatogenous retinal detachment, and intraoperative hypertension. Infusion cannula retraction was observed in the case with suprachoroidal SF_6 infusion (Patient 11) and presumed in the case with suprachoroidal silicone oil (Patient 12). In cases with infusion cannula retraction, removal of the infusion and replacement in one of the superior cannulas with subsequent creation of a new inferonasal infusion resulted in immediate intraoperative stabilization or improvement in all cases. Postoperatively, all 6 cases of SCD were improved on Postoperative Day 1; 5 of 6 were resolved by Postoperative Week 1; and the remaining case resolved by Postoperative Month 1 without intervention and without any apparent adverse visual acuity outcome. All 4 of the HCD cases improved during the postoperative period by Week 1, Week 6, Month 4, and Month 5, respectively, without intervention and without any apparent adverse visual outcome. The SF_6 choroidal detachment was immediately drained intraoperatively, and the associated hemorrhage resolved spontaneously over the course of 6 weeks. The silicone oil choroidal detachment required subsequent surgical drainage at Postoperative Week 4. Despite choroidal detachment, anatomical success was achieved and the anticipated postoperative visual acuity was achieved in all patients (Table 2).

Laboratory Results

We noted intraoperatively that many of the choroidal detachments were associated with cannula retraction beneath the pars plana and into the suprachoroidal space. Moreover, most of the cannulas that had retracted had been placed through a shallow-angle biplanar wound in which the initial incision was nearly parallel to the sclera. We generated an equation describing the relationship between length of exposed internal cannula (I), total cannula length (C), conjunctival–scleral thickness (S), and wound angle (θ): $I = C - (S/\sin\theta)$ (Figure 2, A–C). Assuming the total cannula length is 4 mm and the conjunctival–scleral thickness can range from 0.8 mm to 1.0 mm over the pars plana, a 90°, 45°, and 15° wound would create an internal cannula length of 3.2 mm to 3.0 mm, 2.59 mm to 2.87 mm, 0.14 mm to 0.91 mm, respectively. Thus, minimal retraction of a 15° cannula may place the cannula opening beneath the pars plana.

To test this hypothesis, 23-gauge cannulas were placed in human autopsy eyes at angles to the external sclera of 90° (perpendicular), 45°, and 15° (nearly parallel) (Figure 2, A–C). Examination of the interior wound revealed the cannula position entering the vitreous cavity through the pars plana (Figure 2, D–F). The 15° cannula had the shortest segment of cannula exposure in the vitreous cavity, but instruments and fluid passed freely through all 3 cannulas. Retraction of each cannula by 1.0 mm (Figure 2G) resulted in a portion of the 90° and 45° cannulas still exposed in the vitreous cavity. However, the 15° cannula retracted completely under the pars plana and was no longer visible in the vitreous cavity (Figure 2H). Viscoelastic material was then injected through each cannula with gentle pressure using an extrusion cannula. Free passage into the vitreous cavity was noted through the cannulas placed at 90° and 45°. Viscoelastic material was not seen exiting the 15° cannula or the sclerotomy, and an extensive choroidal detachment developed at the cannula site noted by direct visualization and transillumination (Figure 2, I and J). To confirm that viscoelastic material was in the suprachoroidal space, a scleral incision was created 9.0 mm posterior to the limbus (Figure 2K). Once a full-thickness scleral wound was created, viscoelastic material readily leaked from the suprachoroidal space (Figure 2L). A hematoxylin and eosin section through this area confirmed detachment of the ciliary body and choroid from the sclera adjacent to the tunnel created by the cannula (Figure 3).

Discussion

Detachment of the choroid occurs when either serous fluid or hemorrhage occupies the potential space between the choroid and the sclera. Compared with previously described mechanisms, our study suggests that cannula retraction may cause increased rates of SCD and HCD observed during 23-gauge vitrectomy.

The incidence of intraoperative SCD during 20-gauge vitrectomy was recently reported to be 0.4% to 0.5% among Medicare beneficiaries.[38] Initial studies examining 23-gauge vitrectomy have had relatively small sample sizes but have described intraoperative choroidal effusion rates of 0% to 1.8% with incidences of 1 of 118,[32] 0 of 100,[31] 0 of 92,[30] 0 of 57,[39] and 8 of 442.[40] The single case of intraoperative choroidal effusion during 23-gauge vitrectomy described in the series published by Chieh et al[32] occurred when the infusion cannula migrated into the suprachoroidal space and resolved spontaneously with infusion repositioning. Of the 8 cases reported by Ooto et al,[40] 7 occurred during scleral depression in the inferotemporal quadrant and 1 occurred when the lid speculum became inadvertently displaced. In each case, the infusion cannula retracted into the suprachoroidal space. Three of the eight eyes developed an associated limited HCD. In 7 of 8 eyes, a 20-gauge infusion was inserted through the pars plana, and in 1 eye, the original 23-gauge infusion was reinserted, resulting in stabilization of the SCD.[40] In our series, we report 6 cases of SCD of 338 consecutive 23-gauge vitrectomies, resulting in an incidence of 1.77%. In four of the six cases, the location of the choroidal detachment was in the same quadrant as the infusion cannula, suggesting that direct infusion into the suprachoroidal space resulted in this complication. In three of six cases, the infusion cannula was visibly retracted. The hypothesis that cannula retraction is responsible for this increased rate of SCD is further supported by cases of direct infusion of SF_6 gas through a cannula that was retracted into the suprachoroidal space, resulting in a localized choroidal detachment.

Previous studies examining the rate of intraoperative HCD during 20-gauge vitrectomy have demonstrated a 0.17% to 1.9% incidence.[41,42] Risk factors have been reported to include high myopia, previous retinal detachment surgery, presence of a rhegmatogenous retinal detachment, encircling with a broad sclera buckle, cryotherapy, external transchoroidal drainage of subretinal fluid, and intraoperative systemic hypertension.[20] The incidence of HCD during 23-gauge vitrectomy has not been established, however; cases during small-gauge vitrectomy have been reported.[43,44] In our series, we report 4 cases of HCD of 338 consecutive 23-gauge vitrectomies, resulting in an incidence of 1.18%. All four cases were limited, and three of four were located in the quadrant of the infusion cannula. In one of four cases, the infusion cannula was visibly retracted, and in two other cases, the infusion cannula became blocked with peripheral vitreous, resulting in hypotony. All cases spontaneously resolved in the postoperative period with no further surgical intervention. A probable mechanism in these cases was cannula retraction, initially causing an SCD with subsequent hemorrhage. This may occur either by direct infusion into the suprachoroidal space or by vitreous incarceration in the short portion of exposed internal infusion cannula in the vitreous base causing hypotony.

We were able to reproduce choroidal detachment in human autopsy eyes. After 1.0 mm of cannula retraction, the tip of the 15° 23-gauge cannula was no longer visible in the vitreous cavity, and experimental choroidal detachments were easily created with viscoelastic material injection. Experimental choroidal detachments have been produced in rabbit, dog, and monkey models by inducing hypotony, intraocular inflammation, vortex vein compression, and injection of substances into the suprachoroidal space.[2,45–48] These previous studies have focused on the etiology and factors that contribute to choroidal detachment. In our experiments, our aim was to examine the internal appearance of 23-gauge cannulas inserted with trocars at varying angles, determine the distance of cannula retraction resulting in cannula placement in the suprachoroidal space, and confirm this location by injecting viscoelastic material and creating a choroidal detachment. Choroidal detachment was confirmed based on clinical appearance, the release of viscoelastic material after scleral incision, and histologic sections. As the angle of a beveled trocar incision becomes more acute, the length of the cannula in the sclera increases; however, the length of the remaining cannula exposed in the vitreous cavity is reduced. When placing the 23-gauge trocar, a desirable insertion angle should produce a wound that has an adequate length to maximize the probability of selfsealing but also allows sufficient internal exposure of the cannula in the vitreous cavity to minimize the risk of inadvertent retraction into the suprachoroidal space or blockage by the vitreous base.

Although hypotony is the accepted mechanism for intraoperative SCD and HCD, our studies suggest that an additional mechanism is relevant to 23-gauge vitrectomy. The unsutured 23-gauge cannula in a shallow beveled sclerotomy may retract beneath the pars plana. In this position, infusion fluid, gas, oil, or instruments may dissect a plane into the suprachoroidal space. Additionally, a flat wound results in a smaller portion of the cannula penetrating the vitreous base with exposure in vitreous cavity. This may result in a higher likelihood of vitreous incarceration causing hypotony and subsequent choroidal detachment and/or hemorrhage. Steps that can be taken to help avoid these complications may include modification of the infusion cannula wound by insertion at a steeper angle, visual confirmation of the at least 2 mm of the infusion cannula in the vitreous cavity after insertion, securing the infusion tubing with steri-strips to the surgical drape so that the cannula is oriented at 90° to the sclera rather than laying flat, alerting surgical assistants against movements that may pull on the infusion tubing, periodically checking the external appearance of the infusion cannula during surgery to identify any retraction, visually reconfirming cannula position before injection of substances such as gas or silicone oil into the eye, and being aware that intraoperative retraction may occur, particularly during scleral depression. If intraoperative cannula retraction or the formation of a choroidal detachment is noted, the infusion should be turned off and the cannula removed. We quickly attach the infusion line to one of the superior cannulas to reestablish intraocular globe pressure, and in many cases, the serous choroidal resolves immediately. The original wound is sutured with subsequent creation of a new inferonasal infusion as needed.

Reasons why our rate of SCD and HCD may be higher than that reported in other series could include the increased length and complexity of cases encountered at a tertiary teaching referral center, shaving of the vitreous base with scleral depression in nearly all cases, and meticulous observation and postoperative drawings to record findings in the peripheral anterior retina. Limitations of this study include its retrospective nature and the lack of a 20-gauge vitrectomy control group. Human autopsy eyes lack conjunctiva and may not have identical scleral thickness to that in living patients. Additional studies with more patients are required to further define the incidence of SCD and HCD associated with 23-gauge vitrectomy.

Key words: 23-gauge vitrectomy, choroidal detachment, serous choroidal detachment, suprachoroidal hemorrhage, hemorrhagic choroidal detachment.

References

1. Bellows AR, Chylack LT Jr, Hutchinson BT. Choroidal detachment. Clinical manifestation, therapy and mechanism of formation. Ophthalmology 1981;88:1107–1115.
2. Brubaker RF, Pederson JE. Ciliochoroidal detachment. Surv Ophthalmol 1983;27:281–289.
3. Taylor DM. Expulsive hemorrhage. Am J Ophthalmol 1974;78: 961–966.
4. Gressel MG, Parrish RK II, Heuer DK. Delayed nonexpulsive suprachoroidal hemorrhage. Arch Ophthalmol 1984;102: 1757–1760.
5. Chu TG, Green RL. Suprachoroidal hemorrhage. Surv Ophthalmol 1999;43:471–486.
6. Palamar M, Thangappan A, Shields CL, Ehya H, Shields JA. Necrotic choroidal melanoma with scleritis and choroidal effusion. Cornea 2009;28:354–356.
7. Kreiger AE, Meyer D, Smith TR, Riemer K. Metastatic carcinoma to the choroid with choroidal detachment. A case presenting as uveal effusion. Arch Ophthalmol 1969;82:209–213.
8. Brockhurst RJ. Nanophthalmos with uveal effusion: a new clinical entity. Trans Am Ophthalmol Soc 1974;72:371–403.
9. McGrand JC. Choroidal detachment in aphakic uveitis. Br J Ophthalmol 1969;53:778–781.
10. Guerry D III, Harbison JW, Wiesinger H. Bilateral choroidal detachment and fluctuating proptosis secondary to bilateral dural arteriovenous fistulas treated with transcranial orbital decompression with resolution: report of a case. Trans Am Ophthalmol Soc 1975;73:64–73.
11. Zamir E, Anteby I, Merin S. Choroidal effusion causing transient myopia after panretinal photocoagulation. Arch Ophthalmol 1996;114:1284–1285.
12. Parikh R, Parikh S, Das S, Thomas R. Choroidal drainage in the management of acute angle closure after topiramate toxicity. J Glaucoma 2007;16:691–693.
13. Velzeboer CM. Spontaneous choroidal detachment: report of two cases. Am J Ophthalmol 1960;49:898–903.
14. Manschot WA. The pathology of expulsive hemorrhage. Am J Ophthalmol 1955;40:15–24.
15. Maumenee AE, Schwartz MF. Acute intraoperative choroidal effusion. Am J Ophthalmol 1985;100:147–154.
16. Beyer CF, Peyman GA, Hill JM. Expulsive choroidal hemorrhage in rabbits. A histopathologic study. Arch Ophthalmol 1989;107:1648–1653.
17. Davison JA. Acute intraoperative suprachoroidal hemorrhage in capsular bag phacoemulsification. J Cataract Refract Surg 1993;19:534–537.
18. Cantor LB, Katz LJ, Spaeth GL. Complications of surgery in glaucoma. Suprachoroidal expulsive hemorrhage in glaucoma patients undergoing intraocular surgery. Ophthalmology 1985; 92:1266–1270.
19. Purcell JJ Jr, Krachmer JH, Doughman DJ, Bourne WM. Expulsive hemorrhage in penetrating keratoplasty. Ophthalmology 1982;89:41–43.
20. Tabandeh H, Sullivan PM, Smahliuk P, Flynn HW Jr, Schiffman J. Suprachoroidal hemorrhage during pars plana vitrectomy. Risk factors and outcomes. Ophthalmology 1999; 106:236–242.
21. Tabandeh H, Flynn HW Jr. Suprachoroidal hemorrhage during pars plana vitrectomy. Curr Opin Ophthalmol 2001;12:179–185.

22. Kuhn F, Morris R, Mester V. Choroidal detachment and expulsive choroidal hemorrhage. Ophthalmol Clin North Am 2001;14:639–650.
23. Routsis P, Garston B. Late traumatic wound dehiscence after phacoemulsification. J Cataract Refract Surg 2000;26: 1092–1093.
24. Gole GA. Massive choroidal haemorrhage as a complication of krypton red laser photocoagulation for disciform degeneration. Aust N Z J Ophthalmol 1985;13:37–38.
25. Meyers SM, Foster RE. Choroidal hemorrhage after Valsalva's maneuver in eyes with a previous scleral buckle. Ophthalmic Surg 1995;26:216–217.
26. Allinson RW, Fante RG, List AF. Recurrent hemorrhagic choroidal detachment associated with disseminated intravascular coagulation. Ann Ophthalmol 1992;24:72–74.
27. Fujii GY, De Juan E Jr, Humayun MS, et al. A new 25-gauge instrument system for transconjunctival sutureless vitrectomy surgery. Ophthalmology 2002;109:1807–1812; discussion 13.
28. Fujii GY, de Juan E, Humayun MS, et al. Initial experience using the transconjunctival sutureless vitrectomy system for vitreoretinal surgery. Ophthalmology 2002;109:1814–1820.
29. Eckardt C. Transconjunctival sutureless 23-gauge vitrectomy. Retina 2005;25:208–211.
30. Gupta OP, Ho AC, Kaiser PK, et al. Short-term outcomes of 23-gauge pars plana vitrectomy. Am J Ophthalmol 2008;146:193–197.
31. Lott MN, Manning MH, Singh J, Zhang H, Singh H, Marcus DM. 23-Gauge vitrectomy in 100 eyes: short-term visual outcomes and complications. Retina 2008;28:1193–1200.
32. Chieh JJ, Rogers AH, Wiegand TW, Baumal CR, Reichel E, Duker JS. Short-term safety of 23-gauge single-step transconjunctival vitrectomy surgery. Retina 2009;29:1486–1490.
33. Lopez-Guajardo L, Pareja-Esteban J, Teus-Guezala MA. Oblique sclerotomy technique for prevention of incompetent wound closure in transconjunctival 25-gauge vitrectomy. Am J Ophthalmol 2006;141:1154–1156.
34. Taban M, Ventura AA, Sharma S, Kaiser PK. Dynamic evaluation of sutureless vitrectomy wounds: an optical coherence tomography and histopathology study. Ophthalmology 2008;115:2221–2228.
35. Singh RP, Bando H, Brasil OFM, Williams DR, Kaiser PK. Evaluation of wound closure using different incision techniques with 23-gauge and 25-gauge microincision vitrectomy systems. Retina 2008;28:242–248.
36. Taban M, Sharma S, Ventura AA, Kaiser PK. Evaluation of wound closure in oblique 23-gauge sutureless sclerotomies with visante optical coherence tomography. Am J Ophthalmol 2009;147:101.e1–107.e1.
37. Gupta OP, Maguire JI, Eagle RC Jr, Garg SJ, Gonye GE. The competency of pars plana vitrectomy incisions: a comparative histologic and spectrophotometric analysis. Am J Ophthalmol 2009;147:243.e1–250.e1.
38. Stein JD, Zacks DN, Grossman D, Grabe H, Johnson MW, Sloan FA. Adverse events after pars plana vitrectomy among medicare beneficiaries. Arch Ophthalmol 2009;127:1656–1663.
39. Schweitzer C, Delyfer MN, Colin J, Korobelnik JF. 23-Gauge transconjunctival sutureless pars plana vitrectomy: results of a prospective study. Eye (Lond) 2009;23:2206–2214.
40. Ooto S, Kimura D, Itoi K, et al. Suprachoroidal fluid as a complication of 23-gauge vitreous surgery. Br J Ophthalmol 2008;92:1433–1434.
41. Piper JG, Han DP, Abrams GW, Mieler WF. Perioperative choroidal hemorrhage at pars plana vitrectomy. A case-control study. Ophthalmology 1993;100:699–704.
42. Sharma T, Virdi DS, Parikh S, Gopal L, Badrinath SS, Mukesh BN. A case-control study of suprachoroidal hemorrhage during pars plana vitrectomy. Ophthalmic Surg Lasers 1997;28:640–644.
43. Kapamajian M, Gonzales CR, Gupta A, Schwartz SD. Suprachoroidal hemorrhage as an intraoperative complication of 25-gauge pars plana vitrectomy. Semin Ophthalmol 2007; 22:197–199.
44. Chen CJ, Satofuka S, Inoue M, Ishida S, Shinoda K, Tsubota K. Suprachoroidal hemorrhage caused by breakage of a 25-gauge cannula. Ophthalmic Surg Lasers Imaging 2008;39:323–324.
45. Aaberg TM. Experimental serous and hemorrhagic uveal edema associated with retinal-detachment surgery. Invest Ophthalmol 1975;14:243–246.
46. Wilson RS, Rutherford A. Serous choroidal detachments: clinical evaluation, animal studies, and an artificially produced clinical model. Surg Forum 1975;26:537–538.
47. Hitz JB, Odell L, Hill CW. Experimental silastic in suprachoroidal space; tissue response of dog eye to different forms of silastic. Arch Ophthalmol 1965;73:721–723.
48. Pederson JE, Gaasterland DE, Maclellan HM. Experimental ciliochoroidal detachment. Effect on intra-ocular pressure and aqueous-humor flow. Arch Ophthalmol 1979;97:536–541.