ORIGINAL RESEARCH

Transvenous embolization of dural carotid cavernous fistulas: the role of liquid embolic agents in association with coils on patient outcomes

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ABSTRACT

Introduction Transvenous embolization is the standard treatment for dural carotid cavernous fistulas (DCCF). Although various embolic materials have been used, the best embolic material for the treatment of DCCF is still unknown.

Objective To assess the safety and efficacy of different embolic materials used for the endovascular treatment of DCCF.

Methods A retrospective data analysis of a consecutive series of 62 patients presenting DCCF was performed. Clinical and radiological data from patients were assessed, and the embolic material used—coils or liquids—were compared between two groups of patients.

Results Complete angiographic occlusion of DCCF after treatment was achieved in 83.9% of the patients (52/62). We found a higher rate of complete occlusion of DCCF when liquids were associated with coils than with coils alone (96.5% vs 71.8%, p=0.01), and no differences in complication rates or clinical outcomes were seen between the two groups. At the 6-month follow-up, we found a higher rate of improvement in ocular symptoms compared with cranial nerve palsy improvement (94.7% vs 77.7%, p=0.02). Two patients (3.2%) had treatment-related complications without clinical symptoms.

Conclusion In this study, in comparison with the use of coils alone, the association of transvenous embolization with liquid embolic agents for DCCF treatment resulted in higher rates of complete occlusion without increasing complication rates. The clinical outcome at the 6-month follow-up showed significant improvement in ocular symptoms over cranial nerve palsy regression, which was independent of the embolic agent chosen for treatment.

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INTRODUCTION

Dural arteriovenous fistulas (DAVF) represent approximately 15% of all intracranial arteriovenous malformations, and the prevalence of DAVF involving the cavernous sinus is about 16%.[1] Dural carotid cavernous fistulas (DCCF) may cause symptoms such as headaches, bruits, chemosis, proptosis, ophthalmoplegia, and high ocular pressures. Moreover, in the presence of cortical venous reflux from DCCF, patients may present seizures, neurologic deficits, or intracranial hemorrhages. The diversified embryologic origins of the cavernous sinus and its highly complex anatomy, the multiple locations of the shunts in the cavernous walls, the multiple possible arterial supply routes to the shunts, the multiple possible venous drainages, and thrombosis of the associated cavernous compartments, make DCCF one of the most complex neurovascular conditions.[2–6] Combinations of these features may explain why the symptoms of DCCF vary from a mild headache to a catastrophic intracranial hemorrhage and why treatments may require different strategies, accesses, and embolic materials.[2–7]

The feasibility, safety, and efficacy of transvenous endovascular embolization has made this approach the standard treatment for DCCF,[7–13] and multiple routes to the cavernous sinus have been described.[12–21] Multiple embolic materials such as coils, n-butyl cyanoacrylate (NBCA), Onyx (Medtronic, Irvine, California, USA), or a combination of these materials have been used for embolization of DCCF. Most studies on endovascular treatment of DCCF have been case series, and no formal comparisons among the embolic materials used have been reported.[7–31]

The aim of this study was to assess clinical and radiological data obtained from patients to determine the safety and efficacy of different embolic materials used for the endovascular treatment of DCCF.

METHODS

This is a retrospective study of a consecutive series of patients presenting DCCF, managed in two interventional neuroradiology centers. The data extraction and manuscript preparation were in accordance with recommendations from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. The study protocol was approved by the institutional review boards, which waived the need for written informed consent from the participants.

We assessed clinical, radiological, and procedural data for all patients presenting with DCCF who were admitted to our institution between January 2006 and December 2016. We excluded all patients who presented intracranial arteriovenous fistulas outside the cavernous sinus or patients with other arteriovenous malformations draining to the cavernous sinus. All patients were examined in the

hospital and at the 6-month follow-up session by an independent neurologist, who measured neurological outcomes using the modified Rankin Scale (mRS) and examined the eyes of patients. The presence of ocular symptoms was defined as any chemosis, proptosis, or ophthalmoplegia. The presence of cranial nerve palsy (cranial nerves III, IV, V, or VI) was defined as any diplopia, ophthalmoplegia, or ptosis. Four-vessel digital subtraction angiography (DSA) was carried out before embolization, immediately after embolization, and at the 6-month follow-up.

Clinical, radiological, and procedural data from patients with DCCF were assessed, comprising details of age, gender, mRS score, the side of DCCF (right, left, or bilateral), the Barrow grade (B, C, or D), the presence of any cortical or spinal venous reflux, the time from onset of symptoms to treatment, the embolic materials used (coils, NBCA or Onyx-18 (Medtronic)), the embolization strategy (venous, arterial, combined venous and arterial embolization), treatment-related complications, and complete angiographic occlusion of DCCF immediately after embolization and at the 6-month follow-up.

The safety end point was evaluated from the incidence of treatment-related complications of endovascular embolization of DCCF, which were defined as vessel perforations during embolization, hemorrhagic or ischemic strokes, death, asystole, or a new neurologic or ocular deficit. The efficacy end points were complete angiographic occlusion immediately and at 6 months after treatment as well as improvement in ocular symptoms and cranial nerve palsy at 6 months after treatment. In addition to the general efficacy end points, we performed subgroup analysis comparing two groups of patients according to the embolic materials used for endovascular treatment (coils vs liquids). In the group 'liquids' were included all patients who were treated using some liquid (coils and NBCA, coils and Onyx, only NBCA or only Onyx). We also compared the outcome of immediate complete occlusion of DCCF after embolization in the two groups of patients.

Embolization procedure

All patients diagnosed with DCCF were evaluated for curative endovascular embolization as a first-line strategy. All procedures were performed under general anesthesia, and continuous anticoagulation was maintained with non-fractionated heparin. After digital subtraction angiography (DSA) of the brain, the embolization strategy was planned. Of the three embolization strategies (venous, arterial or combined embolization), venous embolization was usually the first choice for treatment, while arterial or combined approaches were indicated if venous embolization could not be achieved. For transvenous embolization, we catheterized the fistula compartment of the cavernous sinus through one of the following venous accesses: inferior petrosal sinuses, superior petrosal sinuses, or facial veins, from both sides if necessary. For the embolic materials used for treatment, coiling by venous access was primarily indicated. Liquid materials were injected through the venous accesses into the cavernous sinus when complete occlusion of the fistula could not be achieved using coils alone (figures 1 and 2), when the fistulas were restricted to small cavernous sinus compartments (figure 3), or in cases where arterial embolization was indicated. Of the liquid materials used, NBCA was used during the initial period of the study when Onyx was not available at our institutions. However, after the Onyx-18 became available, it was used for all cases for which liquid embolization was indicated as a treatment for DCCF.

In general, a 5 F diagnostic catheter with continuous saline perfusion was positioned in the cervical carotid artery related to the DCCF. A 6 F guiding catheter (Guider Softip, Boston

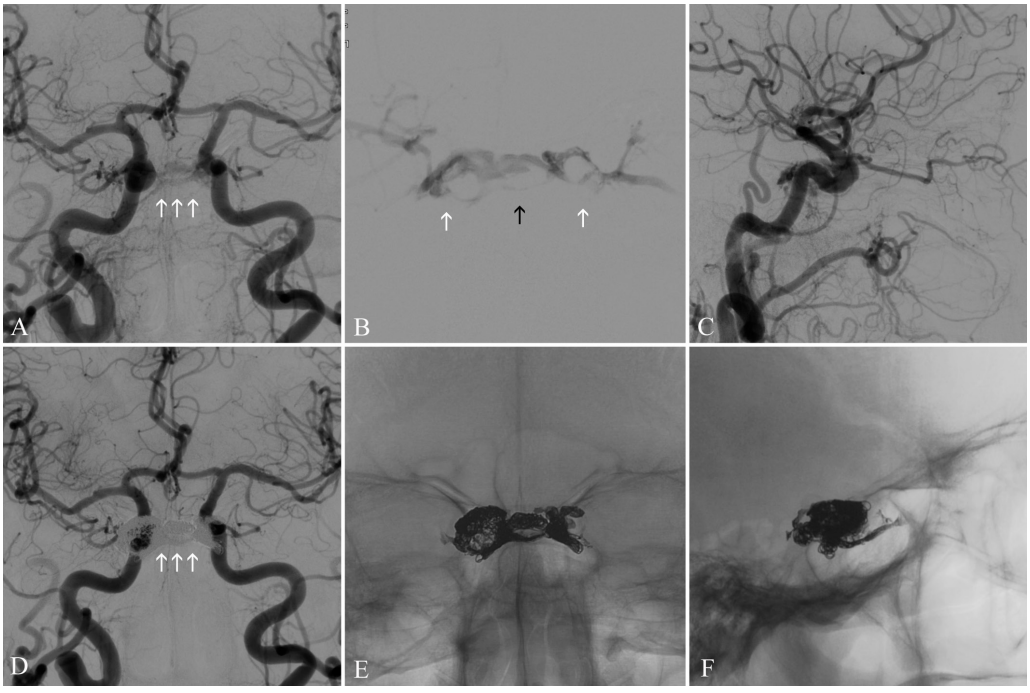

Figure 1 (A) Digital subtracted angiography (DSA) of bilateral common carotid arteries, frontal view, showing a bilateral dural carotid cavernous fistula (DCCF) Barrow type D (white arrows); (B) selective DSA of the cavernous sinus (white arrows) and intercavernous sinus (black arrow); (C) DSA of the right common carotid artery, lateral view, a DCCF Barrow type D; (D) DSA of bilateral common carotid arteries, frontal view, showing a complete occlusion of the DCCF by a cast of coils and Onyx (Medtronic) (white arrows) (E, F) X-rays showing the final cast of coils and Onyx (Medtronic), (E) frontal view and (F) lateral view, after embolization of bilateral DCCF.

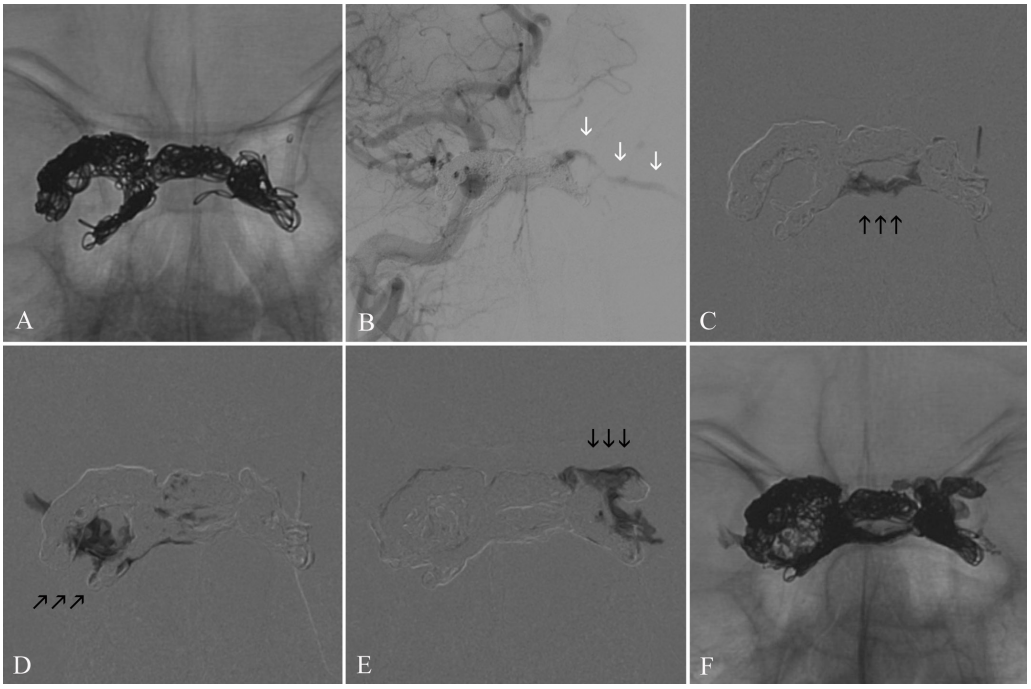

Figure 2 Procedure details of the case of figure 1; (A) X-ray, frontal view, showing the final cast of only coils; (B) DSA of the right common carotid artery, frontal view, late arterial phase, showing an early contrast of the left cavernous sinus, which indicates a partial occlusion of the dural carotid cavernous fistula (DCCF) (white arrows); (C, D, E) roadmap, frontal view, demonstrating sequential steps of Onyx injection thorough the Echelon catheter positioned in the left cavernous sinus. The Onyx (Medtronic) injection filled compartments of the right cavernous sinus (C), anterior intercavernous sinus (D), and left cavernous sinus (E); X-ray, frontal view, showing the final cast composed of coils and Onyx (Medtronic).

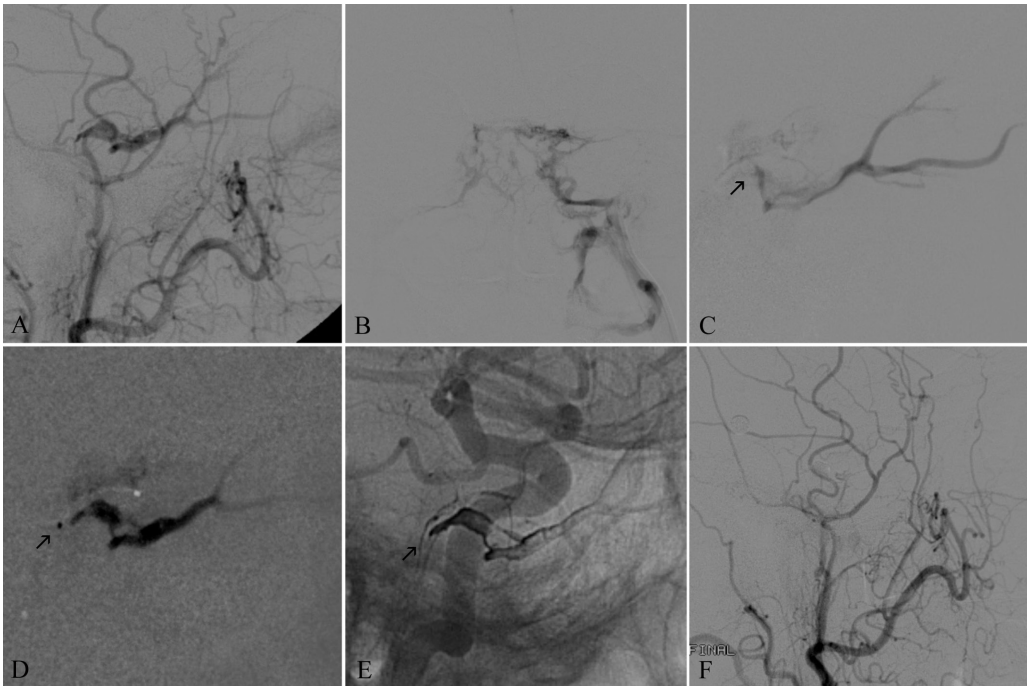

Figure 3 (A) DSA of the left external carotid artery, lateral view, shows a left dural carotid cavernous fistula (DCCF), Barrow type C; (B) DSA of the left jugular vein bulb shows the cavernous sinuses and the access to the left cavernous sinus through the left inferior petrosal sinus; (C) selective DSA of the posterior compartment of the left cavernous sinus, lateral view, contrast injection by the Exelon catheter (Medtronic); (D) roadmap, lateral view, showing Onyx injection into the posterior and progressive filling of the anterior compartment occluding the DCCF; (E) final cast of Onyx occupying the compartments of the left cavernous sinus where the DCCF drained before embolization; (F) DSA of the left external carotid artery, lateral view, showing a complete occlusion of the DCCF.

Scientific, Natick, Massachusetts, USA) or a 5 F diagnostic catheter with continuous saline perfusion was positioned in the internal jugular vein or in the inferior petrosal sinus. Through the guiding catheter, a dimethyl sulfoxide-compatible microcatheter (Echelon; Medtronic, Irvine, California, USA) was advanced with a 0.014 inch guidewire (Silverspeed - Medtronic or Transend - Stryker). The coils used were Guglielmi detachable coils, Target (Stryker), or Axium (Medtronic). The liquids used were Onyx-18 (Medtronic) or a solution of the acrylic glue NBCA (Hystoacryl; B Braun Melsungen AG, Melsungen, Germany or Glubran 2 (GEM, Viareggio, Italy)) and lipiodol. Corticosteroids were administered for 5 days after the procedure. In the absence of complications, patients were extubated in the operating room and were discharged 24 or 48 hours after treatment.

Statistical analysis

Continuous variables were presented as the means (range ±SD), and the Mann–Whitney test or Student's t test was used when appropriate. Categorical variables were presented as numbers and percentages and compared among groups using the X^2 or Fisher's exact tests, when appropriate. One independent blinded statistician received all data collected for statistical analysis. The IBM SPSS Statistics software version 20.0 (Chicago, Illinois, USA) was used for statistical analysis. We considered p values <0.05 as significant.

RESULTS

Sixty-two patients presenting DCCF were included, with a mean (SD) age of 62.7 (12.5) years (range 21–82). The sample comprised 24 male (38.7%) and 38 female (61.3%) subjects, and the median and mean baseline mRS scores were 1 and 1.3, respectively (range 0–2, SD=0.61). Ocular symptoms were present in 57 patients (91.9%), while 27 patients (43.5%) had cranial nerve palsy. In 29 (46.8%) patients, DCCF were located on the right side, in 27 (43.5%) on the left side, while 6 (9.7%) patients were bilateral. For the Barrow classification, 15 DCCF (24.2%) were Barrow B, six (9.7%) were Barrow C, and 41 (66.1%) were Barrow D. Cortical or spinal venous reflux was observed in 18 patients (29.5%) (table 1).

The embolization results were venous embolization performed in 58/61 patients (95.1%), arterial embolization in two patients (3.3%), and combined venous and arterial embolization in only one patient (1.6%). A total of 62 sessions were conducted for embolization of all patients (mean one session for each patient). One patient (1.6%) had a spontaneous occlusion of the fistula at the time of the procedure hence, no embolization was necessary. Another patient had a recurrence of symptoms after treatment and a second embolization was performed. The embolic materials used for embolization of the 61 patients were as follows: coils in 32 patients (52.5%), liquids in 29 patients (47.5%), NBCA in three patients (4.9%), Onyx in five patients (8.2%), coils and liquids in 21 patients (34.4%), coils and NBCA in six patients (9.8%), coils and Onyx in 15 patients (24.6%) (table 2). The median and the mean time from the onset of symptoms to embolization were, respectively, 90 and 163 days (range 5–2520, SD=332). Eighteenpatients (29.5%) were treated within 1 month of onset of symptoms, and 32 (51.6%) were treated within 3 months of onset of symptoms (table 1).

Complete angiographic occlusion of DCCF immediately after treatment was achieved in 52 patients (83.9%), while in 10 (16.1%) patients a partial occlusion was obtained. One of these 10 patients presented with worsened ocular symptoms and cranial nerve palsy after 2 months of embolization hence, a new embolization was performed with coils and Onyx through venous access. In this second treatment, an immediate complete occlusion of the fistula was obtained and the patient's ocular symptoms and diplopia resolved completely. The other nine patients with partial occlusion of DCCF showed improvement in their symptoms and had complete spontaneous angiographic occlusion of DCCF at the 6-month follow-up. All patients who had complete immediate occlusion of DCCF after treatment (83.9%) showed DCCF occlusion at the 6-month follow-up also.

Treatment-related complications were seen in two patients (3.2%). One patient had an asystole for 5 s caused by a trigeminal reflex during Onyx injection, and the other had a perforation of the inferior petrous sinus during catheterization, which was promptly managed by coiling. Both patients had no clinical symptoms after treatment. Thirteen patients (21%) did not undergo brain DSA after 6 months of treatment. Among the 49 (79%) patients who underwent DSA at 6 months, all (100%) had complete angiographic occlusion of DCCF. All 62 patients were clinically evaluated at the 6-month follow-up. Of the 57 patients with ocular symptoms on admission, 54 patients (94.7%) showed complete improvement, while three patients (4.8%) showed no improvement in symptoms at the follow-up after 6 months. Twenty-seven patients presented cranial nerve palsy on admission, and 21 of those (77.8%) showed complete improvement of diplopia, while five patients (18.5%) had partial or no improvement of diplopia at the 6-month follow-up. At the 6-month follow-up, all patients demonstrated a higher rate of improvement in ocular symptoms compared with the rate of cranial nerve palsy improvement after embolization (94.7% vs 77.7%, p=0.02). The median and mean mRS at the 6-month follow-up were 0 and 0.14, respectively (range 0–2, SD=0.5).

In the analyses of groups, comparing embolic materials used for embolization (coils vs liquids), baseline characteristics of the two groups were balanced (table 1), and we found a higher rate of complete immediate occlusion of the cranial DAVF with liquids compared with coils (96.6% vs 71.9%, respectively, p=0.01) (table 1).

Comparison of the outcome of complete immediate occlusion of the DCCF between the groups showed that the two groups were homogeneous for baseline characteristics (table 2). Compared with the group in which immediate occlusion of the DCCF was not obtained, the group in which complete immediate occlusion was achieved had a higher proportion of embolization with liquids (53.8% vs 10%, p=0.01), and a lower proportion of embolization with coils alone (44.2% vs 90%, p=0.01) (table 2).

DISCUSSION

In this study, we reported results of a consecutive series of patients who exclusively presented with DCCF. The patients were treated by the endovascular approach as a first-line strategy and most of the patients underwent transvenous embolization (95%). Despite the non-randomized design of this study, all baseline variables were balanced between the groups. The overall rates of DCCF angiographic occlusion were 84% immediately after embolization and 100% at the 6-month follow-up, with a mean of one embolization session for each patient and a complication rate of 3.2% with no clinical sequelae. We observed that liquid embolic agents significantly increased the rate of complete immediate occlusion of DCCF. However, no differences in complications, recurrence rates, re-treatment rates, improvements of symptoms or angiographic occlusion rates during 6 months were demonstrated when liquids were used. Only one patient of the 10 (10%) that had a partial occlusion of DCCF after treatment with coils alone showed worse

Table 1 Data of patients in the two groups divided according to the embolization materials

Data	Coils (n=32)*	Liquids (n=29)†	p Value
Age (mean, range, SD)	62.4 (21–80, 13.7)	63.6 (34–82, 11.1)	0.81
Female (n, %)	20 (62.5)	17 (58.6)	0.79
Male (n, %)	12 (37.5)	12 (41.4)	0.79
Baseline mRS (mean, range, SD)	1, 1.2 (0–2, 0.59)	1, 1.3 (0–2, 0.62)	0.29
Baseline ocular symptoms (n, %)	29 (90.6)	27 (93.1)	1.00
Baseline cranial nerve palsy (n, %)	9 (28.1)	17 (58.6)	0.02
Side of the fistula (n, %)			
Right	14 (43.8)	14 (48.3)	0.79
Left	16 (50)	11 (37.9)	0.44
Bilateral	2 (6.3)	4 (13.8)	0.41
Arterial afferents: Barrow classification			
B (n, %)	4 (12.5)	10 (34.5)	0.06
C (n, %)	3 (9.4)	3 (10.3)	1.00
D (n, %)	25 (78.1)	16 (55.2)	0.10
Baseline venous cortical reflux (n, %)	8 (24.2)	9 (33.3)	0.77
Time from onset of symptoms to treatment ≤1 month (n, %)	9 (27.3)	9 (33.3)	0.78
Time from onset of symptoms to treatment ≤3 months (n, %)	16 (50.0)	16 (55.1)	0.79
Time from onset of symptoms to treatment (days) (mean, range, SD)	130.8 (10–540, 115)	210.7 (5–2520, 487.4)	0.40
Embolization strategy			
Venous embolization (n, %)	32 (100)	26 (89.7)	0.10
Arterial embolization (n, %)	0 (0)	2 (6.9)	0.22
Venous+arterial embolization (n, %)	0 (0)	1 (3.4)	0.47
Complete immediate angiographic occlusion (n, %)	23 (71.9)	28 (96.6)	0.01
Treatment related complication (n, %)	0 (0)	2 (6.8)	0.22
Ocular symptoms at the 6-month follow-up			
Absence of symptoms (n, %)	30 (93.8)	27 (93.1)	1.00
Partial improvement or unchanged (n, %)	1 (3.1)	2 (6.9)	0.60
Symptoms worsened (n, %)	1 (3.1)	0 (0)	0.47
Cranial nerve palsy at the 6-month follow-up			
Absence of cranial nerve palsy (n, %)	28 (87.5)	27 (93.1)	0.67
Partial improvement or unchanged (n, %)	3 (9.4)	2 (6.9)	1.00
Symptoms worsened (n, %)	1 (3.1)	0 (0)	1.00
Complete angiographic occlusion at the 6-month follow-up (n, %)	25/25 (100)	24/24 (100)	1.00
Complication during 6-months' follow-up (n, %)	0 (0)	0 (0)	1.00
mRS at the 6-month follow-up (median, mean, range, SD)	0, 0.18 (0–2, 0.58)	0, 0.11 (0–2, 0.42)	0.69

*One patient who had spontaneous occlusion of the fistula was not included in this analysis.
†(Liquids) includes any use of liquid embolic agents with or without coils.
Among the 29 patients we had NBCA (three patients); coil +NBCA (five patients); Onyx: (six patients); Coil +Onyx (15 patients).
mRS, modified Rankin Scale, NBCA, n-butyl cyanoacrylate.

ocular symptoms after treatment and required a second embolization using coils and Onyx. This specific case elicited a change in the management of patients with DCCF by the interventional neuroradiologists, who began ensuring that a complete occlusion of the fistula was attempted in a single treatment session. If a complete occlusion of the DCCF could not be achieved using coils alone, injection of liquids though the cavernous sinus was indicated aiming to reach complete immediate occlusion of the fistula. This represented a change in our daily clinical practice that would become a methodological cornerstone of this study and which explains the origins of the two groups analyzed.

DCCF is a rare cerebrovascular condition and interpretation of the results of our study in parallel with studies previously published is difficult because most of those studies were small series of cases, had mixed groups of patients with DCCF and other similar conditions, and included DCCF treated using diverse endovascular strategies and materials. Some previous studies combined the results of DCCF and direct carotid cavernous fistulas, which are conditions with a different etiology but share similar locations and symptoms with DCCF.[7–9 16] Other studies combined the results of DCCF with other DAVFs.[8 11 24] Although DCCF and DAVF have similar etiologies, they differ in their location, arterial supplies, and multiple venous drainages and have variable clinical manifestations and diverse treatment strategies.

Studies investigating the rate of complete occlusion of DCCF have reported highly variable results. The average number of

Table 2 Data of patients divided between two groups according to the outcome of complete immediate angiographic occlusion after embolization

Data	Immediate occlusion (n=52)	No immediate occlusion (n=10)	p Value
Age (mean, range, SD)	63.1 (21–82, 12.1)	61.3 (31–80, 15)	0.90
Female (n, %)	29 (55.7)	8 (80)	0.07
Male (n, %)	23 (44.2)	1 (10)	0.07
Baseline mRS (median, mean, range, SD)	1, 1.3 (0–2, 0.59)	1, 0.8 (0–2, 0.6)	0.10
Baseline ocular symptoms (n, %)	49 (94.2)	8 (80)	0.18
Baseline cranial nerve palsy (n, %)	25 (48.1)	2 (20)	0.16
Side of the fistula (n, %)			
Right (n, %)	25 (48.1)	4 (40)	0.73
Left (n, %)	21 (40.4)	6 (60)	0.16
Bilateral (n, %)	6 (11.5)	0 (0)	0.57
Arterial afferents: Barrow classification			
B (n, %)	14 (26.9)	1 (10)	0.42
C (n, %)	6 (11.5)	0 (0)	0.57
D (n, %)	32 (61.5)	9 (90)	0.14
Baseline venous cortical reflux (n, %)	15 (28.8)	2 (22.2)	0.71
Time from symptoms onset to treatment ≤1 month	14 (26.9)	4 (44.4)	0.25
Time from symptoms onset to treatment ≤3 months	28 (52)	4 (44.4)	1.00
Time from symptoms onset to treatment (mean, range, SD)	166.7 (5–2520, 351)	161.8 (22–720, 222)	0.66
Embolization strategy (n, %)			
Venous embolization (n, %)	48 (94.1)	10 (100)	1.00
Arterial embolization (n, %)	2 (3.9)	0 (0)	1.00
Venous+arterial embolization (n, %)	1 (2.0)	0 (0)	1.00
Embolic materials, n (%)			
Spontaneous occlusion	1 (1.9)	0 (0)	1.00
Coils	23 (44.2)	9 (90)	0.01
Liquids	28 (53.8)	1 (10)	0.01
NBCA	3 (10.3)	0 (0)	1.00
Onyx	4 (13.8)	1 (10)	1.00
Coils+NBCA	6 (20.7)	0 (0)	0.57
Coils+Onyx	15 (51.7)	0 (0)	0.10
Treatment related complication (n, %)	2 (3.8)	0 (0)	1.00
Ocular symptoms at the 6-month follow-up (n, %)			
Absence of ocular symptoms	49 (94.2)	9 (90)	0.51
Partial improvement or unchanged	3 (5.8)	0 (0)	1.00
Symptoms worsened	0 (0)	1 (10)	0.16
Cranial nerve palsy at the 6-month follow-up (n, %)			
Absence of cranial nerve palsy	47 (90.4)	9 (90)	0.51
Partial improvement or unchanged	5 (9.6)	0 (0)	0.58
Symptoms worsened	0 (0)	1 (10)	0.16
Complete occlusion at the 6-month follow-up (n, %)	41/41 (100)	8/8 (100)	1.00
Complication during 6-months' follow-up (n, %)	0 (0)	0 (0)	1.00
mRS at the 6-month follow-up (median, mean, range, SD)	0, 0.17 (0–2, 0.55)	0, 0 (0–0, 0)	0.31

mRS modified Rankin Scale; NBCA, n-butyl cyanoacrylate.

embolization sessions per patient was also diverse across studies. The rates of total occlusion of DCCF with embolization vary from 51.7% to 90% using coils,[10 13 21 23 30] from 80% to 100% using coils and NBCA,[10 22 23] and from 76.9% to 100% using coils and Onyx.[6 15 25–30] Independent of the embolization strategies reported, the improvement in symptoms varied from 70% to 94.1%.[10 18 22–24 26 31] The rates reported for the recurrence of symptoms ranged from 0.0% to 12.5%.[7 9 10 22–24] As observed in our study, although infrequent, recurrence of symptoms was related to incomplete occlusion of DCCF.[7 9 10 22–24] The complication rates ranged from 2.3% to 53.3%.[10 13 22–31] Bradycardia or asystolia have been described as relatively frequent occurrences during Onyx injection into the cavernous sinus, and no significant consequences were seen in most cases.[27] Although

liquid injection into the cavernous sinus could lead to lesions or infarction of cranial nerves,[32 33] no nerve lesion was observed in our study.

This study is one of the largest series reporting results of patients presenting exclusively with DCCF that was treated with coils and liquids injection through transvenous access (95% of cases) into the cavernous sinus. A high immediate complete occlusion rate of DCCF was achieved with association of liquids without an increase in complication rates. Most of the previous studies reporting results of liquid injections into the cavernous sinus for the treatment of DCCF were small case series. An original characteristic of this study was a formal comparison of two intervention groups dichotomized between the use of coils or liquids by the transvenous approach. Most of the previous studies reviewed did not compare embolic materials using the transvenous approach. Previous studies usually indicated liquids for transarterial embolization and coils for transvenous embolization and required an average number of embolization sessions, usually more than one. Therefore, although we did not observe differences between the number of embolization sessions in this study, use of liquids by the transvenous route may be a factor in reduction of the number of embolization sessions. This was a multicenter study and the outcomes were reasonably satisfactory, suggesting that our results may have good generalizability.

The limitations of this study were its retrospective design, the lack of data on the amount of embolic materials used, and the assessment of clinical outcomes only once at the 6-month follow-up. Because we recorded clinical outcomes of patients 6 months after treatment, progressive clinical improvements or the exact times from treatment to complete clinical improvements in patients were not known. Therefore, possible associations between complete or partial DCCF occlusions and the time from treatment to clinical improvement could not be assessed. Among all patients, eight (12.9%) were treated using only liquids (five Onyx and three NBCA, table 2). Seven of these eight patients (87.5%) had complete immediate occlusion of the DCCF. As we described in the 'Methods' section, one of the three indications for embolization with liquids was a small cavernous sinus compartment. Therefore, these eight patients presented small cavernous compartments, which may be associated with a higher probability of complete immediate occlusion of the DCCF independent of the embolic agent used. Another limitation of the study was the small sample. A larger sample study could show potential differences in clinical outcomes between groups and sub-groups of the types of patients analyzed in this study.

CONCLUSION

In this study, compared with the use of coils alone, the association of transvenous embolization with liquid embolic agents for DCCF treatment resulted in higher rates of complete occlusion without increasing complication rates. The clinical outcome at the 6 month follow-up showed significantly greater improvement in ocular symptoms over cranial nerve palsy regression, independent of the embolic agent chosen for treatment.

Contributors LHC-A helped to conceive the study, drafted and approved the manuscript; FPT helped to conceive the study and design, carried out data analysis, revision, and gave final approval of the manuscript; MTR, ACU GSN, LMM, BOC, AAVeC participated in data acquisition, editing of figures and tables , revision, and final approval of the manuscript; DGA conceived the study, acquired data, revised the manuscript critically, and approved the final manuscript.

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Transvenous embolization of dural carotid cavernous fistulas: the role of liquid embolic agents in association with coils on patient outcomes

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