Radioactive Embolization of Intracranial Aneurysms Using ^{32}P-Implanted Coils

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Introduction

Local beta radiation can prevent recanalization after coil embolization of arteries or aneurysms[1].

We have proposed to treat aneurysms with coils ion-implanted with a predetermined linear activity of ^{32}P[1].

An "effective linear" activity of 0.13 μCi per cm of coil has shown 88% efficacy in preventing recanalization[1].

The interventionist would then attempt to fill the aneurysm with coils implanted with at least that level of activity of ^{32}P, without exceeding total activities prescribed by the historical use of colloidal ^{32}P in craniopharyngiomas[2].

To assess the feasibility of this protocol, we reviewed aneurysms treated with standard coils, and calculated the resulting activities per volume of aneurysms had the coils been radioactive.

We then proceeded with a pilot study on 26 patients actually treated with ion-implanted ^{32}P coils to assess if the target activity could be reached in clinical practice.

Methods

Retrospective Study

We retrospectively studied aneurysms that were treated by endosaccular coiling and prospectively entered into a database from 1992 to 2001.

Partially thrombosed aneurysms and interventions that were prematurely interrupted because of complications or for which records were incomplete were excluded from analysis.

There were 357 aneurysms in 341 patients, 25 to 86 years old, for a mean age of 54 ± 12. Most patients were female (73.6%).

Most frequent lesions were basilar bifurcation (103; 28.9%). Initial angiographic results classified as previously described[3] were: complete occlusions in 130 (36.4%), residual necks in 181 (50.7%) and residual aneurysms in 46 (12.9%) cases.

The total length of coils deployed within each aneurysm was re-corded without distinction between calibre 0.010" and 0.015" coils.

Volumes were estimated according to formulas that assimilate aneurysms to spheres, cylinders or to ellipsoids.

Dimensions were estimated using the size of the first coil as a reference.

The "effective" dose per volume was extracted from previously publish-ed animal data[1].

The volumetric activity found to be effective in the arterial occlusion model was 0.018 μCi/mm^3 (0.13 mCi/ 70 mm^3).

Assuming coils would be ion-implanted with activities that would permit a shelf life of 14 days (the half-life of the isotope), the higher activity (0.26 μCi/cm) corresponds to double the "effective" linear activity.

Colloidal ^{32}P has been used for years in cystic craniopharyngiomas[2]. Tables have been designed to prescribe the activity of ^{32}P to be injected according to cyst volumes.

To ensure the safety of radioactive coil embolization of aneu-

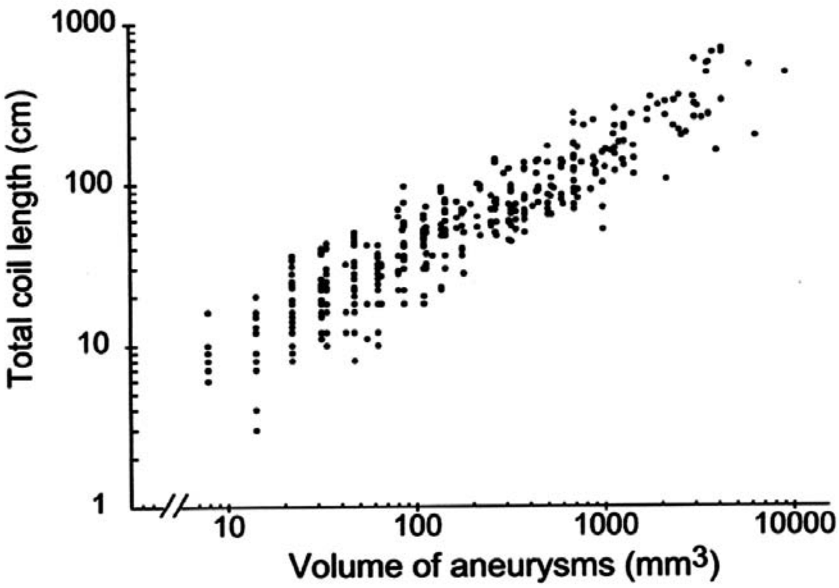

Figure 1 Relationship between coil length and aneurysmal volume. Retrospective study of total length of platinum coils introduced into 357 intracranial aneurysms treated between 1992 and 2001. Each point represents one aneurysm. Volumes of aneurysms were estimated according to an ellipsoid model.

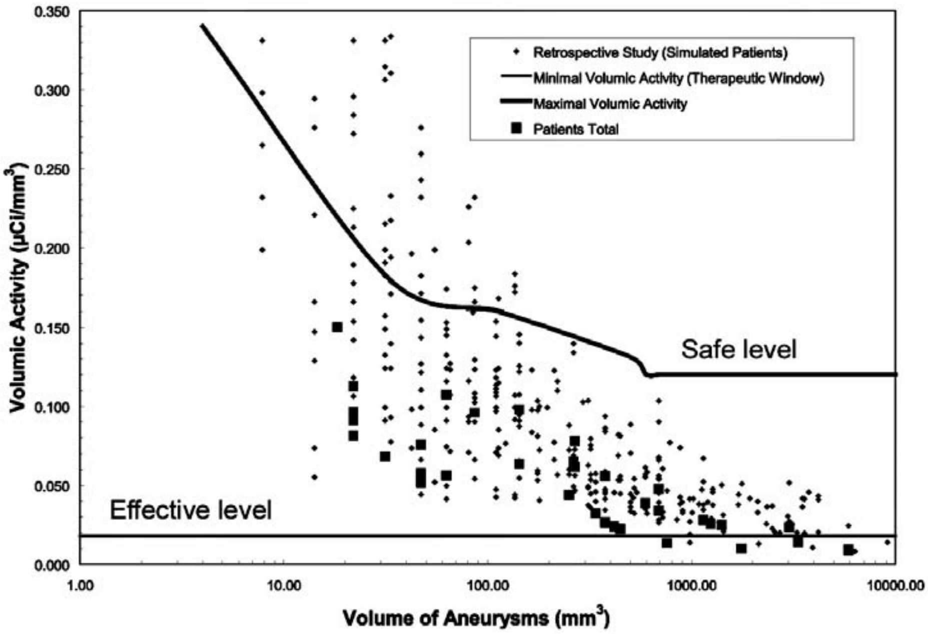

Figure 2 Theoretical aneurysmal activities in relation to volumes. Aneurysmal activities/cm had the platinum coils been ion-implanted with 0.26 mCi/cm of ^{32}P. Each points represents one aneurysm. Each square represents one patient from the pilot study actually treated with radioactive coils. Volumes were estimated using the ellipsoid model. The grey line represents the volumetric activity shown effective in the arterial occlusion model (0.018 mCi/mm^3)[1]. The black line is the "safe" activity level, derived from the use of colloidal 32P in cystic craniopharyngiomas[2].

rysms, we have used these tables to arbitrarily set the "maximum activities" to be inserted according to size of lesions.

Aneurysmal values have been doubled: since ion implantation of ^{32}P is limited to half the coil surface and because of platinum attenuation only half the activity contributes to the dose to tissues.

Pilot Study

The first 13 patients were recruited because of a previous recurrence after coiling or with characteristics suggestive of a high risk of recurrence (large or giant aneurysms with wide necks).

The last 13 patients were enrolled in a feasibility study designed to assess if it was possible to treat, with radioactive coils, any aneurysm considered for endovascular treatment, and reach the target activity without exceeding prescribed maximal activities.

There were four men and 22 women, 34 to 84-years-old.

Eleven patients were treated during the acute phase after subarachnoid haemorrage.

Most common locations were basilar bifurcation [8], anterior [4] or posterior [3] communicating, and ophtalmic carotid aneurysms [3].

Aneurysms had a mean size of 11.5 mm with a 4.8 mm neck.

Results

Figure 1 illustrates the relationship between the ratio total length of coils/ volume and aneurysmal volumes, and figure 2 the activity levels obtained in each patient according to aneurysmal volumes, had the coils been implanted with 0.26 µCi/cm.

From the retrospective study, 92 to 98% of lesions would have contained volumetric activities shown to be effective in preventing recanalization in animal experiments.

The maximal and minimal limits are also shown in figure 2. Only in small lesions (< 100 mm^3 or < 6 mm in both axis) would the total activity exceed arbitrary maximal values.

For larger aneurysms (> 1000 mm^3), the packing density decreases to such an extent that it becomes difficult to reach the "effective" volumetric activity.

Aneurysms could be treated with radioactive coils in 22/22 patients actually treated using the endovascular approach.

In four patients, anatomical factors precluded the endovascular approach, even with non-radioactive coils.

The activities actually introduced into aneurysms in the pilot study are also shown in figure 2.

Target activities could be reached in 18 patients (82%).

In 3 patients with giant lesions, total activities were too low, and in 1 patient the procedure was aborted because of a technical complication (coil protrusion despite the use of an aneurysmal neck bridge device).

Initial angiographic results were complete occlusion in 29%, residual neck in 36%, residual aneurysm in 21% and failure in 14% of lesions.

There was no complication related to radiation after a mean follow-up period of 5 months.

Discussion

In situ beta radiation is a new strategy designed to prevent recanalization after endovascular treatment [1].

The retrospective study has shown that, had the coils been ion-implanted with 0,26 µCi/ cm, 92-98% of 357 lesions would have reached "effective" therapeutic levels according to preclinical data [1].

The pilot study, often performed in patients selected for a higher risk of recurrence, confirmed that the target activity could be reached in more than 80% of patients treatable by the endovascular route.

The current study shows that effective therapeutic levels are difficult to reach in large and giant lesions, and higher activities could be implanted onto large coils.

A longer follow-up period is necessary to assess the safety of in situ beta-radiation.

Only a randomized study comparing long-term results of radioactive and non-radioactive coil embolization could prove the efficacy of this new strategy.

Conclusions

Radioactive coil embolization of aneurysms of platinum is feasible in most patients.

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