Preliminary Report on the Thrombogenic Properties of Tantalum-GDC Coils

An Experimental study

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Summary

In order to overcome the possibility of recanalization and compaction with Platinum GDC coils Tantalum coils were placed in three aneurysms in swine. Comparative coiling was done on the other side in each animal with platinum GDC.

More stable thrombus was observed on the aneurysms coiled with Tantalum GDC.

Introduction

Endovascular occlusion of brain aneurysms is currently performed with platinum coils. Intra-aneurysmal platinum coils induce thrombosis of the aneurysm to a degree that may be insufficient to avoid compaction of the coils over time, particularly in wide necked aneurysms¹. As a consequence, portions of the aneurysm neck or body may become re-exposed to the blood flow, a phenomenon known as aneurysm recanalization.

In order to overcome this limitation, GDC coils made of tantalum were tested in an experimental study. As to the rationale of this research, one has to consider that, according to the Pauling scale of electronegativity², tantalum is more electropositive than platinum. Therefore it should strongly attract the electronegative constituents of blood (white and red blood cells, platelets, and fibrinogen) thus

forming a much firmer thrombus. This might prevent the phenomena of coil compaction and aneurysm recanalization.

Material and Methods

Six experimental aneurysms were utilized in three swine. This study was conducted at the Leo G. Rigler Center, University of California at Los Angeles. With the swine under general anesthesia, two aneurysms were created on the common carotid artery, one on each side. Then, under systemic heparinization, microcatheterization of the aneurysm was performed via transfemoral route.

The left sided aneurysms were subtotally filled with standard Platinum GDC coils, while the right sided aneurysms were subtotally filled with Tantalum GDC coils. Three 10-sized helical coils (n. 1 8 x 20 and n. 2 5 x 15) were utilized to embolize each aneurysm. Both kinds of coils were manufactured by Boston Scientific Neurovascular (Fremont, California). Pre and post-procedure angiograms were obtained.

One week follow-up angiograms were performed in two animals, while a two week follow-up angiogram was performed in one animal. Just after the follow-up angiograms, the animals were sacrificed and the specimen harvested. Histological examinations of the embolized aneurysms were subsequently performed.

Figure 1 Histological examination of the interior of an experimental aneurysm 14 days after treatment with tantalum coils. HE X 100. The coil defect observed in the center is surrounded by fibrous tissue with several different cellular components such as inflammatory cells and fibroblasts. Note that a band of prominent calcification is seen in a semicircular fashion, at the inferior aspect of the coil defect (dark purple depositions).

Results

No adverse events were observed in the animals after the deposit of the coils, in the acute and in the follow-up period. Both kinds of GDC (Platinum-GDC, and Tantalum-GDC) were well visible under fluoroscopy.

The delivery, advancement, deposition and electrolytic detachment of the T-GDCs was as simple as with the standard P-GDC coils. No unwanted findings (such as clot migration or parent artery compromise) were observed with either kind of coils. As expected, coil compaction of the coils in the aneurysms was observed in the follow-up angiograms due to the intentional underpacking of the aneurysms (*vide supra*).

The histological examination of the aneurysms treated with Tantalum-GDCs showed dystrophic calcification, inflammatory cells, organized thrombus, and fibroblasts surrounding the coil (figure 1). The histological examination

of the aneurysms treated with Platinum-GDCs showed only the presence of immature thrombus surrounding the coil (figure 2).

Discussion

The most important drawback of endovascular coiling of brain aneurysms is that the platinum coils may become compacted in the aneurysm in the months that follow the procedure. This is observed not infrequently in wide-necked aneurysms (1). This phenomenon of possible wide-necked aneurysm recanalization could be due in part to insufficient thrombogenic properties of the platinum coils. As an attempt to overcome this problem, this experimental research was undertaken testing coils made of tantalum.

As to the rationale of this research, one should take into consideration that blood particles (red blood cells, white blood cells, platelets, and fibrinogen) are all negatively charged³. The

Figure 2 Histological examination of the interior of an experimental aneurysm 14 days after treatment with platinum coils HE x 100. The coil defect seen in the center of the picture is surrounded by the immature thrombus composed of a fibrin rich mesh-work. No remarkable cellular migration, e.g. inflammatory cell, is observed around the coil. No calcification is visible.

intima (endothelium) of arteries is also negatively charged. As a consequence, all blood particles and the endothelium repel each other. We have to imagine an environment where the blood is a colloid flowing in a conduit where every constituent (blood and endothelium) is negatively charged. This prevents the formation of blood clots. In normal conditions, we can say that blood vessels (and aneurysms) are “full” of electronegativity. When an artery is injured, the endothelium becomes immediately electropositive⁴ and attracts the blood particles so that the hemorrhage stops.

The Pauling scale of electronegativity was devised in 1932 by Linus Pauling². On this scale, the most electronegative chemical element (Fluorine) is given an electronegativity value of 4; the least electronegative element (Francium) has a value of 0.8, and the remaining elements have values in between. Platinum has a value of 1.8, being one of the most electronegative of all metals. Tantalum has a value

of 1.4 and is almost the least electronegative of all metals.

Looking at the periodic table of elements and in particular at the Pauling scale of electronegativity, it is clear that platinum is very electronegative. A metal was needed that was less electronegative than platinum, i.e. a metal that, compared to platinum, is substantially electropositive. This way, the blood particles would be attracted to the intra-aneurysmal metal (i.e. coils) and a firm thrombus could develop in the aneurysm, possibly preventing aneurysm recanalization and coil compaction. Looking at the various elements, Tantalum was identified as the ideal metal. It has a low electronegativity (i. e. substantial electropositivity) and a high atomic weight (181) and therefore it is radiopaque. It is already used in surgery (biocompatible): it is utilized to construct dental implants, intra-corporeal prostheses and brain aneurysm clips. It is also used to add radiopacity to the embolic agents for the treatment of

brain arteriovenous malformations. Being a non-ferrous metal (non-magnetic), tantalum is safe for MRI imaging.

The findings of the histological examination of the aneurysms treated with Tantalum-GDCs are somewhat unexpected, especially the dystrophic calcification surrounding the coils. It is known, however, that dystrophic calcification may occur around medical implants. Dystrophic calcification, inflammatory reaction, thrombus organization, and fibroblast ingrowth are all signs indicating that tantalum is more biologically active than platinum.

Theoretically, if GDCs were made of tantalum rather than platinum, a firmer more stable thrombus might develop in an aneurysm, possibly allowing a more stable and permanent occlusion. Based on the results of this study, fur-

ther research using Tantalum-GDCs in experimental aneurysms is warranted, to confirm the results of this preliminary investigation.

Conclusions

From the histological results of this preliminary study, tantalum coils appear to be more biologically active than platinum coils in experimental aneurysms. Further research is needed to confirm the results of this investigation.

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