Journal of Clinical Neuroscience 21 (2014) 40–46

Contents lists available at ScienceDirect

Journal of Clinical Neuroscience

journal homepage: www.elsevier.com/locate/jocn

Clinical Study

Endovascular treatment of carotid cavernous aneurysms: Complications, outcomes and comparison of interventional strategies

Robert M. Starke [a,b], Nohra Chalouhi [b], Muhammad S. Ali [b], Stavropoula I. Tjoumakaris [b], Pascal M. Jabbour [b], L. Fernando Gonzalez [b], Robert H. Rosenwasser [b], Aaron S. Dumont [b,*]

[a] Department of Neurological Surgery, University of Virginia, Charlottesville, VA, USA
[b] Department of Neurological Surgery, Thomas Jefferson University, 901 Walnut Street, 3rd Floor, Philadelphia, PA 19107, USA

ARTICLE INFO

Article history:
Received 23 January 2013
Accepted 10 March 2013

Keywords:
Aneurysm
Cavernous
Embolization
Flow diversion
Stent
Subarachnoid hemorrhage

ABSTRACT

The best treatment modality for cavernous carotid aneurysms (CCA) remains unclear. We treated 82 CCA in 79 patients with endovascular coiling (n = 14), stent assistance (n = 53), and carotid vessel deconstruction (CVD) (n = 15). Favorable outcomes were defined as a Glasgow Outcome Scale of 4 to 5 without worsening signs or symptoms. Mean CCA size was 13.3 ± 9.2 mm, and CCA treated with CVD were larger ($p = 0.010$). Fourteen patients had incidental CCA, 40 (50.6%) had cranial nerve palsies (CNP), and 25 (31.7%) had pain leading to diagnosis. Immediate occlusion (>95%) occurred in 91.5% of aneurysms. Ischemic or hemorrhagic complications developed following eight treatments (9.8%) and three were permanent (3.7%). There were no deaths, and favorable discharge outcome occurred following 87.8% of procedures. Although there was no difference in immediate occlusion or complications amongst treatment cohorts, fewer permanent complications (0% *versus* 10.3%, $p = 0.041$) and favorable discharge outcomes ($p = 0.039$) were associated with stent assisted treatment. Follow-up was available following 75 procedures (mean 21.4 ± 17.4 months). Recanalization occurred in 36% of patients and retreatment in 25%. Patients presenting with CNP improved over time ($p < 0.001$); 54% of patients presenting with CNP remained unchanged while 46% improved; there was no difference in improvement rates stratified by treatment. Favorable follow-up outcome occurred after 96% of treatments and those receiving stents were more likely to have favorable outcome in multivariate analysis ($p = 0.039$). Endovascular therapy is a safe and effective therapy for CCA. When possible, stent assisted therapy may be the best option with fewer complications and low recanalization rates.

1. Introduction

Aneurysms arising from the cavernous segment of the internal carotid artery represent approximately 2–12% of intracranial aneurysms.[1–3] Due to increasing use of non-invasive imaging, a larger percentage of cavernous carotid aneurysms (CCA) are found incidentally. These lesions may also cause signs or symptoms secondary to mass effect on adjacent structures or rupture resulting in carotid cavernous fistulas or subarachnoid hemorrhage (SAH). Due to the complexity and risk of microsurgical treatment,[4] endovascular intervention has become the preferred therapy when necessary. Although results following treatment of aneurysms originating from the Circle of Willis have been extensively reviewed in the literature, rates of complications and outcomes following treatment of symptomatic CCA remain less clear.[1,2,5–15] Additionally, improvements in technology have increased the number of treatment options for CCA. We review our experience with the endovascular treatment of CCA, assess results following intervention with endovascular coiling, stent assistance, or carotid deconstruction, and determine predictors of outcome.

2. Materials and methods

2.1. Patient cohort

The study protocol was approved by the Thomas Jefferson University Institutional Review Board. We searched our prospectively maintained database for all patients with CCA undergoing endovascular treatment between 2005 and 2011. A total of 79 patients with 82 CCA were identified. Medical charts, angiographic studies, MRI, and CT scans were carefully reviewed. Patients' age, sex, Hunt and Hess grades, and aneurysm locations were recorded. Treatment was dictated by the attending neurosurgeon. Asymptomatic patients were considered for treatment if there was aneurysmal extension beyond the subarachnoid space and there was

* Corresponding author. Tel.: +1 21 5955 7000; fax: +1 21 5503 7038.
E-mail address: aaron.dumont@jefferson.edu (A.S. Dumont).

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http://dx.doi.org/10.1016/j.jocn.2013.03.003

concern for possible SAH. Any aneurysm that displayed a decreasing percentage of occlusion (>5%) on follow-up angiography was considered recurrent. Thromboembolic and ischemic complications were diagnosed clinically (new deficits or change in level of consciousness) or on CT scans or MRI (new infarcts) after excluding confounders like vasospasm, hydrocephalus, and metabolic disorders. CT scans or MRI studies were typically performed in patients with sudden neurological compromise. Thromboembolic complications were diagnosed intra-operatively on digital subtraction angiography (DSA) as well as for endovascular procedures. Endovascular treatment was carried out as previously described.[16,17]

2.2. Patient outcome

Clinical outcome was initially evaluated at time of discharge using the Glasgow Outcome Scale (GOS). The GOS was determined based on patient's neurological examination and functional status at discharge, and classified as follows: 1 = deceased; 2 = vegetative state; 3 = severely disabled; 4 = moderately disabled; and 5 = mildly or not disabled. Angiographic follow-up (DSA or MRI) was scheduled at 6 months, 1 year, 2 years, and 5 years after endovascular procedures. Patient clinical status was also subsequently assessed on the latest follow-up visit. Patients unable or without routine follow-up were contacted for assessment via a structured telephone interview and medical records were obtained from outside hospital facilities. Favorable discharge and follow-up outcome was defined as a GOS score of 4 to 5 without worsening symptoms or cranial nerve (CN) function.

2.3. Statistical analysis

Data are presented as mean and range for continuous variables, and as frequency for categorical variables. Patients treated with parent vessel deconstruction, endovascular coiling, and stent assistance were compared. Statistical analyses of categorical variables was carried out using the chi-squared and Fisher's exact tests, comparison of means was carried out using Student's *t*-test, and analysis of variance followed by Bonferroni post hoc testing was carried out as appropriate. Patients failing initial therapy who were then treated with the Pipeline stent (ev3 Neurovascular, Irvine, CA, USA) were categorized by their initial treatment modality and as having failure of occlusion. Univariate analysis was used to test covariates predictive of the following dependent post-treatment variables: treatment related complications; complete initial aneurysm occlusion (>95%); recanalization following endovascular treatment; and favorable follow-up clinical outcome. Factors predictive in univariate analysis ($p < 0.20$)[18] were entered into a multivariate logistic regression analysis. p values of $\leqslant 0.05$ were considered statistically significant.

3. Results

3.1. Patient characteristics

Of 79 patients with CCA, the mean age was 60.2 ± 10.7 years and 73 were women (92.4%). Mean aneurysm size was 13.3 ± 9.2 mm and 12 (15.2%) were found to be enlarging on serial imaging. CCA were treated with endovascular coiling (14; 17.7%), carotid vessel deconstruction (CVD) following balloon occlusion test (15; 18.3%), and stent assistance (53; 64.6%). A representative patient treated with stent assisted coiling is presented in Fig. 1, CVD in Fig. 2, and coiling in Fig. 3. Of those receiving treatment with stents, 50 were also treated with coils and three were treated with stent-within-stent techniques for flow diversion and parent vessel reconstruction. The mean aneurysm size was larger in those treated with CVD, but there was no difference in mean size between those receiving coils or stents. Comparison of overall patient and aneurysm characteristics stratification according to treatments received is demonstrated in Table 1.

3.2. Initial obliteration rates

Immediate occlusion (>95%) occurred in 75 of 82 CCA (91.5%, Table 2). There was no significant difference in immediate occlusion rates between those treated with coils only (92.9%), stents (88.7%), or CVD (100%, $p = 0.533$). Those with a history of an enlarging aneurysm were less likely to have initial occlusion and those with a history of headache or cranial nerve palsy (CNP) VI on presentation were more likely to have initial occlusion in univariate analysis, and so were entered into multivariate analysis. In multivariate analysis, aneurysms enlarging on serial imaging (odds ratio [OR] = 0.17; 95% confidence interval [CI] 0.03–1.0, $p = 0.05$) were less likely to achieve occlusion and patients with history of headache (OR = 9.2; 95% CI 1.01–84.3, $p = 0.049$) were more likely to achieve occlusion. This was unchanged after controlling for treatment modality and aneurysm size.

3.3. Endovascular related complications

Ischemic or hemorrhagic complications developed following eight treatments (9.8%) and three were permanent (3.7%). There were no procedural related deaths and only one intra-operative rupture. There were six peripheral complications (7.3%) consisting of two femoral pseudoaneurysms that resolved without intervention, two retroperitoneal hematomas that did not require intervention, one lower extremity thrombus that required thrombectomy, and one injury to the profunda femoris requiring primary repair. There was no significant difference in rates of central nervous system (CNS) complications between CCA treated with coils (two; 14.3%), stents (three; 5.7%), or CVD (three; 20%, $p = 0.143$), but those receiving stent assistance experienced fewer permanent complications (0% *versus* 10.3%, $p = 0.041$). Univariate predictors included in multivariate analysis were treatment modality, age, CNP on presentation, and aneurysm size. In multivariate analysis the only factor predictive of CNS complications was age (OR = 1.1; 95% CI 1.01–1.18, $p = 0.026$). Patients older than 65 were 17.7 times more likely to experience a complication (95% CI 2.0–152.4, $p < 0.001$). This was unchanged after controlling for patient, aneurysm, and treatment characteristics.

3.4. Discharge outcome

Two patients with SAH required ventriculoperitoneal shunts for persistent hydrocephalus and two patients experienced vasospasm. Overall functional outcome was good (GOS of 4 to 5) following 79 of 82 treatments and discharge outcome was favorable (GOS 4 to 5 without worsening symptoms or CN function) following 72 of 82 treatments (87.8%). Following treatment of a CCA, those treated with coils or CVD were less likely to have a favorable discharge outcome (22 of 29, 75.9%) *versus* those receiving stents (50 of 53, 94.3%, $p = 0.029$). The following univariate predictors were included in multivariate analysis: age; diplopia; CN III palsy, or any CNP on presentation; history of hypertension; Hunt and Hess grade; ruptured aneurysm; treatment modality; history of vasospasm; and shunt dependent hydrocephalus. In multivariate analysis those less than 65 years of age were 10 times (95% CI 1.9–54.1, $p = 0.007$) more likely and those treated with stent assistance were 5.1 times (95% CI 1.1–23.7, $p = 0.039$) more likely to have a favorable discharge outcome.