



The Corkscrew Technique - A Minimally Invasive, Trans-Nasal Anterior Skull Base Reconstruction Using a Wedge-Shaped Construct for Treatment of Cerebro-Spinal Fluid Leak

Yazid Badarny^{1*}, Samih Badarny^{3,4}, Dmitry Ostrovsky⁵, Rachel Grosman^{1,2} and Gill E Sviri^{1,2}

¹The Neurosurgery Department, Rambam (Maimonides) Medical Center, Ha'aliya street, Haifa 3109601, Israel

²Technion – Israeli institute of technology, The Faculty of Medicine, Israel

³The Department of Neurology, Galilee Medical Center, Zafed, Israel

⁴Bar-Ilan University, the Faculty of Medicine, Israel

⁵The department of otolaryngology-head and neck surgery, Rambam (Maimonides) Medical Center; 2 Ha'aliya street, Haifa 3109601, Israel

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***Corresponding author:** Yazid Badarny, the Neurosurgery Department, Rambam (Maimonides) Medical Center, 2 Ha'aliya street, Haifa 3109601, Israel

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Abbreviations: CSF: Cerebro-Spinal Fluid, CSFL: CSF Leak, ASBR: Anterior Skull Base Reconstruction, EES: Endonasal Endoscopic Approach, CST: Corkscrew Technique, ST: Standard (Non-CST) Technique, ENT: Ear, Nose and Throat, MRI: Magnetic Resonance Imaging, CT: Computerized Tomography, NSF: Nasoseptal Flap, SD: Standard Deviation, LP: Lumboperitoneal Shunt, VP: Ventriculoperitoneal

Introduction

Leakage of cerebro-spinal fluid (CSF) results from abnormal communication between the subarachnoid space and the extracranial space. Persistent CSF leaks (CSFL) usually imply the development of a CSF fistula. There are various reasons for the development of such a fistula, including trauma, tumors of the skull base, and congenital defects. Such fistulae may also develop following skull base surgery, post-traumatically or spontaneously [1-4]. When CSFL involves the anterior skull base, it usually presents as rhinorrhea [1,4]. Once a fistula has been identified and localized, treatment of the leak is pursued. In some of the cases, CSF diversion – temporary or permanent, may be considered. When CSF diversion is not used, or is unsuccessful in alleviating the CSFL, an anterior skull base reconstruction (ASBR) is employed. ASBR may be approached by the endonasal endoscopic approach (EEA) or trans-cranially, via a craniotomy.

Factors affecting the approach decision include the etiology of the leak, the exact localization of the leak (if located), the leak

flow severity or the estimated size of the fistula. There has been much research aimed at describing the success rate of ASBR: Failure rates have ranged between 0-30% in different series, on first attempt of reconstruction, and 0-14% on second attempt [5,6,7-9-14]. Open intracranial approaches, or non-endoscopic endonasal accesses have historically been used for the treatment of ASBR, but in recent decades these have largely been replaced by EES that show high success rate and relatively low morbidity [15-22]. There is a variety of materials available in EES to seal CSFL. These include fat, bone, vascularized grafts, fascia lata, muscle, and other, artificial materials including fibrin glues and various sealants to secure these materials in place [10,23,24,4].

The size of the defect is a significant determinant of success rates in ASBR. A major challenge of ASBR in case of large defect or high flow CSF leak is to overcome the CSF pressure and brain pulsation, that may push the implanted graft to protrude extracranially [25,26,8]. Several techniques have been described

to overcome this issue: Warmold and McDonogh described a fat “bathplug” closure for small (1cm) cranial defects and entailed a success rate of 94% from the first attempt and a 100% success from the second attempt [27]. Luginbuhl et al. [26] proposed a bilayer button technique for a high-flow CSF leak, with 10% postoperative CSF leak [26]. Leng et al suggested the “gasket seal” technique and reported no postoperative leak, albeit in a small cohort of 10 patients [15]. The aim of this study is to describe our high throughput, single-center experience in the EES approach for management of CSF leak. Herein we present the use of a novel technique, we named the “Corkscrew technique” and evaluate the outcomes in those treated with the corkscrew technique (CST) applied in an EES procedure, for ASBR.

Methods

The corkscrew technique has been used in our center since 2013. A corkscrew endoscopic reconstruction technique is defined as the use of a strip of fascia lata as an inlay graft in the shape of a corkscrew, with a relatively large part of the inlay placed above the fistula, thereby reducing the risk of graft prolapse in patients with intraoperative high-flow CSF leak [28,29]. The lower part of the construction is wedged into the aperture in the dura, to prevent lateral migration of the construct sideways, away from the opening. The procedure includes harvesting a 10-cm fascia lata graft, double the width size of the cranial defect, and its width-to-length ratio is 1:4. The narrow aspect of the fascia is introduced first through the bony and dural defects. After the strip is inserted through the cranial defect, the tendency of the graft is to form a dome-shaped cap so that its external margins are compressed between the bone and the arachnoid. Thus, a wedge-shaped construct is built, with CSF pressure from above compressing the construction into the defect. A portion of the fascia graft is externalized at the aperture of the defect, preventing displacement of the reconstruction [30]. A depiction of the corkscrew technique is presented in Figure 1.

Patient Selection

We retrospectively reviewed the charts of all patients treated surgically by EES approach for treatment of CSFL in Rambam (Maimonides) Medical Center between the years 2013-2019. All patients with CSFL were included, whether their leak was spontaneous, post-traumatic or post-operative. All patients underwent an endoscopic endonasal repair of a CSF leak. Patients were categorized in 2 groups: those who underwent a repair using corkscrew technique (CST group) and those who underwent repair using standard technique (ST group). For our analysis, patients who were operated more than once are reported as two separate cases. All patients, in both groups, underwent routine evaluation by both ENT and neurosurgeons for a minimum follow-up of 3 years postoperatively.

CSF Leak Management Protocol

A clinical diagnosis of CSF leak was based on history of

clear watery nasal drainage, unilateral or bilateral, amount and frequency, increasing drainage while performing Valsalva maneuver or while leaning down. We considered a leak to be of CSF if it was proven by beta-2-transferrin detected in the fluid, or in suggestive cases where the patient had proven meningitis accompanied by a persistent leak. The suspected cause of CSFL was also noted, including a history of trauma, previous surgery involving paranasal sinuses, previous endonasal endoscopic surgery for tumor removal and unknown causes. All patients underwent MRI or CT myelography or CT cisternography preoperatively, to identify the exact localization of the fistula. However, in cases of proven, persistent CSF rhinorrhea, we performed an ASBR without supporting imaging evidence of a leak or a localization of the fistula.

Operative Technique

After intraoperative localization of the fistula and assessment of its size, a decision was made about the method of fistula closure. For small defects, in which we believed the hole could support the corkscrew construct, or for defects with suspected high CSF pressure, a corkscrew reconstruction was undertaken. In cases where we performed CST, a nasoseptal flap (NSF) was also used, except in re-operation cases, or in cases where a NSF was not possible to harvest. A lumbar drain was placed intraoperatively, or immediately after surgery, for 3-5 days after surgery, if the attending neurosurgeon deemed it necessary.

Generally, a lumbar drain was placed if a high-flow leak was noted, if high pressure was suspected, in cases of high BMI (>30) or if the fistula was large on intraoperative evaluation. Groups were compared for various parameters including demographic characteristics including age and gender, preoperative imaging, and whether or not these yielded a localization of the defect, etiology of the leak was classified into three groups: post-traumatic CSFL, following head trauma, post-surgical CSFL and spontaneous CSFL, surgical techniques including materials used to repair the defect, CST vs. ST. Surgical complications: intraoperative and postoperative complications, outcome of CSFL and follow-up measures included the need for CSF diversion and repeat operations.

Results

Between the years 2013-2017, we performed 28 ASBR procedures on 26 patients, using EES techniques for treatment of CSFL. There were 11 male patients (42.3%) and 15 females (57.7%). Both cases that were operated twice were female. The age of the patients ranged from 23 to 77 years. Mean age (+/-SD) was 51.1±14.2 years. Twelve cases were operated using the CST, and 16 with ST for ASBR. When comparing both groups, the patients who underwent CST were slightly older. Mean age ± SD was 46.5±14.6 in the ST group, compared to 60±11.6 in the CST group. Eight of the 16 cases in the ST group were female patients (50%), and 9 of 12 in the CST group were female (75%).

Preoperative Evaluation

Of the 28 cases, 19 had a spontaneous CSF leak (67.9%), 4 patients post-traumatic CSFL (14.3%), and 5 patients had undergone previous endoscopic endonasal surgery (including paranasal sinuses surgery, 17.8%). For 16 patients (57%) Beta-2 transferring test was performed and was positive. The remaining had previously suffered meningitis and/or persistent CSF leaks. In 6 cases (21.4%), preoperative high-resolution MRI was sufficient for localization of the fistula. In 20 patients (71.4%), the MRI was

not considered definitive, and they underwent CT myelography for localization of the fistula. In 17 of twenty patients (85%), CT myelography was successful in identifying the site of the leak, and in 3 patients it was not. In two cases the operation was a second operation for treatment of CSFL, and the location of the leak was known preoperatively, therefore it did not require localizing imaging before the second operation. All in all, brain CT/MRI/CT myelography/ CT cisternography was successful in identifying the site of the fistula in 23 of 26 cases (88.5%). Patient baseline data and preoperative details are provided in Table 1.

Table 1: Patient baseline data and preoperative details.

Age	51.1±14.2; [23-77]
Gender	
Male	11 (39%)
Female	17 (61%)

Operative Procedure

12 patients underwent ASBR using a CST, and 16 patients underwent ST for the repair of their leak. One patient was operated twice with use of ST, since her fistula was initially too large for CST. Another patient underwent CST as primary operation, and after failure underwent a ST re-operation. All patients, operated with either one of those techniques, had a vascularized nasoseptal flap placed, in case it was available. A lumbar drain was placed intraoperatively or immediately after surgery for 3-5 days after surgery in 13 patients. Lumbar drain was placed in 6 of the 16 patients operated with ST (37.5%) and in 7 of 12 patients operated with CST (58.3%).

Outcome and Complications

The mean follow-up was 62 months calculated from the first operation (Range 36-86 months). All patients were followed for at least 3 years in both neurosurgery and ENT clinic. Two patients in the ST group (12.5%) and 1 patient in the CST group (8.3%) had persistent rhinorrhea after the operation. These two patients from the ST group underwent re-operation by using ST and a VP shunt placement respectively. The patient in the CST group with

the persistent rhinorrhea, described above, underwent a second operation using ST, and a LP shunt placed in the same operation. Following this second operation she enjoyed resolution of the leak. Therefore, the success rate in alleviating the leak was 91.7% in the CST group, and 87.5% in the ST group. One patient in the ST group had a brain abscess in the area above the operation. There were no postoperative infectious complications in the CST group. 3 of the 16 patients who underwent ST (18.8%) lost the sense of smell after the operation.

We observed this complication in none of the CST cases. Altogether, 3 patients in the ST group (18.8%) required CSF diversion procedures (VP shunt or LP shunt). The patient mentioned above, who required a CST, then a ST operation with LP shunt placement, was the only patient in the CST group who required CSF diversion (1/12, 8.3%) All in all, complications (including CSF leak, anosmia, need for re-operation, permanent CSF diversion or infection) were encountered in 1 of 12 patients in the CST group (8.3%), and in 6 of the 16 patients who had a ST operation (37.5%). All the differences between the two groups were not statistically significant ($p>0.05$). A summary of outcomes and complications is presented in Table 2.

Table 2: A summary of outcomes and complications.

CORCKSCREW					
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	??	12	42.9	42.9	42.9
	X	16	57.1	57.1	100
	Total	28	100	100	

Discussion

The use of Corkscrew technique is a useful and efficacious technique to prevent CSFL. The success rate in alleviating the leak was 91.7% in the CST group, and 87.5% in the ST group. The overall complication rate was 8.3% in the CST group, and 37.5% in the ST group. Due to its relatively high success rate and low complication rate, we consider CST appear to be a feasible and effective treatment modality for post-traumatic, post-surgical and

for spontaneous CSF leak cases. The main shortcoming of EES techniques described in the literature is two forms of migration. The first is protrusion of the construct extracranially due to the pulsating pressure of CSF from above. The CST gives, in our experience, a feasible solution, whereby the cone shape of the construction uses the downward-pulsating pressure to wedge the construct further into the opening, yet the larger part above the opening prevents extracranial migration Tables 3-5.

Table 3:

	CORCKSCREW, yes; N=12	X, ₁₆	Total N=28	P
Complication	0	7 (44%)	7 (25%)	P=0.01
Age	55.7±12.1	47.6±15.0	51.1±14.2	P=0.14
Gender- female	9 (75%)	8 (50%)	17 (61%)	P=0.25
Recurrent leak	1 (8%)	2 (12.5%)	3 (11%)	P=1.00
Meningitis before yes	3 (25%)	4 (25%)	7 (25%)	P=1.00
LP/VP SHUNT	0	4 (25%)	4 (14%)	P=0.11
CD yes	7 (58%)	6 (37.5%)	13 (46%)	P=0.44
BETA TRAFERRIN				
Positive	7 (58%)	9 (56%)	16 (57%)	P=1.00
X	5 (42%)	7 (44%)	12 (43%)	

Table 4:

	CORCKSCREW, yes; N=12	X, ₁₆	Total N=28	P
Complication	0	7 (44%)	7 (25%)	P=0.01

Table 5:

	Complication, N=7
Age; mean±SD; range	50.0 ±18; 23-77
Gender	5 male; 2 female
Recurrent leak	1yes; 6 no
Meningitis before	3 yes; 4 no
LP/VP SHUNT	3 yes; 4 no
CD yes	4 yes; 3 no
BETA TRAFERRIN	
Positive ; X	4 yes; 3 no

The second form of migration is lateral displacement of the construct to different areas atop the skull base. This is the rationale to place the edge of the wedge-shaped construct into the aperture, thus anchoring it and preventing this lateral migration. A wide range of ASBR techniques has been described over the past decades using different type of materials (REF). Most of these techniques appear to be effective. The use of fascia lata as the material for construction is not novel and has been used by others. Since the current study focus on those two surgical sealing techniques, we cannot comment on the efficacy of other approaches or sealing materials. Still, the current series has

shown that the use of a wedge-shaped construct is an effective and may be beneficial addition to the skull-base neurosurgeons routine in case of CSFL.

Limitations

The current cohort of patients is relatively small and no meaningful statistical analysis could be made. We acknowledge an inherent bias in our comparison between groups, in that the size of the fistula was the basis for the choice of technique used. Thus, the comparison between the two groups is given in descriptive terms, and not in quantitative, statistical analysis. We

aim to present in this study the efficacy and safety profile of this technique. We found that CST provide higher rate of ceiling in recurrent leaks and relatively lower rate of complications. These findings support the use of CST technique in treatment of large portion of cases with CSF leak regardless the site or size of the defect and regardless the intra-operative expected CSF leak is low or high.

Conclusion

The Corkscrew technique is a safe, feasible and efficacious method for reconstruction of the anterior skull base in cases of significant CSF leak.

Declarations

Ethics Approval and Consent to Participate: Ethical approval of Rambam Medical Center, local committee 12.06.20219, approval no. 201913751.

Consent for Publication: Not applicable.

Availability of data and materials: the datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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