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Clinical Study

Predictors of treatment failure following coil embolization of intracranial aneurysms

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ABSTRACT

We present a retrospective review of 357 consecutive patients with 419 aneurysms treated with coil embolization. Although incomplete occlusion and recurrence of intracranial aneurysms following coil embolization is a well-known problem, the factors that influence and predict treatment failure are still debated. For this study, we excluded non-coiling endovascular techniques (flow diversion) and non-saccular aneurysms (fusiform). The modified Raymond–Roy occlusion classification (MRRC) was used to grade the aneurysms. Treatment failure was defined as filling of the aneurysm dome (MRRC Class IIIa or IIIb) at the first angiographic follow-up (average 8 months). Univariate statistical tests were employed to select variables for incorporation into a multivariable logistic regression model. Multivariate analysis identified greater aneurysm volume ($p < 0.001$), packing density (PD) less than 31% ($p = 0.007$) and initial MRRC Class IIIb ($p < 0.001$) as predictors of treatment failure. Incomplete neck coverage with coils was associated with treatment failure in univariate but not multivariate analysis. Class IIIb status was more predictive of treatment failure compared to all Class III (odds ratio 168 *versus* 14.4). Clinical outcomes were similar in both groups except that there were more retreatments in the treatment failure group ($p < 0.001$). Aneurysm volume, PD and initial occlusion class are associated with angiographic outcome, consistent with prior literature. The MRRC is a powerful predictor of treatment failure. These results will be useful in the effort to both prevent and predict treatment failure after coil embolization, however, they should be verified in a prospective study.

1. Introduction

Coil embolization has been increasingly used over the last two decades for the treatment of intracranial aneurysms. Incomplete occlusion and aneurysm recurrence, however, remain disadvantages of this approach [1–3]. A recent systematic review estimated the overall recurrence rate following coil embolization to be approximately 20% [4]. Although a number of different factors have been implicated in aneurysm recurrence [5–14], it is still debated which of these factors is most influential. The purpose of this study is to evaluate factors that predict treatment failure after coil embolization. Therefore, we performed multivariate analysis utilizing a database of consecutive patients treated at a single institution.

2. Methods

2.1. Study design

Institutional Review Board approval was obtained for this study. We performed a retrospective analysis of 357 consecutive patients with 419 intracranial aneurysms treated with coil embolization at a single institution from 2005 to 2013. Patients with previous treatment were included. Exclusion criteria included non-coiling endovascular treatment (flow diversion or coil-assisted flow diversion) and non-saccular aneurysms (fusiform).

2.2. Patient and aneurysm characteristics

Aneurysmal and patient characteristics were determined by review of both medical charts and angiographic data. Aneurysm volume was determined using equations for spherical, ellipsoid or bilobed aneurysms. Aspect ratio (AR) was defined as the

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maximal aneurysm diameter divided by the aneurysm neck. Aneurysm location was determined by angiographic review. Posterior communicating artery aneurysms were included in the anterior circulation.

2.3. Procedure characteristics

Different degrees of procedural assistance were utilized including stand-alone (n = 257), balloon-assisted (BAC; n = 39) and stent-assisted coiling (SAC; n = 123). Coil types included Galaxy (Codman & Shurtleff, Raynham, MA, USA), Guglielmi detachable coil (GDC; Stryker, Kalamazoo, MI, USA), Hydrocoil (MicroVention, Aliso Viejo, CA, USA), Matrix (Stryker), Orbit (Codman), Penumbra (Penumbra, Alameda, CA, USA), Target (Stryker), and Trufill (Codman). Stent types included Enterprise (Codman), Liberty (Penumbra) and Neuroform (Stryker). All aneurysm embolizations were performed by two interventional neurosurgeons and one interventional radiologist. Packing density (PD) was defined as coil volume divided by aneurysm volume as a percentage and was determined using a web-based, open-source calculator (www.angiocalc.com; AngioCalc, LLC.).

2.4. Angiographic outcome

All initial and follow-up angiograms were reviewed using the modified Raymond–Roy occlusion classification (MRRC) [15], which is slightly different to the traditional Raymond–Roy occlusion classification (RROC) [16]. In this system, Class IIIa designates contrast within the coil interstices and Class IIIb designates contrast outside the coil mass/along the aneurysm wall (Fig. 1). Treatment failure was defined as residual filling of the aneurysm dome (MRRC Class IIIa or IIIb) at first follow-up. Although the subject is debatable, a Class II result was not regarded as a treatment failure. The experience at our institution is that Class II aneurysms behave more like Class I than Class III [17].

Additionally, the degree of coil coverage across the neck of the aneurysm was graded as either complete or incomplete. Both subtracted and unsubtracted images were used to make this determination (Fig. 2). To be deemed complete, coils needed to cover the entire length of the aneurysm neck. All others were deemed to be incomplete.

2.5. Statistical methods

Differences in pre-treatment variable distribution between groups were assessed using the Mann–Whitney or chi-squared test for continuous and categorical variables, respectively. The significant results on univariable analysis were subsequently incorporated into a multivariable logistic regression model to measure their combined effect at follow-up angiography. Backward likelihood ratio testing was used to construct a final logit model. Fit lines were constructed utilizing least squares regression to investigate linear relationships between treatment variables and outcomes.

For determining optimal PD with regards to treatment failure, we used a supervised binning algorithm designed to minimize the informational entropy of the resulting bins of aneurysms. This optimal PD number was used to create a binary classification of all treated aneurysms as being treated above or below this value which was subsequently utilized for other analyses. All reported p values are two sided with a standard alpha set at 0.05. All ranges were reported as interquartile ranges, and plus-minus values are reported as mean ± one standard deviation. All data management and analyses were conducted using SPSS statistics (version 20.0; IBM Corporation, Armonk, NY, USA).

3. Results

3.1. Patient and aneurysm characteristics (Table 1)

The patient and aneurysm characteristics were similar to most large aneurysm series in the literature. The majority of patients were women (76.1%) and the average age was 55.4 years. Approximately half of the patients presented with subarachnoid hemorrhage (SAH; 49.4%). The majority of aneurysms were in the anterior circulation (91.2%) and the average aneurysm volume was 247.9 mm^3. Aneurysms were previously treated in 11.9% of patients.

3.2. Procedure characteristics (Table 2)

The majority of patients in the entire study population were treated with bare platinum coils (95.7%) using stand-alone coiling (61.3%). SAC and BAC was used 29.4% and 9.3% of the time,

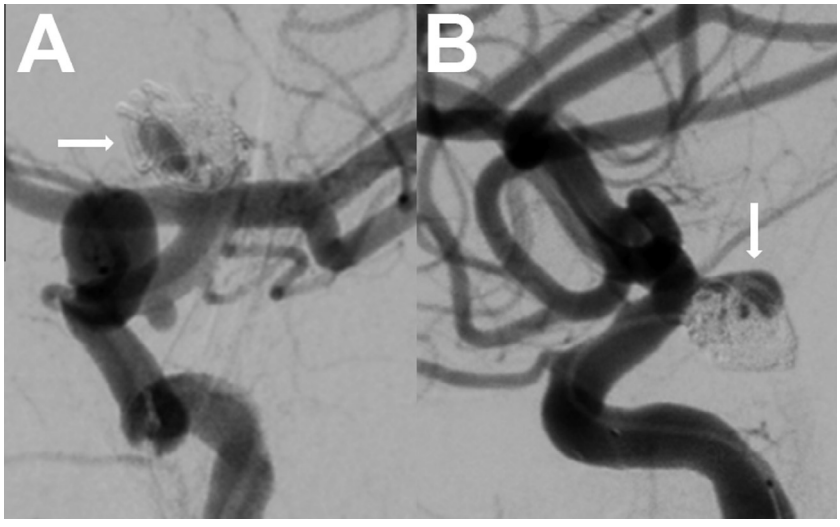

Fig. 1. (A) Digital subtraction angiography of an internal carotid artery bifurcation aneurysm treated with stand-along coil embolization. There is contrast filling within the central aspect of the coils (white arrow; MRRC IIIa). (B) A posterior communicating artery aneurysm treated with stand-alone coil embolization. There is contrast filling outside the coil mass, along the aneurysm wall (white arrow; MRRC IIIb). MRRC = the modified Raymond–Roy classification.