Surgical Treatment for SWS Glaucoma: Experience From a Tertiary Referral Pediatric Hospital

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Precis: Glaucoma associated with Sturge-Weber syndrome (SWS) often requires surgical intervention. Our study shows that trabeculotomy is efficacious in treating this condition.

Purpose: The purpose of this study was to describe the surgical outcomes of glaucoma associated with SWS in children presenting to the tertiary Paediatric Ophthalmology Department at The Children’s Hospital at Westmead.

Materials and Methods: A retrospective study of patients with SWS referred to the Department of Ophthalmology at The Children’s Hospital at Westmead between 2003 and 2016 with at least 2 years of follow-up were identified, and information was collected from the clinical notes of all subjects.

Results: A total of 27 patients with SWS were evaluated for glaucoma in which 8 were excluded due to inadequate follow-up. In total, 19 patients with SWS were included in this study in which glaucoma was diagnosed in 15 patients and 19 eyes, of which 13 eyes required glaucoma surgery. A total of 21 surgical procedures were performed with a median follow-up of 85 months. A primary trabeculotomy was performed in 5 eyes of which 4 required re-do trabeculotomy, and 3 of these eyes underwent a Baerveldt tube (BVT) shunt as a third procedure. One eye with a primary trabeculotomy underwent a BVT as a secondary procedure. A BVT was inserted in a total of 6 eyes in which it was a primary procedure in 2 eyes. Of the 6 eyes undergoing a BVT insertion, 5 achieved success (2 complete and 3 qualified), and 1 failed. One case underwent intraluminal stent removal. Six eyes underwent a primary trabeculotomy and needed no further surgical intervention. In the trabeculotomy group, 4 eyes achieved complete success and 2 eyes achieved qualified success.

Conclusions: Glaucoma affects a significant proportion of patients with SWS and is associated with the presence of an ipsilateral port-wine stain in most cases. In our study, trabeculotomy was the most efficacious procedure for controlling intraocular pressure and reducing the burden of ongoing treatment in SWS-associated glaucoma.

Key Words: Sturge-Weber syndrome, glaucoma, trabeculotomy, glaucoma drainage device

Sturge-Weber syndrome (SWS) or encephalotrigeminal angiomatosis is a rare congenital neurocutaneous disorder that occurs sporadically in ~1 in 50,000 live births.1 A somatic activating mutation in GNAQ has been found associated with both SWS and nonsyndromic facial cutaneous capillary malformations (port-wine stains).2 This phakomatosis affects the cephalic venous microvasculature and is characterized by a varying expression of port-wine stains in the distribution of the ophthalmic division (V1) of the trigeminal nerve,3 ipsilateral venous-capillary abnormalities of the leptomeninges, and ocular abnormalities.4 Port-wine stains affecting the entire V1 distribution are strongly predictive of underlying neurological and/or ocular disorders (78%), while the overall risk for ocular and/or neurological disorders with partial V1 involvement has been estimated at 26%.5

Association of SWS with facial port-wine stains significantly increases with bilateral topography, involvement of the upper eyelid, and extension from V1 to another territory.6

Ocular complications arise primarily from vascular malformations of the conjunctiva, episclera, and choroid.7 The choroidal vascular malformations are common and may be localized to the posterior pole or extend to the whole fundus, giving the fundus a smooth red appearance with loss of the normal choroidal vascular pattern.8 These vascular malformations expand slowly and may lead to degenerative changes of the overlying retina with serous retinal detachments. While bilateral cases can be difficult to detect, enhanced depth optical coherence tomography imaging may assist in identifying the extent of the lesions.8,9

Glaucoma remains the major sight-threatening complication in SWS occurring in 30% to 70% of patients.1,3,10 Weiss first proposed the dual mechanism of glaucoma in SWS, in the 1970s, reflecting the bimodal glaucoma presentation.11 In early-onset glaucoma, congenital angle anomaly may play a dominant role, whereas late-onset glaucoma may worsen due to elevated episcleral venous pressure and hypersecretion by

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the ciliary processes. Glaucoma management in SWS is challenging, and the choice of treatment remains controversial. In the early-onset glaucoma group, when angle anomalies are likely to dominate, angle surgery has been regarded as the primary treatment, although the success rate for long-term glaucoma control remains low. Although topical ocular hypotensive medications are the initial treatment for the late-onset glaucoma group, they will often fail to control intraocular pressure (IOP) adequately in most patients. Filtering surgery in the form of trabeculectomy or glaucoma drainage devices (GDDs) is often required, although there is little consensus on the best filtering operation in these patients. The risk of hypotony and suprachoroidal hemorrhage is proportional to the size of the vascular malformation. Alterations to surgical technique are essential to avoid this sight-threatening complication. Measures to avoid hypotony in trabeculectomy surgery include tight flap closure and the use of an anterior chamber (AC) maintainer. Methods to restrict flow in a GDD include use of an AC maintainer, intraluminal stent with 3-0 nylon, and a tight tunnel into the AC.

The purpose of this study was to assess the outcomes of surgical intervention in patients presenting to our unit with SWS-associated glaucoma.

MATERIALS AND METHODS

Data Collection

A retrospective cohort study was conducted investigating the medical records of all patients with SWS referred to the Department of Ophthalmology at The Children’s Hospital Westmead between 2003 and 2016. Ethics approval was sought and granted from the institution’s Hospital Human Research and Ethics Committee. The study was carried out in adherence to the tenets of the Declaration of Helsinki. Patients were excluded if they had <2 years of follow-up, surgery at another institution before referral to The Children’s Hospital Westmead, or had concurrent morbid congenital ocular pathologies other than glaucoma associated with SWS.

Outcome Measures

This study used the Childhood Glaucoma Research Network Classification of Childhood Glaucoma in which the definition of childhood glaucoma was standardized to require 2 or more of the following criteria: an IOP > 21 mm Hg, optic disc cupping, corneal findings (Haab striae, corneal edema, or diameter > 11 mm in newborns, > 12 mm infants less than 1 year of age, or > 13 mm in any age), ocular enlargement by progressive myopia or axial length out of keeping with normal growth, or a visual field defect consistent with glaucoma.

The following variables were recorded for analysis: age at presentation, sex, laterality (of cutaneous hemangioma, glaucoma), presence of choroidal vascular malformation, age of initial surgery, preoperative and postoperative IOP, vision, optic disc appearance, number and type of ocular surgeries, need for reoperation, complications, and glaucoma medication use. Corneal diameter was recorded initially but inconsistently after this, and it was therefore not included in this study. IOP was measured in the outpatient department with an Icare tonometer (Icare tonometer Helsinki, Finland) or in theater during induction with a Perkins hand-held tonometer (Clement Clark; Haag-Streit, Essex, UK). Visual acuities (VAs) were measured at diagnosis and final visit using fixation or Teller grating acuity cards for nonverbal children and Lea symbols, Kay pictures, Sheridan Gardner, and Snellen letters progressively for verbal children, as cooperation allowed. Any development of amblyopia was treated with glasses and patching, as per the Pediatric Eye Disease Investigator Group (PEDIG) studies.

All surgical procedures were performed by 1 of 2 glaucoma subspecialists (J.R.G. and T.K.). Similar operative technique was used for all patients for each of the surgical procedures. Trabeculotomy and trabeculectomy were performed using standard procedures. The trabeculotomy procedure opened 4 clock hours of angle (120 degrees). All trabeculectomies were augmented with Mitomycin C at a dose of 0.4 mg/mL on 3 sponges each 3 mm equilateral triangles for 3 minutes with preplaced releasable sutures. The aqueous drainage device used was the Baerveldt (350 mm²; Abbot Medical Optics, Santa Ana, CA) as a single procedure.

The outcome of surgical intervention was analyzed and considered successful once no further glaucoma surgical procedure was necessary. This was based on IOP ≤ 21 mm Hg and stable optic disc appearance, without the need for glaucoma medication. Qualified success was defined as an IOP ≤ 21 mm Hg and stable optic disc appearance achieved with antiglaucoma medication and/or stent removal or as ocular hypotony without visual loss. We believe that the need for an additional operative procedure under general anesthesia to remove a stent justifies this classification. Surgical failure was defined as IOP > 21 mm Hg with maximal medical therapy, persistent hypotony with visual loss, and severe visual loss.

Statistical Analysis

Data were tabulated using Microsoft Excel 2011 (Microsoft) and statistical analysis performed using IBM SPSS statistics for Windows (version 26.0; IBM Corp., New York, NY). Quantitative data that followed a normal distribution were expressed as mean and SD, and those that did not follow a normal distribution were expressed as median and interquartile ranges (IQRs). Qualitative data were described using number and percentage. Preoperative and postoperative mean IOP and mean number of glaucoma medications were compared with paired sample Student t tests.

As the VA was assessed using different methods in the various age groups, a grading scale was used to analyze the recorded VA as either normal VA (grade 1: 6/3.9 to 6/7.5); mild VA impairment (grade 2: 6/9.5 to 6/15); moderate VA impairment (grade 3: 6/24 to 6/48); severe VA impairment (grade 4: 6/60); or profound VA impairment (grade 5: count fingers to no perception of light). A paired t test analysis was used to assess the difference in initial VA and final VA in patients who underwent surgery. P-value < 0.05 was considered statistically significant. Eyes were grouped into the number of surgical procedures they underwent, and a comparison of means of final VA and initial VA were represented in box plots.

RESULTS

A total of 27 patients with SWS were referred to the Ophthalmology Department for glaucoma evaluation, of which 8 were excluded due to inadequate follow-up. In the remaining 19 patients, glaucoma was diagnosed in 15...
patients (19 eyes), of which 13 eyes required glaucoma surgery. The demographic data for these patients are listed in Table 1. The data for each eye undergoing glaucoma surgery are listed in Supplemental Table 1 (Supplemental Digital Content 1, http://links.lww.com/IJG/A442).

The median age for glaucoma diagnosis was 14 months (IQR: 44 mo) with a median follow-up of 87 months (IQR: 54 mo). For those diagnosed with glaucoma, 11 were unilateral (73%) and 4 (26%) had bilateral disease, giving a total of 19 eyes affected with glaucoma. Of these eyes, 13 required glaucoma surgery. Average (± SD) IOP on initial assessment in glaucomatous eyes was 20.5 mm Hg (± 9) compared with 17 mm Hg (± 8) in all eyes of patients with SWS. Facial capillary malformations were ipsilateral to the glaucoma-affected eye in 100% of eyes. Choroidal vascular malformations were present in 14 (74%) of the glaucoma-affected eyes.

A total of 21 surgical procedures were performed with a median follow-up of 87 months (IQR: 54 mo). Figure 1 outlines the treatment algorithm and success rates. The IOP outcomes at separate timepoints for each of the different surgical procedures are outlined in Figure 2. The median age in months for children undergoing a primary trabeculotomy was 7 (IQR: 1), whereas the median age for a trabeculectomy was 57 months (IQR: 33.25 mo), and, for BVT insertion, it was 74 months (IQR: 46.75 mo).

A primary trabeculotomy was performed in 5 eyes of which 4 required re-do trabeculotomy with an average (± SD) time to repeat trabeculotomy of 43 (± 33.3) months. The average (± SD) IOP preoperatively was 29 ± 6 mm Hg, and, postoperatively at 12 months, it was 16 ± 7. At 2 years, 50% of patients required a second glaucoma surgical procedure.
A BVT was inserted as a second surgical procedure in 1 eye with a prior trabeculotomy and as a third procedure in 3 eyes with 2 prior trabeculotomies. It was the primary procedure in 2 eyes (Fig. 1). The average time to BVT insertion was 67.5 (± 45.6 mo). Of the 6 eyes undergoing a BVT insertion, 1 eye was classed as a failure due to failure to control IOP despite maximally tolerated medical therapy. Three cases achieved qualified success of which one required removal of the intraluminal stent. At 2 years after stent removal, this patient maintained qualified success. The average preoperative IOP was 29 ± 1.7 mm Hg, and, at final follow-up, it was 15.6 ± 5.4 mm Hg. Of the 6 patients undergoing a BVT insertion, complete success was achieved in 33%, qualified success in 33%, and failure in 33% of patients.

A total of 6 eyes underwent a primary trabeculectomy and needed no further surgical intervention. The average preoperative IOP was 29.5 ± 4 mm Hg, and the average IOP at final follow-up was 12.6 ± 4 mm Hg. Complete success was achieved in 67% and qualified success was achieved in 33% of patients. The average number of preoperative and postoperative medications is displayed in Figure 3.

Mean initial VA of all patients with SWS-associated glaucoma was 1.73 (± 2.22), and mean final VA was 3.0 (± 1.17), where 1 is normal VA, 2 is mild VA impairment, and 3 is moderate VA impairment. Of the 13 eyes that underwent surgery, 8 eyes had only 1 procedure, 2 eyes required 2 procedures, and 3 eyes required 3 procedures. These eyes were grouped into the number of surgical procedures performed, and their final VA outcomes are demonstrated in Figure 4. Overall, patients who underwent glaucoma surgery had poorer VA outcomes than those who did not require surgical intervention.

### DISCUSSION

SWS-related glaucoma is a rare ocular condition with the potential for devastating vision loss due in part to the difficulty of managing this condition surgically. There is little consensus in the literature with regard to the best surgical technique; this is compounded further by the mixed pathophysiology of this condition and bimodal presentation. This large cohort study has looked at 3 available surgical techniques in the management of this condition across a range of patient ages.

Supplemental Table 2 (Supplemental Digital Content 2, http://links.lww.com/IJG/A443) outlines the results of previous similar studies looking at the surgical management of SWS-related glaucoma. While previous studies have demonstrated good early and intermediate success of trabeculotomy in early-onset glaucoma associated with SWS, the study by Wu et al had only 9 months of follow-up. A large case series by Olsen et al demonstrated a 66.7% success rate after 1 or more angle procedures in a cohort of SWS patients all less than 4 years of age presenting in early childhood, with follow-up ranging between 1.4 and 15 years. The success of angle surgery in the long-term control of IOP remains low in this group.

The results of our study reflect this finding, with all of our patients undergoing a primary trabeculectomy requiring further surgery to control IOP. Most of our patients undergoing a trabeculotomy were infants. This further supports the theory that raised episcleral venous pressure is the other likely cause of the second wave of glaucoma progression in this population. The lower complication rate associated with angle surgery still makes this an attractive option as an initial procedure in infant patients to address any underlying angle anomalies.

Most SWS patients will require further filtering glaucoma surgery to achieve adequate IOP control with time.
Previous studies have demonstrated greater success with trabeculectomy or GDD surgery; however, these procedures have been hampered by their risk of serious complications such as choroidal hemorrhage or effusion and high failure rate in infancy. Iwach and colleagues recorded a 24% choroidal expansion rate with trabeculectomy, although studies looking at combined trabeculotomy-trabeculectomies have shown high surgical success rates with low complication rates. Our study demonstrated a 67% complete success and 33% qualified success in patients undergoing a primary trabeculectomy with no reported complications and no need for further surgery.

Our results demonstrated reasonable success with a BVT insertion, which had no intraoperative or postoperative complications aside from failure to control IOP in 1 patient. Only 1 patient required removal of the intraluminal stent to achieve qualified success. Budenz et al reported good IOP control in all 10 eyes undergoing a 2-stage BVT insertion and Celebi et al reported IOP success with Ahmed valve implants. The benefit of a BVT to control IOP in the patients is that the procedures avoid an acute reduction in IOP with the use of an intraluminal stent and ligation of the tube intraoperatively. These devices also require less rigorous postoperative follow-up and a reduction in the burden of
examinations under anesthesia in the immediate postoperative period compared with a trabeculectomy, which may require needling, or suture manipulation postoperatively. The VA results do demonstrate poorer vision in patients undergoing surgical intervention compared with those with glaucoma not requiring surgical procedures. This likely reflects that SWS-associated glaucoma is difficult to manage and the need for multiple procedures reflects the aggressiveness of this condition.

Westmead Children’s Hospital treats a large population of children from a vast geographical area. While some of the patients who were excluded from analysis were followed-up in private clinics, the remaining children had follow-up in hospitals closer to the family’s place of residence. The latter remains a challenge in the Australian setting where the distances required in traveling to reach tertiary health care may be difficult. It is important that families and practitioners involved in the care of these patients are aware of the bimodal presentation of glaucoma that may present later in childhood or early adulthood despite initially normal IOP and ocular examination findings and that these patients do require life-long follow-up. It is worthwhile to note that the obviously large SDs in the age and follow-up periods in this study that resulted from the study cohort reflects a relative lack of homogeneity, which is an obvious limitation of retrospective studies. Finally, it was a limited retrospective case series from a tertiary referral hospital. A large prospective study to characterize the effect of different surgical procedures in the management of glaucoma in SWS would be extremely difficult to perform, and management decisions continue to rely on data from small selective studies such as ours.

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