Bedside optical coherence tomography for Terson's syndrome screening in acute subarachnoid hemorrhage: a pilot study

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OBJECTIVE Approximately 10% of patients with subarachnoid hemorrhage (SAH) become permanently, legally blind. The average cost of lifetime support and unpaid taxes for each blind person amounts to approximately \$900,000. This study evaluates the feasibility and potential role of bedside optical coherence tomography (OCT) in Terson's syndrome (TS) in patients with acute SAH (aSAH) and its potential role in blindness prevention.

METHODS The authors conducted an open-label pilot study, in which 31 patients with an angiographic diagnosis of aSAH were first screened for TS with dilated funduscopy and then with OCT in the acute phase and at 6-week follow-up visits. Outpatient mood assessments (Patient Health Questionnaire–depression module, Hamilton Depression Scale), and quality of life general (NIH Patient-Reported Outcomes Measurement Information System) and visual scales (25-item National Eye Institute Visual Functioning Questionnaire) were measured at 1 and 6 weeks after discharge. Exclusion criteria included current or previous history of severe cataracts, severe diabetic retinopathy, severe macular degeneration, or glaucoma.

RESULTS OCT identified 7 patients with TS, i.e., a 22.6% incidence in our aSAH sample: 7 in the acute phase, including a large retinal detachment that was initially missed by funduscopy and diagnosed by OCT in follow-up clinic. Dilated retinal funduscopy significantly failed to detect TS in 4 (57.1%) of these 7 cases. Intraventricular hemorrhage was significantly more common in TS cases (85.7% vs 25%). None of the participants experienced any complications from OCT examinations. Neither decreased quality of life visual scale scores nor a depressed mood correlated with objective OCT pathological findings at the 6-week follow-up after discharge. There were no significant mood differences between TS cases and controls.

CONCLUSIONS OCT is the gold standard in retinal disease diagnosis. This pilot study shows that bedside OCT examination is feasible in aSAH. In this series, OCT was a safe procedure that enhanced TS detection by decreasing false-negative/inconclusive funduscopy examinations. It allows early diagnosis of macular holes and severe retinal detachments, which require acute surgical therapy to prevent legal blindness. In addition, OCT aids in ruling out potential false-positive visual deficits in individuals with a depressed mood at follow-up.

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KEY WORDS diagnosis; Terson's syndrome; subarachnoid hemorrhage; optic coherence tomography; diagnostic technique; vascular disorders

ABBREVIATIONS aSAH = acute SAH; GCS = Glasgow Coma Scale; H&H = Hunt and Hess; HDS = Hamilton Depression Scale; ILM = inner limiting membrane; IVH = intraventricular hemorrhage; mRS = modified Rankin Scale; NIH-PROMIS = NIH Patient-Reported Outcomes Measurement Information System; OCT = optical coherence tomography; PHQ-9 = Patient Health Questionnaire–depression module; SAH = subarachnoid hemorrhage; TS = Terson's syndrome; VFQ-25 = 25-item National Eye Institute Visual Functioning Questionnaire.

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PATIENTS with acute subarachnoid hemorrhage (aSAH) may experience complications from Terson's syndrome (TS).¹⁸ This entity manifests as ocular bleeds associated with aSAH or other types of intracranial hemorrhages.¹⁸ Estimations of the incidence of TS in aSAH range from 8% to 40%,¹⁸ and are limited by the report's sample size, varying definitions, and use of different diagnostic methodologies.²¹ TS is easily diagnosed by funduscopy and/or ocular ultrasonography/CT in a minority of patients who present with vitreous hemorrhages (approximately 4% of cases).⁵ However, most frequently TS manifests as retinal, preretinal, or subretinal hemorrhages,¹⁸ retinal detachments,^{2,34} and macular holes,^{28,29} which may remain undetected by these techniques.^{23,24,30} Other challenges to TS diagnosis involve lack of cooperation with the ophthalmological examination in patients with a decreased consciousness, or speech impairment.

Early TS identification is critical because approximately 10%¹² of patients with aSAH develop permanent legal blindness.^{11,20,29,33} Legal blindness involves an average cost of \$900,000 in lifetime support and unpaid taxes per patient (<https://www.actionfund.org/blindness-america>). In addition, it limits rehabilitation, impacts survival,³¹ and involves an estimated annual loss of more than \$209,000 in quality-adjusted life years.^{9,26,27} The potential risk for legal blindness warrants an immediate ophthalmological evaluation in patients with aSAH, and operative removal of intraocular blood if required.^{10,13,14,18,20}

While optical coherence tomography (OCT) is the standard for diagnosis of retinal disease,^{6,24} its use has remained limited to outpatient clinics and non-critical care settings. Alternatively, dilated funduscopy examinations have remained the mainstay for identification of TS in aSAH populations. This study explores the feasibility of bedside OCT in aSAH in the critical care setting and portrays its potential role in legal blindness prevention.

Methods

Sample Population

Thirty-one consecutive patients admitted with aSAH to our neurocritical care unit were screened for the diagnosis of TS using OCT within the first 72 hours of admission when each patient's clinical status allowed for eye dilation. Inclusion criteria for the study were as follows: 1) aSAH, diagnosed using CT by 3 independent faculty members, including a board-certified neuroradiologist, a neurosurgeon, and a neurointensivist; 2) aneurysm, diagnosed and measured through arteriography by a board-certified neuroradiologist, a neurointensivist, and an endovascular interventionalist; and 3) TS, i.e., the presence of ocular bleeds, vitreous hemorrhages, or retinal bleeds associated with aSAH;¹⁸ TS was diagnosed by dilated funduscopy examination and/or OCT by 2 independent board-certified ophthalmologists. The exclusion criteria were individuals with current or previous history of severe cataracts, severe diabetic retinopathy, severe macular degeneration, or glaucoma.

Inpatient Procedures

Capacity was evaluated in all patients through the Aid to Capacity Evaluation score.⁷ This tool has been validated

and shown to have high interrater reliability in diverse patient populations. It assesses appreciation of disorder and treatment, as well as understanding of informed consent. This tool involves an approximately 15-minute administration period. In addition, it may be tailored to each patient's disorder. Informed consent was obtained from the patient or next of kin if capacity was not maintained.

Neurological examinations were performed prior to the beginning of the testing and at the end of the procedures by 2 independent board-certified physicians: a neurointensivist and a neurosurgeon. If the neurointensivist and neurosurgeon deemed it clinically safe, a dilated eye examination followed.

For the ophthalmological examination, evaluators were blinded to visual acuity complaints. Visual acuity examinations were performed by 2 trained ophthalmologists. A single 0.5% proparacaine drop (anesthetic) and 1 drop of 1% tropicamide were instilled in both eyes 30 minutes prior to the ophthalmological examination. Intraocular pressure measurements performed with Tono-pen technology (Reichert Technologies) ruled out undiagnosed glaucoma. For the OCT examination we used the FDA-approved OCT device Optovue iVue SD-OCT. This spectral domain OCT enables shorter acquisition times, and subsequently results in fewer motion-related artifacts. This is a noninvasive technique that provides up to 3- μ m axial resolution.⁶ Thus, OCT provides the most detailed ocular anatomical information (Fig. 1B), of approximately 2 orders of magnitude superior to conventional ophthalmic ultrasonography.^{6,30}

The Glasgow Coma Scale (GCS) score, modified Rankin Scale (mRS) score, Hunt and Hess (H&H) grade, and Fisher grade were obtained by 2 independent board-certified physicians (a neurointensivist and a neurosurgeon).^{3,8,17,32}

Additional evaluations performed during admission in patients with a proper level of consciousness were 1) quality of life assessment, involving completion of the sections of the NIH Patient-Reported Outcomes Measurement Information System (NIH-PROMIS; <http://www.healthmeasures.net/explore-measurement-systems/promis>) devoted to the "ability to participate in social roles and activities" and "satisfaction with social roles and activities"; 2) an ophthalmological disability and quality of life questionnaire, the 25-item National Eye Institute Visual Functioning Questionnaire (VFQ-25; https://www.rand.org/health/surveys_tools/vfq.html); and 3) depression screening and diagnosis, consisting of completing the depression module of the Patient Health Questionnaire (PHQ-9); if this was positive for depression, further evaluation followed with the Hamilton Depression Scale (HDS).^{15,19}

Outpatient Procedures

All patients underwent subsequent follow-up clinic visits with the neurosurgery and neurology departments. If the patient's condition allowed for it, specific questionnaires were administered (the NIH-PROMIS, VFQ-25, PHQ-9, and HDS).

Statistical Analysis

Statistical analysis was performed with IBM SPSS (ver-

FIG. 1. OCT images of mild TS (case 1). **A:** Retinal image with hyporefective areas representing shadows of blood remnants (*rectangle*). **B:** Follow-up a month later confirmed TS resolution with intact anatomy (*rectangle*). GCL = ganglion cell layer; INL = internal nuclear layer; IPL = internal plexiform layer; IS-OS = photoreceptor inner segment–outer segment junction; ONL = outer nuclear layer; OPL = outer plexiform layer; PHM = posterior hyaloid membrane; RNFL = retinal nerve fiber layer; RPE = retinal pigment epithelium.

sion 23, IBM Corp.). Observer interrater reliability for all examinations and rating scales was satisfactory. Specifically, we found a Cohen's kappa > 0.9 for nominal variable observations using 2 evaluators. When 3 observers were involved, we reported a Light's kappa > 0.9 . Ordinal variables showed an intraclass correlation coefficient of 0.96. Data are expressed as mean (SD), or number (%). Non-parametric analysis with Fisher's exact test was performed when required. This protocol received IRB approval from University Hospitals Cleveland Medical Center.

Results

Neurological Outcomes

Table 1 depicts the main demographic and medical history characteristics in this series and compares groups with and without TS. OCT was performed uneventfully in all participants. OCT identified 7 patients with TS, i.e., a 22.6% incidence of TS in our aSAH sample: 6 in the acute phase and 1 in the follow-up clinic. Dilated retinal funduscopy significantly failed to detect TS in 4 (57.1%) of these 7 cases. Table 1 shows that intraventricular hemorrhage (IVH) was significantly more common in TS cases (85.7% vs 25%, $p < 0.05$). The same trend is depicted for Fisher grade and H&H grade. IVH incidence also accounts for the lower mean GCS score in patients with TS. Classic sites for IVH secondary to aSAH are depicted in Table 1. No significant aneurysmal site or size differences were noted. Aneurysmal anatomy and its repair procedure did not correlate with the presence of TS. The presence of TS had no influence on mRS outcomes. Specifically, the comparison of TS cases with controls showed no sig-

nificant differences between mRS scores within a week of discharge and at the 6-week follow-up (Table 1). Table 2 details individual characteristics of the patients with TS.

Psychiatric Outcomes

Mood evaluations are expressed as mean $\pm$ SD. Results were similar in patients with TS and controls. The TS group had minimal depression with mean PHQ-9 scores of 5 ± 2.1 at presentation and 9.6 ± 5.2 at the 6-week follow-up. The HDS scores in the TS sample were consistent with PHQ-9 results: mean 8.8 ± 4.1 during admission and 11.6 ± 4.4 (mild depression) at follow-up.

Visual Outcomes

The results for visual outcomes are expressed as mean $\pm$ SD. There were no significant differences between TS cases and controls at follow-up. There was a substantial improvement in TS at 6 weeks, whereas the controls reported that deficits remained similar to their initial evaluation. Notably, both groups reported persistent visual deficits with no correlated anatomical substrate findings. The following results depict specific evaluations in the TS group. All subscales reflect a current subjective visual-related task performance around 25%. "General Health and Vision" subscale evaluations showed clinically relevant impairment on presentation (16.3 ± 3.8) and follow-up (9.8 ± 4.0) as well. The "Difficulty with Activities" subscale results improved at follow-up (61.3 ± 14.1 vs 36.6 ± 28.7). The "Responses to Visual Problems" subscale improved from 41 ± 3.2 to 24.8 ± 10.3 . The "Driving" subscale remained similar across evaluations (11.5 ± 1 vs 8 ± 3.8).

TABLE 1. Acute SAH baseline characteristics and ocular outcomes

Variables	All Patients	TS	Controls
Demographics			
No. of patients	31	7	24
Mean age (yrs) $\pm$ SD	55 $\pm$ 2.3	54.7 $\pm$ 5.2	55.3 $\pm$ 2.4
Females, n (%)	24 (77.4)	6 (85.7)	18 (75)
HTN, n (%)	13 (41.9)	4 (57.1)	9 (37.5)
DM, n (%)	4 (12.9)	2 (28.6)	2 (8.3)
Smoker or ex-smoker, n (%)	10 (32.2)	1 (14.3)	9 (37.5)
FMD, n (%)	1 (3.2)	1 (14.3)	0
Renal artery stenosis, n (%)	2 (6.4)	1 (14.3)	1 (4.2)
Neurological features			
Aneurysm location, n (%)			
BA	5 (16.1)	3 (42.9)	2 (8.3)
PCoA	7 (22.6)	2 (28.6)	5 (20.8)
ICA	3 (9.7)	1 (14.3)	2 (8.3)
MCA	2 (6.4)	0	2 (8.3)
ACoA	11 (35.4)	1 (14.3)	10 (41.7)
Other sites	3 (9.7)	0	3 (12.5)
Mean max aneurysm diameter (mm) $\pm$ SD	6.6 $\pm$ 2.7	6 $\pm$ 2*	6.7 $\pm$ 2.8
Mean H&H grade $\pm$ SD	2.2 $\pm$ 0.4	2.7 $\pm$ 1.1	2 $\pm$ 0.4
Mean Fisher grade $\pm$ SD	3 $\pm$ 0.7	3.7 $\pm$ 0.7	2.8 $\pm$ 0.7
IVH, n (%)	12 (38.7)	6 (85.7)	6 (25)
Mean GCS score $\pm$ SD	12.8 $\pm$ 5.1	10.1 $\pm$ 4.7	13.6 $\pm$ 5.3
Mean mRS score $\pm$ SD			
Within 1 wk of discharge	2.8 $\pm$ 2.2	2.7 $\pm$ 1.9	2.8 $\pm$ 2.2
At 6-wk follow-up	2.8 $\pm$ 2.7	3 $\pm$ 2.3	2.8 $\pm$ 2.3
Coiling/clipping, n (%)	14/16 (45.1/51.6)	3/3 (42.8/42.8)	11/13 (45.8/54.2)
Ophthalmological features, mean $\pm$ SD			
VA (OD)	20/83.2 $\pm$ 5/202.5	20/200 $\pm$ 0/336†,‡	20/44.3 $\pm$ 5.1/112.6
VA (OS)	20/77.5 $\pm$ 3.6/92.6	20/124 $\pm$ 0/157†,‡	20/62.3 $\pm$ 3.8/71.2
IOP (OD)	15.2 $\pm$ 3.4	12.8 $\pm$ 3.1§	17.7 $\pm$ 3.4§
IOP (OS)	15.5 $\pm$ 3.9	13.7 $\pm$ 3.7§	17.3 $\pm$ 3.9§
TS diagnosis, n (%)			
Funduscopy	3 (9.7)	3 (42.9)	0
OCT	7 (22.6)	7 (100)	0

ACoA = anterior communicating artery; BA = basilar artery; DM = diabetes mellitus; FMD = fibromuscular dysplasia; HTN = hypertension; ICA = internal carotid artery; IOP = intraocular pressure; MCA = middle cerebral artery; OD = oculus dexter (i.e., right eye); OS = oculus sinister (i.e., left eye); PCoA = posterior communicating artery; VA = visual acuity.

* Excludes 1 patient due to 2 negative angiograms that failed to recognize any aneurysms.

† Excludes 2 patients due to low GCS scores.

‡ Risk of blindness.

§ Within normal range.

The subscale pertaining to “Role Limitations in Social Life” was also impaired (6 ± 3.2 at diagnosis vs 4.4 ± 1.1 at follow-up). The “Well-Being and Dependency” subscale results were consistent with prior data (5.8 ± 3.1 vs 3.8 ± 1.1 at follow-up). The “General Vision” subscale results (2 ± 2.2 vs 5.4 ± 2.5) followed the same trend. “Near Vision” (1.5 ± 1.3 vs 6 ± 1.9) and “Distance Vision” subscales (1.5 ± 1.3 vs 5.4 ± 2.5) confirm the level and pattern of reported impairment.

TS patients 5 and 6 were at risk for developing per-

manent legal blindness. Unfortunately, they died due to medical complications and subsequent goals of care decisions made by their health care proxies. Specifically, the initial H&H score of 4 in case 5 improved to 2 after external ventricular drain placement and hydrocephalus resolution. This patient developed acute respiratory failure requiring extended ventilatory support due to a massive pulmonary embolism. Her family decided she would not have wanted a temporary tracheostomy and withdrew care. Patient 6 presented with an H&H score of 2 and

TABLE 2. Neurological characteristics of TS cases

Characteristic	Case No.						
	1	2	3	4	5	6	7
Age (yrs), sex	59, F	45, F	81, F	62, F	44, F	41, F	51, M
Previous medical history	HTN, DM	HTN	None	None	FMD, smoker, renal artery stenosis	HTN	HTN
SAH initial evaluation & treatment							
Aneurysm location	Tip of BA	PCoA	ACoA	ICA terminus	Tip of BA	PCoA	NA*
Maximum aneurysmal diameter (mm)	6	8	7	5	2.2	8	NA*
H&H grade	3	1	3	4	4	2	2
Fisher grade	4	4	4	4	4	4	2
GCS score	9	15	7	5	5	15	15
Surgical procedure	Coiling	Clipping	Coiling	Clipping	Coiling	Clipping	NA
Initial ophthalmological examination							
VA							
OD	20/50	20/70	NA†	NA†	20/800	20/60	20/20
OS	20/30	20/400	NA†	NA†	20/400	20/50	20/100
IOP							
OD	12	17	7	12	14	13	15
OS	12	14	7	12	16	17	18
Funduscopy							
OD	Preretinal bleed	Normal	Normal	Nondefinitive examination	Vitreous bleed	Vitreous bleed	Normal
OS	Preretinal bleed	Vitreous bleed	Normal	Nondefinitive examination	Vitreous bleed	Vitreous bleed	Vitreous bleed
OCT							
OD	Intraretinal bleed	Normal	Bilat retinal bleeds	Bilat optic disc bleeds	Large retinal detachment‡	Macular hole & intraretinal bleed	Normal
OS	Intraretinal bleed	Retinal (sub-ILM) bleed	Bilat retinal bleeds	Bilat optic disc bleeds	Large retinal detachment‡	Intraretinal bleed	Intraretinal bleed

NA = not applicable.

* Two angiograms failed to identify any aneurysms.

† See H&H grade.

‡ OCT performed in follow-up.

Fisher grade of 4. However, she developed sepsis, which determined her need for tracheostomy and percutaneous endoscopic gastrostomy. Her family decided to withdraw care.

Quality of Life

Both quality of life measures reflected a decreased quality of life in all patients with aSAH. Regarding the “ability to participate in social roles and activities” measure, the results were lower and similar in case and control groups at follow-up (2.3 ± 1.1 vs 2.5 ± 1.2). The “satisfaction with social roles and activities” measure was consistent with these findings (cases 2.2 ± 1.3 vs controls 2.7 ± 1.3).

Discussion

Approximately 10% of patients with aSAH may develop legal blindness.^{12,18,23,24} TS is typically symptomatic in patients with large subhyaloid hemorrhages and preserved mentation.^{12,22,25} However, individuals with an impaired

level of consciousness or those presenting with typically asymptomatic isolated retinal hemorrhages (Fig. 1A) may remain unidentified.^{18,23,24,30,31} Early diagnosis of retinal involvement is essential because retinal detachment^{2,24} and macular holes^{28,29} may develop within a week of TS onset.^{18,35} As strategic strokes (in the eloquent regions) trigger dementia due to specific anatomical substrates, macular holes represent discrete foveal lesions that may rapidly lead to legal blindness.^{10,28,28} Thus, an early retinal evaluation in aSAH may indicate the necessity for a prompt surgical intervention,^{10,14,18,20,28} which has been successfully reported in aSAH.¹³

OCT is a well-established gold standard for retinal disease diagnosis.^{6,24} However, dilated funduscopy examinations remain the rule in critical care settings. Notably, funduscopy examination (Table 2, cases 3 and 4), ocular ultrasonography, or CT may fail to reliably identify TS.^{5,6,23,24,30} More importantly, funduscopy lacks the anatomical resolution to rule out retinal disease (Table 2).^{5,6,23,24,30} Higher-resolution OCT imaging is desirable to

FIG. 2. OCT images of severe TS. **A:** Subhyaloid and retinal sub-ILM bleeds (case 2). **B:** Severe TS with large retinal detachment (case 5). **C:** Severe TS with large retinal hemorrhage (rectangles) and macular hole (case 6).

distinguish retinal and nonretinal hemorrhages. This is a difficult task because the posterior hyaloid membrane encasing the vitreous body and the inner limiting membrane (ILM) isolating the retina are 2.5- μ m-thick adjacent layers with no space between them (Fig. 2A).⁶ In the event of a subhyaloid hemorrhage between these 2 layers, a virtual space would be created and may not be evident to funduscopy in the setting of a lesser blood volume.¹⁸ Moreover, funduscopy may suggest a nonretinal bleed when there is a retinal component (cases 2, 5, 6, and 7). OCT aids in distinguishing between dangerous intraretinal hemorrhages, which may trigger a macular hole (case 6, Fig. 2C), and blindness.^{10,18,28} OCT also detects patients at risk for retinal detachment when blood deposits between the photoreceptor inner segment–outer segment junction and the retinal pigment layer (case 5, Fig. 2B).^{18,34} In this situation, close follow-up and expeditious therapy (if needed) would prevent visual loss. Thus, following funduscopy, OCT allowed TS diagnosis confirmation (cases 1, 2, and 7; Figs. 1 and 2), identification (cases 3 and 4), and detection of patients with TS at higher risk for legal blindness (cases 5 and 6, Fig. 2).

From the neurological perspective, functional outcomes were similar in cases and controls. Regarding ocular outcomes, cases 1–4 and 7 lacked any features indicative of risk for permanent legal blindness, and recovered spontaneously. Conversely, cases 5 (retinal detachment) and 6 (macular hole) would have benefited from emergency ocular surgery had their families not withdrawn care due to medical complications. This is clinically relevant because acute surgical correction is currently feasible in SAH. Historically, retinal holes and detachments have required prone positioning for 48 hours after the procedure for sec-

ondary glaucoma prevention. However, new evidence suggests that these surgeries may be followed by regular supine positioning, which allows for it to occur in intubated patients.^{1,4}

Lastly, cases 1–4 and 7 reported subjective visual acuity deficits at follow-up. However, OCT confirmed resolution of their TS and the absence of any other pathology. These individuals were diagnosed with depression, which appeared to influence their report. OCT allowed us to rule out false-positive symptomatology.

Limitations of this study include its pilot nature, which precludes a safety evaluation, and extracting conclusions regarding diagnosis or outcomes. However, the absence of complications secondary to OCT is promising and needs further testing. Likewise, although efficacy and effectiveness would not be properly assessed through a pilot design as compared with funduscopy, OCT is already established as the gold standard for retinal disease diagnosis.^{6,24} Other drawbacks include those of the OCT technique, i.e., media opacities can interfere with OCT light waves and prevent the acquisition of optimal resolution images. As a result, OCT's value, although superior to funduscopy,^{6,24} may be limited in the setting of large vitreous hemorrhage, dense cataract, or corneal opacities.¹⁶

Strengths of our study include an excellent interrater reliability, and controlling for workup bias (all patients received funduscopy and OCT) and for a potential expectation bias (ophthalmological evaluators were blinded to visual acuity complaints). In addition, OCT allows rapid image acquisition, which is particularly helpful in avoiding motion artifacts in uncooperative subjects (i.e., those with a depressed mental status or agitation). OCT's anatomical resolution allows identification of retinal disease (i.e., large

retinal detachment and macular hole). This characteristic is of the essence, for unidentified individuals may become legally blind if not treated in the acute setting.^{10,12,14,18,28,31}

Conclusions

The current pilot study proves the feasibility of bedside OCT in the critical care setting. This methodology does not allow hypothesis testing or safety assessments. Nevertheless, as OCT remains the gold standard for retinal disease diagnosis, our results suggest the possibility of a clinically meaningful value in the prevention of legal blindness. Thus, we propose that this affordable noninvasive method be further evaluated as a bedside early screening tool for TS in aSAH. Bedside OCT might prove particularly useful in patients with an impaired mentation, or concomitant depression. An ongoing prospective study is currently underway.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ramos-Estebanez, Kohen, Manjila, DeGeorgia, Bambakidis, Orge. Acquisition of data: Ramos-Estebanez, Kohen, Pace, Bozorgi, Alambyan, Nwankwo. Analysis and interpretation of data: Ramos-Estebanez, Kohen, Pace, Alambyan, Nwankwo, DeGeorgia, Bambakidis, Orge. Drafting the article:

Ramos-Estebanez, Kohen, Alambyan. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Ramos-Estebanez. Statistical analysis: Ramos-Estebanez, Kohen, Alambyan. Administrative/technical/material support: Ramos-Estebanez, Kohen, Pace, Bozorgi, Manjila, DeGeorgia, Bambakidis, Orge. Study supervision: Ramos-Estebanez, Kohen, Manjila, DeGeorgia, Bambakidis, Orge.

Supplemental Information

Previous Presentations

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