ORIGINAL RESEARCH

Guglielmi Detachable Coils versus Matrix Coils: A Comparison of the Immediate Posttreatment Results of the Embolization of 364 Cerebral Aneurysms in 307 Patients: A Single-Center, Single-Surgeon Experience

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BACKGROUND: Matrix coils are based on Gugliemi detachable coils (GDC) but are covered with polyglycolic/polylactic acid. We present our experience regarding the immediate posttreatment results of aneurysm embolization using the 2 coil systems.

PATIENTS: We embolized 219 aneurysms in 187 patients with the use of GDCs and 145 aneurysms in 120 patients with the use of Matrix coils. Age, sex distribution, unruptured aneurysm cases, and multiple aneurysm cases were similar in the 2 groups. The percentage of patients in severe clinical condition was significantly higher in the Matrix group. The mean aneurysm size was slightly larger in the GDC group but the mean neck size was larger in the Matrix group.

RESULTS: Satisfactory occlusion (at least 90%) was achieved in 95.9% of GDC-treated aneurysms and in 98.6% of Matrix-treated aneurysms. Procedure-related complications occurred in 19.6% of GDC procedures and in 15.6% of the Matrix ones resulting in procedure-related mortality and morbidity of 3.7% and 2.7% for the GDC group and 2.5% and 1.7% for the Matrix group. In the GDC group, outcome was good (modified Rankin Scale 0–2) in 92.6% of patients with unruptured aneurysms, in 82.6% of patients with Hunt and Hess grade I–III, and in 20.5% of those with Hunt and Hess grade of IV–V. The respective figures were 95%, 85.7%, and 22.7% in the Matrix group.

CONCLUSION: In our series, Matrix coils have yielded slightly better results regarding satisfactory occlusion rate and clinical outcome but these differences are not statistically significant and probably reflect our increased experience in aneurysm embolization during the period we used Matrix coils.

Fifteen years ago, Guido Guglielmi revolutionized the endovascular treatment of cerebral aneurysms by inventing and introducing the Guglielmi detachable coil (GDC).[1,2] This was the first coil system to allow for easy repositioning and controlled detachment and was also very effective and safe in the obliteration of aneurysms.[3-7] The use of the GDC spread rapidly around the world and, after the results of the International Subarachnoid Aneurysm Trial (ISAT),[8] became an integral part of the treatment of aneurysms and actually the treatment of choice in some parts of the world. Over the years, technology progressed and a new generation of coils was introduced. The Matrix coils are based on the GDC system but are covered with polyglycolic/polylactic acid (PGLA), a bioactive material that has been proved experimentally to cause intense inflammation in the thrombosed aneurysm sac and promises more stable occlusion and a lower rate of recanalization.[9]

Ours is the only department in a public hospital in Greece to have used the endovascular treatment of cerebral aneurysms for 6 years on an emergency basis, with ruptured aneurysms being coiled on the day of admission or the next day at the latest. Unruptured aneurysms are also treated as soon as possible.

This retrospective study was carried out to assess the safety and procedural outcome of Matrix coils compared with a historical cohort of patients treated with GDCs in our department. Long-term results cannot be reported yet because the follow-up is not complete.

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Patients and Techniques

We analyzed retrospectively the files of all patients who were treated with aneurysm embolization in our department in the 4 years and 9 months between January 2001 and September 2005 by a single surgeon. Of a total 317 patients with 374 aneurysms treated by endovascular method, 307 patients with 364 aneurysms were treated using either GDCs or Matrix coils (both manufactured by Boston Scientific, Fremont, Calif). GDCs were used in 187 (60.9%) patients with 219 (60.2%) aneurysms and Matrix coils in 120 (39.1%) patients with 145 (39.8%) aneurysms. For the purposes of this study, we divided the patients into 2 groups: a GDC group comprising all patients in whom at least 1 aneurysm was embolized with GDCs and a Matrix group consisting of all patients in whom at least 1 aneurysm was embolized with Matrix coils. During the treatment of these patients, we had avoided using both kinds of coils in the same patient, even in patients with multiple aneurysms treated in different sessions. As a result, all our patients could be clearly entered into one or the other of the 2 groups.

There was no significant difference in age or sex distribution between the 2 groups. In addition, there were no significant differences in the percentage of patients presenting with a ruptured aneurysm or with multiple aneurysms. On the contrary, there was a statistically significant difference ($P = .001$) in the percentage of patients presenting in severe initial post-subarachnoid hemorrhage (SAH) condition (Hunt and Hess grade IV–V) being 24.4% and 44% for the GDC and

Table 1: Patient characteristics

	GDCs	Matrix Coils	Total
Patients (%)	187 (60.9)	120 (39.1)	307
Age, mean (range)	52.4 ± 13.9 (21–80)	52 ± 12 (20–79)	52.8 (20–80)
Sex, M/F	96/91	61/59	157/150
With ruptured aneurysm (%)	160 (85.6)	100 (83.3)	260 (84.7)
Hunt and Hess grades I–III	121 (75.6)	56 (56)	177 (68.1)
Hunt and Hess grades IV–V	39 (24.4)	44 (44)	83 (31.9)
ICH	34 (21.25)	20 (20)	54 (20.8)
ICH removal	11 (6.9)	13 (13)	24 (9.2)
Post-SAH hydrocephalus	38 (23.8)	23 (23)	61 (23.5)
With unruptured aneurysm (%)	27 (14.4)	20 (16.7)	47 (15.3)
With multiple aneurysms (%)	28 (15)	22 (18.3)	50 (16.3)
×2	18 (9.6)	13 (10.8)	31 (10.1)
×3	8 (4.3)	3 (2.5)	11 (3.6)
×4	0	4 (3.3)	4 (1.3)
×5	1 (0.5)	2 (1.7)	3 (1)
×6	1 (0.5)	0	1 (0.3)

Note:—GDC indicates Gugliemi detachable coil; ICH, intracerebral hematoma; SAH, subarachoid hemorrhage.

Matrix groups, respectively. The percentage of patients presenting with an intracerebral hematoma (ICH), regardless of its size, was not significantly different between the 2 groups. It is interesting that the percentage of patients with an ICH requiring surgical evacuation was almost double in the Matrix group (13%) compared with the GDC group (6.9%), though this difference is not statistically significant. The difference in initial presentation condition cannot be attributed to hydrocephalus incidence because an almost equal percentage of patients in the 2 groups presented with post-SAH hydrocephalus requiring drainage. The characteristics of the patients in the 2 groups are reported in Table 1.

The percentage of aneurysms embolized of the total number of aneurysms harbored by the populations of the 2 groups was similar: 219 of 230 (95.2%) in the GDC group and 145 of 159 (91.2%) in the Matrix group. The main reason for not coiling the remaining aneurysms in the GDC group was that we were unable to contain the coils in the aneurysm sac because of a wide neck despite using 3D coils and the balloon remodeling technique. In the Matrix group, the main reason was that many patients with multiple aneurysms were in severe condition, and we had to defer treatment of many aneurysms for a later date. Unfortunately, some patients died and the aneurysms were not embolized. This situation was more frequent in the Matrix group because the percentage of patients in Hunt and Hess grade IV–V was higher. The problem of the wide neck of the aneurysm was especially important in the GDC group because stents for intracranial use were available to us only a few months before we stopped using GDC. In the Matrix group, with stents available, we had to abandon the embolization as a result of the wide neck in only 2 cases (4 aneurysms harbored in total) because we were unable to place the stent in the correct anatomic location in one case and to catheterize the aneurysm after the stent deployment in another. Another reason for not coiling 4 aneurysms in the GDC group and 3 in the Matrix group is that a vessel was clearly originating from the aneurysm sac. In our view, this is an absolute contraindication for coiling and an indication for microsurgical clip reconstruction of the branching vessel lumen.

No significant differences existed between the 2 groups regarding the distribution of aneurysms in the anterior or posterior circulation as well as their location on specific vessels.

All diagnostic angiographies and endovascular procedures were carried out with the use of a monoplane angiography unit (Integris; Philips Medical Systems, Best, the Netherlands). Aneurysm sac and neck measurements were made using the software of this unit. The mean size of the aneurysms treated was larger in the GDC group than in the Matrix group (5.8 ± 1.3 and 5.3 ± 1.1 mm, respectively). On the contrary, the mean size of the neck was smaller in the GDC group (2.3 ± 0.4 versus 2.7 ± 0.5 mm). Of course, during most of the period we were using GDC, intracranial stents were unavailable to us, and we were able to coil less wide-necked aneurysms. The characteristics of the aneurysms treated are summarized in Table 2. All endovascular interventions were carried out under general anesthesia by the senior author (V.K.) assisted by 1 of the 2 coauthors (C.P., C.V.).

Patients with SAH regardless of their neurologic status (Hunt and Hess grade) were considered emergency cases and were subjected to digital subtraction angiography (DSA) on the same or the next day of admission regardless of the day post-SAH. Hunt and Hess V patients with severe cardiorespiratory disturbances or signs of imminent death were treated in the ICU and DSA was deferred until they stabilized. Upon discovery of an aneurysm, all conscious patients were intubated in the angiography suite, and the aneurysm was embolized using either GDC or Matrix coils. GDCs were used in the early period from January 2001 to April 2004 (28 months) and Matrix coils in the later period from May 2004 to September 2005 (18 months). Patients with unruptured aneurysms were considered urgent cases and were subjected to DSA and aneurysm embolization at the earliest convenient date (usually 1–3 days later).

After the discovery of an aneurysm, the actual embolization process began by replacing the angiographic catheter with a wide lumen 6F neurointerventional catheter. A 7F catheter was used in cases in which balloon-assisted technique was planned. The catheter was flushed for the duration of the intervention with a solution of 2000 IU of heparin in 1000 mL of saline at a rate of approximately 500 mL per hour. Thereafter, because we did not have 3D angiography capability, we performed multiple angiography runs to analyze the location, the size of the sac, and the size of the neck of the aneurysm as well as its relationship to adjacent vessels. After the analysis of this information, we decided whether the aneurysm was amenable to coiling (simple coiling or assisted by various devices and techniques such as 3D coils, balloon-assisted technique, or stent-assisted technique).

Patients with a ruptured aneurysm considered unsuitable for coiling were immediately transferred to the operating room, and the aneurysm was microsurgically clipped. This rule applied as well in patients with multiple aneurysms after SAH. If the ruptured aneurysm

Table 2: Characteristics of aneurysms treated

	GDCs	Matrix Coils	Total
Aneurysms harbored	230	159	389
Embolized aneurysms (%)	219 (95.2)	145 (91.2)	364 (93.6)
Nonembolized aneurysms (%)	11 (4.8)	14 (8.8)	25 (6.4)
Wide neck	6 (54.6)	4 (28.6)	10 (40)
Branch from sac	4 (36.4)	3 (21.4)	7 (28)
Severe condition	1 (9.1)	7 (50)	8 (32)
Ruptured	160 (73.1)	100 (69)	260 (71.4)
Unruptured	59 (26.9)	45 (31)	104 (28.6)
Anterior circulation (%)	198 (90.4)	134 (92.4)	332 (91.2)
ICA	71 (32.4)	54 (37.2)	125 (34.3)
AcomA	65 (29.7)	49 (33.8)	114 (31.3)
MCA	47 (21.5)	23 (15.9)	70 (19.2)
ACA	15 (6.9)	8 (5.5)	23 (6.3)
Posterior circulation (%)	21 (9.6)	11 (7.6)	32 (8.8)
BA	14 (6.4)	6 (4.1)	20 (5.5)
VA	5 (2.3)	4 (2.8)	9 (2.5)
PCA	1 (0.5)	0	1 (0.3)
PICA	1 (0.5)	1 (0.7)	1 (0.3)
Aneurysm size, mean ± SD	5.8 ± 1.3	5.3 ± 1.1	5.7 ± 1.0
(range) (mm)	(2–26)	(2–25)	(2–26)
Neck size, mean ± SD	2.3 ± 0.4	2.7 ± 0.5	2.6 ± 0.4
(range) (mm)	(1–5)	(1–6)	(1–6)

Note:—GDC indicates Gugliemi detachable coil; ICA, internal carotid artery; AcomA, anterior communicating artery; MCA, middle cerebral artery; ACA, anterior cerebral artery; BA, basilar artery; VA, vertebral artery; PCA, posterior cerebral artery; PICA, posterior inferior cerebral artery.

could not be coiled, we did not embolize any unruptured ones either in an attempt to treat the ruptured one as soon as possible. The patient was operated upon, and the surgeon attempted to clip, apart from the ruptured aneurysm, as many of the multiple ones as possible through the same craniotomy. Any unruptured aneurysms left unclipped were scheduled for embolization later.

In cases of aneurysms considered to be suitable for coiling, we proceeded to place the tip of a microcatheter into the sac. The microcatheter was flushed with the same heparin solution as the guide catheter during the embolization process. When the first coil was satisfactorily placed into the aneurysm, we administered 5000 IU heparin IV bolus. More coils were delivered as needed, aiming for the total occlusion of the aneurysm. In cases of long duration of the intervention, more heparin was administered intraoperatively to maintain activated clotting time at approximately 200 seconds. Upon completion of the intervention, the heparin was not reversed unless there was an intraoperative rupture, in which case the heparin was reversed immediately. In cases not complicated by thromboembolic events, no more heparin or antiplatelet drugs were administered. When a stent was deployed to contain the coils into the wide-necked aneurysm, the patient received 0.6 mg of nadroparin subcutaneously upon completion of the intervention. Thereafter, the patient was started on 0.6 mg of nadroparin subcutaneously twice daily for 3 days. The next day of the intervention, we started administering 75 mg of clopidogrel daily for 3 months and 100 mg of aspirin daily for 6 months. In cases in which a hematoma had to be surgically evacuated after the stent-assisted embolization, the patient did not receive medication other than additional boluses of heparin, maintaining the activated clotting time at 200–250 seconds during surgery and for the next 3 days. No craniotomy was complicated by hemorrhage using this anticoagulation regimen. When the risk of postsurgical hemorrhagic complications had diminished, the patient was started on the nadroparin, clopidogrel, and aspirin protocol.

In cases of patients with ruptured aneurysms in which vasospasm was detected on DSA, 30 mg of papaverine was added to the flush solution irrigating the guide catheter. The same amount of papaverine was added to the flushing solution in cases of internal carotid or vertebral artery spasm due to the catheterization and the catheter exchange process. In addition to the papaverine infusion, when the spasm was identified as segmental in the internal carotid or the middle cerebral artery, angioplasty was performed with a compliant balloon after the occlusion of the aneurysm.

A considerable number of our patients were discovered to harbor multiple aneurysms. Patients with up to 3 aneurysms were treated with embolization of all aneurysms in the same session if it was feasible. The ruptured aneurysm was always the first to be treated. Patients with 4 or more aneurysms were treated in 2 sessions of embolization.

In cases of intraoperative automatic aneurysm rupture or puncture of the sac with the guidewire, the microcatheter, or a coil, we never terminated the procedure prematurely; rather, we proceeded in an attempt to occlude the bleeding aneurysm as soon as possible. This has been possible in all cases. Thereafter, all patients with considerable intraoperative bleeding exhibiting clinical signs of raised intracranial pressure (anisocoria, mydriasis, high blood pressure with bradycardia) received an external ventricular drain (EVD) that was placed immediately in the angiography suite and were controlled by CT to evaluate the need for surgical removal of a possible ICH. Patients who showed no signs of raised intracranial pressure were subjected to CT after the embolization and were treated with EVD placement or ICH removal as needed. Patients initially presenting with post-SAH hydrocephalus did not receive an EVD until completion of the embolization procedure unless they exhibited signs of brain herniation.

All patients presenting initially with an ICH requiring removal and raising the suspicion of a ruptured aneurysm, were considered candidates for DSA and embolization before surgery. When the hematoma evacuation was not a priority, we embolized the ruptured aneurysm first and surgery was performed subsequently under safer conditions without the risk of intraoperative aneurysm rerupture.

A total of 317 endovascular procedures were carried out to occlude 364 aneurysms in 307 patients. GDCs were used in 194 proce-

Table 3: Angiographic results

	GDCs	Matrix Coils	Total
Aneurysms coiled	219	145	364
Total occlusion, 95–100% (%)	196 (89.5)	128 (88.3)	324 (89)
Near-total occlusion 90–94% (%)	14 (6.4)	15 (10.3)	29 (8)
Incomplete occlusion < 90%(%)	9 (4.1)	2 (1.4)	11 (3)
Vasospasm detected (%)	67/160 (41.9)	61/100 (61)	128/260 49.2)
Improvement with papervine (%)	42/67 (62.7)	41/61 (67.2)	83/128 (64.8)
Angioplasty (%)	13/160 (8.1)	4/100 (4)	17/260 (6.5)
Angioplasty successful (%)	12/13 (92.3)	4/4 (100)	16/17 (94.1)

Note:—GDC indicates Gugliemi detachable coil.

dures to embolize 219 aneurysms in 187 patients and Matrix coils in 123 procedures for 145 aneurysms in 120 patients.

The balloon-assisted coiling technique was used in 27 (12.3%) aneurysms treated with GDCs and in 2 (1.4%) aneurysms treated with Matrix coils. Stent-assisted coiling was used in 8 (3.7%) aneurysms in the GDC group and 48 (33.1%) aneurysms in the Matrix group. All stents used were Neuroform2 (Boston Scientific). Therapeutic parent artery occlusion was performed after a successful test occlusion in 6 (2.7%) patients treated with GDCs and in 2 (1.4%) treated with Matrix.

Results

Angiographic Results

The degree of aneurysm occlusion was assessed by the authors based on final postprocedure DSA findings. Total occlusion (95%–100%) of the aneurysm was achieved with GDC use in 89.5%, near-total occlusion (94%–90%) in 6.4%, and incomplete (<90%) in 4.1% of aneurysms. The respective percentages for the Matrix group were 88.3%, 10.3%, and 1.4%. An occlusion between 100% and 90% was considered satisfactory, and the percentages were 95.9% for the GDC group and 98.6% for the Matrix group. In all cases of therapeutic parent artery occlusion, there were no angiographic findings of aneurysm opacification through collateral circulation.

Papaverine was infused to relieve angiographically evident vasospasm in 67 (41.8%) post-SAH patients treated with GDC, and there was angiographic evidence of improved blood flow in 42 for a 62.7% success rate. The same method was applied to 61 (61%) patients treated with Matrix and improved flow was achieved in 41 (67.2%) of those patients. Angioplasty for severe segmental spasm in the internal carotid or the middle cerebral artery was attempted in 13 (8.1%) patients treated with GDCs and 4 (4%) patients treated with Matrix and was successful in 12 (92.3%) and 4 (100%) of those patients, respectively. All angiographic results are reported in Table 3.

Procedural Complications

Procedure-related complications and their clinical consequences were noted and assessed by the authors. Complications occurred in 38 of 194 (19.6%) procedures performed with GDCs and in 19 of 123 (15.6%) performed with Matrix.

The most common complication in both groups was aneurysm perforation, occurring in 13 (6.7%) GDC procedures and in 6 (4.9%) Matrix procedures. In most cases, the aneurysm was perforated by a coil, usually the first one inserted into the aneurysm. It is interesting that in a patient treated with GDCs, the aneurysm was perforated by the second coil delivered, and in 2 patients treated with Matrix, the aneurysm was ruptured by the third coil inserted. The aneurysm was ruptured by the microcatheter being inserted into the sac once in the GDC group and twice in the Matrix group. These ruptures in the GDC group resulted in ICH formation requiring surgical removal in 2 cases. Nevertheless, the ruptures influenced the patient's outcome in only 4 cases (none of the ICH cases) resulting in 3 deaths and 1 permanent neurologic deficit. In the Matrix group, they were responsible for 1 death and 1 patient with permanent neurologic deficit.

Thromboembolic complications occurred in 11 (5.7%) GDC and in 7 (5.7%) Matrix procedures. In the GDC group, there were 4 cases of thrombus formation in the parent artery as a result of coil loops prolapsing and 7 cases with no apparent cause. In all cases, thrombolysis was attempted and was successful in 9 of 11 (81.8%). Nevertheless, these complications resulted in 2 deaths and 2 patients with permanent neurologic deficit. In the Matrix group, 2 thrombus formations were due to coil loop prolapse, and 5 had no apparent cause. All cases were successfully thrombolized, but they resulted in 1 death and 1 permanent neurologic deficit.

Parent vessel occlusion by the coil mass was noted in 3 (1.6%) GDC procedures and 1 (0.8%) Matrix procedure, resulting in 1 death and 1 neurologic deficit in the former group but no consequences in the latter.

Coil loop prolapse into the parent artery occurred in 4 (2.1%) GDC cases and resulted in neurologic deficit in 1 patient. In the Matrix group, there were 3 (2.4%) cases of coil-related complications: (1) a coil tail prolapse into the parent artery left untreated without consequences, (2) a coil loop prolapse successfully treated by deploying a stent into the parent artery, and (3) a coil loop prolapse in which an attempt to reposition into the aneurysm by inflating a compliant balloon resulted in the rupture of the parent vessel and the death of the patient.

In the GDC group there were 4 (2.1%) cases of coil breakage and prolapse in the vessel tree. In one of these cases, we managed to retrieve the fragment that was protruding from the microcatheter by aspirating blood into it and allowing time for thrombus to form in the microcatheter around the

Table 4: Procedural complications, clinical significance, and procedure-related mortality and morbidity

	GDCs	Matrix Coils	Total
Complications	38/194 (19.6)*	19/123 (15.6)	57/317 (18)
Mortality	7/187 (3.7)	3/120 (2.5)	10/307 (3.3)
Morbidity	5/187 (2.7)	2/120 (1.7)	7/307 (2.3)
Aneurysm rupture	13/194 (6.7)	6/123 (4.9)	19/317 (6)
Mortality	3/187 (1.6)	1/120 (0.8)	4/307 (1.3)
Morbidity	1/187 (0.5)	1/120 (0.8)	2/307 (0.7)
Thromboembolic	11/194 (5.7)	7/123 (5.7)	18/317 (5.7)
Mortality	2/187 (1.1)	1/120 (0.8)	3/307 (1)
Morbidity	2/187 (1.1)	1/120 (0.8)	3/307 (1)
Parent artery occlusion	3/194 (1.6)	1/123 (0.8)	4/317 (1.3)
Mortality	1/187 (0.5)	0	1/307 (0.3)
Morbidity	1/187 (0.5)	0	1/307 (0.3)
Loop prolapse	4/194 (2.1)	3/123 (2.4)	7/317 (2.2)
Mortality	0	1/120 (0.8)	1/307 (0.3)
Morbidity	1/187 (0.5)	0	1/307 (0.3)
Coil breakage	4/194 (2.1)	0	4/317 (1.3)
Mortality	0	0	0
Morbidity	0	0	0
Hemorhage following angioplasty	1/194 (0.5)	0	1/317 (0.3)
Mortality	1/187 (0.5)	0	1/307 (0.3)
Morbidity	0	0	0
ICA dissection	2/194 (1)	2/123 (1.6)	4/317 (1.3)
Mortality	0	0	0
Morbidity	0	0	0

Note:—GDC indicates Gugliemi detachable coil; ICA, internal carotid artery.
* Values in parentheses are percentages.

coil. In the remaining 3 cases, the coils were left in place and the patients were placed in antiplatelet treatment with no sequelae. None of the GDCs that broke were of the stretch-resistant type. No Matrix coil broke during the 123 procedures.

In one (0.5%) GDC case, the attempt to treat the severe segmental vasospasm of the middle cerebral artery with balloon angioplasty resulted in rupture of the artery, massive hemorrhage, and the death of the patient.

Dissection of the cervical or petrous ICA occurred in 2 (1%) GDC and in 2 (1.6%) Matrix cases. In all instances, the artery was stented successfully with no resulting morbidity.

The overall mortality and morbidity of the procedure-related complications were 3.7% and 2.7%, respectively, in the GDC group and 2.5% and 1.7%, respectively, in the Matrix group. The procedural complications, their clinical significance, and the procedure related mortality and morbidity are summarized in Table 4.

Clinical Outcome

The clinical outcome of patients was assessed by the authors using the modified Rankin Score scale (mRS). Outcome was considered good for patients classified as mRS 0–2 and bad for those classified as mRS 3–5. The outcome reported in this study reflects the condition of patients upon discharge from the hospital and not their final condition. The long-term follow-up of these patients is not yet complete and the results are to be reported later.

Only one rebleeding occurred during the short-term post-treatment period from a large aneurysm, unsatisfactorily occluded with GDCs. No Matrix-treated aneurysm, even those unsatisfactorily occluded, reruptured.

In the GDC group, with a total population of 187 patients harboring both ruptured and unruptured aneurysms, 133 (71.1%) had a good outcome (mRS 0–2). The outcome was good for 77 (64.2%) patients of 120 in the Matrix group. Overall disease mortality was 18.2% for the GDC group and 20.8% for the Matrix group, with the latter including significantly more severely ill patients. Of the patients presenting with unruptured aneurysms, 25 (92.6%) had a good outcome in the GDC group and 19 (95%) in the Matrix group, with no mortality in either group.

In the patients with ruptured aneurysms, 108 (67.5%) and 58 (58%) patients had good outcome in the GDC and Matrix groups, respectively. Mortality was 21.3% in the GDC group and 25% in the Matrix group.

Categorizing the ruptured aneurysm patients in the GDC group into those with good initial condition (Hunt and Hess I–III) and those with bad (Hunt and Hess IV–V), the good outcomes were 82.6% and 20.5%, respectively, and the mortality was 6.6% and 66.7%. In the Matrix group, the respective percentages were 85.7% and 22.7% for the good outcome and 7.1% and 47.7% for the mortality. The clinical outcome of patients in the 2 groups is reported in Table 5.

Discussion

The endovascular treatment of cerebral aneurysms was revolutionized by the introduction of the GDCs, a system that proved effective, safe, and "user-friendly."[1,2] The advantages of the GDC system allowed for the spread of its use worldwide in a short period and resulted in numerous publications reporting on its use.

Over the next few years, coiling was gaining ground as the preferred method of treatment of aneurysms. When the results of the International Study on Unruptured Intracranial Aneurysms[8] and of the International Subarachnoid Aneurysm Trial (ISAT)[9] were published, a controversy was raised over their interpretation. Nevertheless, the final effect of these studies, combined with an ever-increasing number of publications

Table 5: Clinical outcome

	GDC	Matrix Coils	Total
Total patients	187	120	307
mRS 0–2	133 (71.1)*	77 (64.2)	210 (68.4)
mRS-3–5	20 (10.7)	18 (15)	38 (12.4)
Death	34 (18.2)	25 (20.8)	59 (19.2)
Unruptured aneurysm patients	27	20	47
mRS 0–2	25 (92.6)	19 (95)	44 (93.6)
mRS-3–5	2 (7.4)	1 (5)	3 (6.4)
Death	0	0	0
Ruptured aneurysm patients	160	100	260
mRS 0–2	108 (67.5)	58 (58)	166 (63.9)
mRS-3 dN5	18 (11.3)	17 (17)	35 (13.5)
Death	34 (21.3)	25 (25)	59 (22.7)
Hunt and Hess grades I–III	121	56	177
mRS 0–2	100 (82.6)	48 (85.7)	148 (81.9)
mRS 3–5	13 (10.7)	4 (7.1)	17 (9.6)
Death	8 (6.6)	4 (7.1)	12 (6.8)
Hunt and Hess grades IV–V	39	44	83
mRS 0–2	8 (20.5)	10 (22.7)	18 (21.7)
mRS 3–5	5 (12.8)	13 (29.6)	18 (21.7)
Death	26 (66.7)	21 (47.7)	47 (66.6)

Note:—GDC indicated Gugliemi detachable coil; mRS, modified Rankin Scale.

reporting on the efficacy and safety of coiling,[3-7] was that endovascular therapy is now considered in many parts of the world the method of choice for the treatment of intracranial aneurysms, both ruptured and unruptured. Despite the controversy and the reactions to the publication of the ISAT, it is our firm belief that this study, along with numerous other publications, has proved beyond doubt that coiling is the method of choice for the treatment of both ruptured and unruptured aneurysms. What we consider important is the percentage of patients discharged in good health, regardless of the number of embolization procedures to which they are subjected and the number of rebleedings they suffer.

The main disadvantage of GDC embolization of aneurysms has always been the high rate of recanalization especially in large or giant ones. This problem has been repeatedly reported since the early period of the GDC system use until recently.[10,11]

The Matrix coil system was introduced promising more stable occlusion of the aneurysms and lower rates of recanalization. It is actually based on the GDC system, but the platinum coils are covered with PGLA, a bioactive material that has been proved experimentally to cause intense inflammation in the thrombosed sac, recruitment of more fibroblasts, and denser scar tissue formation. The PGLA is absorbed in a few weeks, reducing the mass of coils by 70% and allowing for the retraction of the scar tissue and the diminishing of the aneurysm size.[12]

Although the Matrix coils are now being used extensively, there has not yet been enough time for sufficient follow-up in large series. Some reports state that a considerable percentage of Matrix-treated aneurysms recanalize,[13] but others have found no recanalized aneurysms.[14]

Our report did not focus on the long-term results of Matrix treatment of aneurysms but on the short-term outcome (angiographic and clinical) and estimated the efficacy and safety of the 2 coil systems: the GDC and the Matrix. We compared the results of GDC treatment of 219 aneurysms in 187 patients with those of Matrix treatment of 145 aneurysms in 120 patients. To our knowledge, this is the largest published series concerning the embolization of cerebral aneurysms with Matrix coils. The long-term follow-up of our patients has not been completed yet and is to be reported later.

We analyzed retrospectively the files of all our patients who had at least 1 aneurysm treated by either GDCs or Matrix coils in our department in the period of 4 years and 9 months from January 2001 through September 2005 by a single surgeon. It is important that during the treatment of these patients, we never used both types of coils in the same patient, even in patients who were subjected to multiple sessions of embolization for multiple aneurysms. This was done deliberately to be able to assess the effect of each type of coil separately at follow-up. As a result, all our patients can clearly fall into one or the other of the 2 study groups.

We used the GDC system in the period from January 2001, when we introduced the endovascular treatment of aneurysms to our hospital, until April 2004 (28 months). The Matrix system was used thereafter until September 2005 (18 months) when this article was written.

The population characteristics of the 2 groups were similar except for the percentage of ruptured aneurysm patients who presented in good (Hunt and Hess grade I–III) or severe (Hunt and Hess IV–V) initial neurologic condition. A significantly higher proportion of patients presented in severe initial condition in the Matrix group (44% versus 24.4%). An almost equal percentage of patients presented with ICH (regardless of size) in both groups, but the percentage of those who needed surgical evacuation of the hematoma was almost double in the Matrix group (13% versus 6.9%). These differences suggest that the Matrix group included more patients with severe prognostic factors than the GDC group.

The mean size of aneurysms treated in the Matrix group was smaller (5.3 $\pm$ 1.1 mm) than in the GDC group (5.8 $\pm$ 1.3 mm). On the other hand, the mean size of the aneurysm neck was larger in the Matrix group (2.7 $\pm$ 0.5 mm versus 2.3 $\pm$ 0.4 mm), revealing that more wide-necked aneurysms were treated in the Matrix group. It is very important to state that

intracranial stents became available to us a short time before discontinuing the use of the GDC. Most wide-necked aneurysms in the GDC group were embolized using only 3D coils and/or the balloon remodeling technique. During the period in which we were using the Matrix coils, we had the advantage of using stents to cover the wide neck of aneurysms.

Regarding the angiographic results, a satisfactory occlusion (at least 90%) was achieved in 95.5% of GDC-treated aneurysms and 98.6% of Matrix-coiled aneurysms. This difference is not statistically significant, but both percentages compare favorably, with results reported in the literature ranging from 62% to 97.6%.[2-5,7,9-16] The higher percentage of satisfactory occlusion in the Matrix group could be attributed to the use of intracranial stents but also to our increased experience, because at the time we began using the Matrix coils, we had already embolized 219 aneurysms with GDC. The slightly lower rate of total (100%) occlusion of aneurysms with Matrix coils was probably because we were reluctant to risk very tight packing of the aneurysm with the coils, bearing in mind the inflammatory properties of their PGLA covering that promised higher secondary occlusion rates. This is a matter to be resolved by the final long-term follow-up of these patients.

The complication rate and mortality and morbidity values were slightly lower in the Matrix group, but the differences are not statistically significant and could also be attributed to our increased experience over time. Ischemic events and aneurysm perforation were the 2 main complications noted in our study. The rates of ischemic complications reported in previous publications range from 2.5% to 5.1%,[3,4] whereas in our series, the rates of thrombotic complications that resulted in neurologic consequences were 3.2% in the GDC group and 1.6 in the Matrix group. Our rates of aneurysm perforation were 6.7% in the GDC group and 4.9% in the Matrix group. The respective rates reported in the literature range from 0.5% for unruptured aneurysms to 4.1% for ruptured ones.[17,18]

The outcome of patients with unruptured aneurysms was excellent in both groups, reflecting the different situations experienced by patients with and without SAH. These results, along with the high rates of excellent outcome (93.9%–97.5%) published in other papers[3,5,19,20,21] justify our belief that unruptured aneurysms should be treated with coiling upon discovery, if feasible.

The rate of good outcome in ruptured aneurysm patients was slightly higher in the GDC-treated group (67.5% versus 58%). Nevertheless, dividing these patients in good (Hunt and Hess grade I–III) and severe (Hunt and Hess grade IV–V) presentation condition and considering the significantly higher proportion of severe condition patients in the Matrix group, the patients treated by Matrix seem to have better results in both categories. Good outcome was 85.7% in patients with a Hunt and Hess grade of I–III and 22.7% in patients with a Hunt and Hess grade of IV in the Matrix group with the respective rates being 82.6% and 20.5% in the GDC group. The differences in rates of good outcome are in favor of the Matrix coils but are not statistically significant. Nevertheless, all these figures compare favorably with the results reported in other series.[2,6,9-11,13,14,22]

Apart from quantifiable attributes, there are some properties of the 2 types of coils that cannot be measured and are judged subjectively. For example, we found no important difference in the ease of handling between the GDCs and the Matrix coils, even in the amount of friction of the coil being advanced inside the microcatheter or entering the aneurysm among previous coil loops, as many physicians have stated in personal communications. Coil breakage occurred with a few GDCs only (no coils were of the stretch-resistant type), but all the Matrix coils we have used were stretch-resistant. The electrolytic detachment seemed to be faster and more consistent with the Matrix coils than with the GDCs. On the other hand, Matrix coils had a tendency to compartmentalize inside the aneurysm, requiring more frequent repositioning of the microcatheter tip to coil the entire aneurysm sac.

Judging the 2 coil types overall, Matrix coils in this series yielded slightly better angiographic and clinical results. The satisfactory occlusion rate of aneurysms was higher, and the favorable outcome rate was higher in the categories of unruptured aneurysm patients, patients with Hunt and Hess grade I–III, and patients with Hunt and Hess grade IV–V. Furthermore, the complication rate and the procedure-related mortality and morbidity were lower in the Matrix group. None of these differences are statistically significant and may well be due to our increased experience in coiling aneurysms, because we used them at a later period of our practice than GDCs, as has already been mentioned. Nevertheless, they may indicate a marginal superiority of Matrix coils in all areas of interest.

The long-term results of aneurysm coiling, regarding the rate of recanalization and rebleeding, are very important. When the Matrix coils were launched, they were supposed to be superior to the GDC regarding long-term outcomes because of the bioactive properties of the PGLA coating. The results of our long-term follow-up, when completed, may be able to indicate whether the Matrix coils have a lower rate of recanalization than GDCs.

Conclusions

In our series of 307 patients treated with either GDCs or Matrix coils for 364 aneurysms, the Matrix coils seem to have yielded slightly better results regarding the satisfactory occlusion rate of aneurysms and the clinical outcome of patients. The quality of these results may have been influenced by our increased experience, because we used the Matrix coils later in our practice. Follow-up results of this series might be able to confirm the advantages of the PGLA-covered Matrix coils over the bare platinum GDCs regarding long-term recanalization rates.

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