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This information is current as of August 24, 2025.

AJNR Am J Neuroradiol 2007, 28 (7) 1384-1387

doi: <https://doi.org/10.3174/ajnr.A0557>

<http://www.ajnr.org/content/28/7/1384>

ORIGINAL
RESEARCH

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Packing Performance of Helical Guglielmi Detachable Coil (GDC) 18 in Intracranial Aneurysms: A Comparison with Helical GDC 10 Coils and Complex Trufill/Orbit Coils

BACKGROUND AND PURPOSE: The purpose of this study was to retrospectively compare the packing performance of helical Guglielmi detachable coil (GDC) 18 (thickness, 0.0135–0.015 inch) with the packing performance of both helical GDC 10 (thickness, 0.010 inch) and complex Trufill/Orbit coils (thickness, 0.012 inch).

MATERIALS AND METHODS: From our data base, we selected aneurysms that were exclusively coiled with GDC 18 coils. For every aneurysm treated with GDC 18 coils, we tried to identify a volume-matched control aneurysm treated with exclusively GDC 10 coils or exclusively Trufill/Orbit coils. This process resulted in 32 aneurysm pairs treated with either GDC 18 or GDC 10 coils and 35 aneurysm pairs treated with either GDC 18 or Trufill/Orbit coils.

RESULTS: The mean packing of 24.2% of aneurysms treated with GDC 18 was significantly higher than the mean packing of 18.3% of aneurysms treated with GDC 10 ($P < .0001$). The mean packing of 23.1% of GDC 18 coils was not different from the mean packing of 25.1% of Trufill/Orbit coils ($P = .15$).

CONCLUSION: In aneurysms of 4 mm or larger, packing performance of helical GDC 18 coils is superior to that of helical GDC 10 coils and equal to that of complex Trufill/Orbit coils.

Approximately 25% of intracranial aneurysms treated with platinum coils show reopening of the lumen with time,¹⁻² compaction of coil mesh being the most important contributing factor. Compaction can be prevented by increasing the packing attenuation, defined as ratio of inserted coil volume and volume of the aneurysm.³ Higher aneurysm packing can be obtained by inserting a higher volume of coils. Volume of inserted coils is dependent on both coil thickness and inserted coil length. In previous studies, we showed that packing is significantly higher in aneurysms treated with complex-shaped coils of 0.012-inch wire thickness (Trufill/Orbit coils; Cordis Neurovascular, Miami Lakes, Fla) than with aneurysms treated with helical coils of 0.010-inch wire thickness (Guglielmi detachable coil [GDC] 10; Boston Scientific, Fremont, Calif).^{4,5} In these studies, the increased packing of 0.012-inch coils over 0.010-inch coils was attributed to the increased coil thickness because the inserted coil length per aneurysm volume was equal. Apparently, the complex shape of the 0.012-inch coils allowed better concentric aneurysm filling with less created dead space. Also in an experimental study, it was shown that complex-shaped coils allowed significantly better aneurysm filling than helical coils of the same thickness.⁶

Besides the 0.010-inch GDC 10 coils and the 0.012-inch Trufill/Orbit coils, GDC 18 coils (Boston Scientific) with 0.0135- to 0.015-inch wire thickness are commonly used for larger aneurysms. In this study, we retrospectively compared the packing performance of helical GDC 18 coils with the

packing performance of both helical GDC 10 coils and complex Trufill/Orbit coils. In addition, we compared procedural complications, procedural ruptures, and additional treatments after coiling in aneurysms treated with any 3 types of coils.

Patients and Methods

Description of Compared Coil Types

GDC 18 Coils. GDC 18 coils are available in 2 softness grades, Regular and Soft. GDC 18 Regular coils have a thickness of 0.015 inch and are available in helical shapes ranging from 2 to 20 mm and in 3D shapes ranging from 6 to 20 mm. GDC 18 Soft coils have a thickness of 0.0135 inch and are available in helical shape ranging from 2 to 6 mm.

GDC 10 Coils. GDC 10 coils are available in 3 softness grades, Regular, Soft, and Ultrasoft. GDC 10 Regular coils have a thickness of 0.010 inch, and GDC 10 Soft and Ultrasoft have a thickness of 0.0095 inch. GDC 10 coils are available in sizes ranging from 2 to 14 mm. GDC 10 coils are also available in 3D shape in sizes ranging from 3 to 10 mm.

Trufill/Orbit Coils. Orbit coils are the evolution of the Trufill detachable coil system with a reduced detachment system profile to allow compatibility with 0.014-inch microcatheters. Trufill/Orbit coils are helical or shaped in a complex 3D configuration, have a thickness of 0.012 inch, and are available in sizes ranging from 2 to 20 mm.

Coiling Procedure. Coiling of aneurysms was performed by either of the authors on a biplane angiographic unit (Integris BN 3000; Philips Medical Systems, Best, the Netherlands) with the use of general anesthesia and systemic administration of heparin. Intravenously or subcutaneously administered heparin was continued for 48 hours after the procedure, followed by 80-mg aspirin daily for 3 months. The aim of coiling was to pack the aneurysm as densely as possible, until not 1 more coil could be placed or when complete angiographic

Received October 19, 2006; accepted after revision December 8.

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DOI 10.3174/ajnr.A0557

occlusion was apparent. With the use of GDC 18 and 10 coils, in some aneurysms, a 3D coil was used as a first coil. With the use of Trufill/Orbit coils, all inserted coils were complex-shaped except for some 2- and 3-mm-diameter helical coils. Coil sizes were chosen as appropriate for the aneurysm size and shape. Coils were neither over- nor undersized. Although maximal aneurysm diameter (20 mm) exceeded maximal coil size in some aneurysms treated with GDC 10 coils (14 mm), coil size was always appropriate for irregular aneurysm shape.

Aneurysm Volume and Packing Calculation. Volume of aneurysms was either calculated from 3D angiographic datasets by using machine software or with a custom-designed computer program that reconstructed 3D aneurysms from 2D angiographic images.^{3,7} Both methods were validated with phantoms. Volume of inserted coils was calculated with a spreadsheet provided by the coil manufacturers, containing volume per centimeter of coils for every coil type used. Packing of the aneurysms was calculated by dividing the volume of inserted coils by the volume of the aneurysm times 100%.

Aneurysm Matching. From our data base containing over 1000 coiled aneurysms, we selected those aneurysms with known aneurysm volume that were exclusively coiled with GDC 18 coils. For every aneurysm treated with GDC 18 coils, we tried to identify a volume-matched control aneurysm, within a 10% volume range, treated with either exclusively GDC 10 coils or exclusively Trufill/Orbit coils. Selection of the volume-matched controls was performed as follows: in case of a single exact volume match, this particular aneurysm was chosen. In case of more than 1 exact volume match, the aneurysm with the same location was selected. In case of 2 exact volume matches on the same location, the rupture status of the aneurysm was the decisive criterion. On the basis of these criteria, 32 pairs of aneurysms treated by either GDC 18 coils or Trufill/Orbit coils and 35 pairs of aneurysms treated by either GDC 18 coils or GDC 10 coils were identified. Of aneurysms treated with GDC 18, 24 were assigned in both matched groups. Aneurysms were treated between 1999 and 2005 on the same equipment by the same operators.

Clinical Data Assessment. For all aneurysms selected for comparison, we assessed the following clinical data: proportion of women, patient mean age, proportion of ruptured aneurysms, proportion of aneurysms located in anterior and posterior circulation, procedural complications of coiling leading to permanent morbidity or mortality, number of procedural ruptures, proportion and mean duration of angiographic follow-up, and number of retreatments.

In addition, for all aneurysms grouped by matched pairs, we assessed the following data: the number of aneurysms treated with GDC coils in which a 3D coil was used as a first coil, initial occlusion rates dichotomized into (near) complete occlusion (90%–100%) and incomplete occlusion (<90%), and occlusion rates at 6 months follow-up interval.

Statistical Analysis. Mean aneurysm volume, mean packing, mean inserted coil length per aneurysm per cubic millimeter, and mean number of coils used per aneurysm in the 32 aneurysms treated with GDC 18 coils and 32 aneurysms treated with GDC 10 coils were compared by using the *t* test. Mean aneurysm volume, mean packing, mean inserted coil length per aneurysm per cubic millimeter, and mean number of coils used per aneurysm in the 35 aneurysms treated with GDC 18 coils and 35 aneurysms treated with Trufill/Orbit coils were compared by using the *t* test. Procedural complications, procedural ruptures, and retreatments were compared by using the Fisher exact test. The chi square test was used to assess differences in the use

of a 3D coil as a first coil between aneurysms treated with GDC 18 and GDC 10. *P* values < .05 were considered statistically significant.

Results

Initial Occlusion Rates and Occlusion at 6-Month Follow-Up

Aneurysms Treated with GDC 18 Coils Compared with Aneurysms Treated with GDC 10 Coils. For 32 aneurysms treated with GDC 18 and matched with aneurysms treated with GDC 10, initial occlusion was (near) complete in 31 aneurysms and incomplete in 1 aneurysm. (The patient with the initial incompletely occluded aneurysm died 3 weeks later of vasospasm). At 6-month follow-up angiography of 26 aneurysms, 24 aneurysms were (near) completely occluded and 2 aneurysms became incompletely occluded and were retreated. Of 32 aneurysms treated with GDC 18, a 3D coil was used as a first coil in 4.

For 32 aneurysms treated with GDC 10 and matched with aneurysms treated with GDC 18, initial occlusion was (near) complete in 31 aneurysms and incomplete in 1 aneurysm that was additionally coiled before 6-month follow-up interval. At 6-months follow-up angiography of 28 aneurysms, 25 aneurysms were (near) completely occluded and 3 aneurysms became incompletely occluded and were retreated. Of 32 aneurysms treated with GDC 10, a 3D coil was used as a first coil in 15.

Aneurysms Treated with GDC 18 Coils Compared with Aneurysms Treated with Trufill/Orbit Coils. For 35 aneurysms treated with GDC 18 and matched with aneurysms treated with Trufill/Orbit, initial occlusion was (near) complete in 34 aneurysms and incomplete in 1 aneurysm. (The patient with the initial incompletely occluded aneurysm died 3 weeks later of vasospasm). At 6-month follow-up angiography of 27 aneurysms, 22 aneurysms were (near) completely occluded and 5 aneurysms became incompletely occluded and were retreated. Of 35 aneurysms treated with GDC 18, a 3D coil was used as a first coil in 8.

For 35 aneurysms treated with Trufill/Orbit and matched with aneurysms treated with GDC 18, initial occlusion was (near) complete in 34 aneurysms and incomplete in 1 aneurysm that was not additionally treated. At 6-month follow-up angiography of 29 aneurysms, 25 aneurysms were (near) completely occluded and 4 aneurysms became incompletely occluded and were retreated.

Results of Comparison Between Different Types of Coils

The results of comparisons between GDC 18 coils and GDC 10 coils are summarized in Tables 1 and 2, and the results of comparisons between GDC 18 coils and Trufill/Orbit coils are summarized in Tables 3 and 4. Mean volumes of the aneurysms in both comparisons were nearly identical: For GDC 18 coils versus GDC 10 coils, this was 329 mm³ and 333 mm³ (*P* = .96), and for GDC 18 coils versus Trufill/Orbit coils, this was 297 mm³ and 295 mm³ (*P* = .98). Mean packing of 24.2% of aneurysms treated with GDC 18 coils was significantly higher than mean packing of 18.3% of aneurysms treated with GDC 10 coils (absolute difference, 5.9%; relative difference, 32%). Mean packing of 23.1% of aneurysms treated with GDC 18 coils was not different from mean packing of 25.1% of aneurysms treated with Trufill/Orbit coils (*P* = .15).

Table 1: Aneurysm volume and relevant packing results of 32 aneurysms treated with GDC 18 coils compared with 32 volume-matched controls treated with GDC 10 coils

	GDC 18	GDC 10	P value (t test)
Number of aneurysms	32	32	
Aneurysm volume			.96
Mean	329 mm ³	333 mm ³	
Median	297.5 mm ³	309 mm ³	
Range	34–1333 mm ³	35–1377 mm ³	
SD	230 mm ³	237 mm ³	
Largest aneurysm diameter			
Mean	10.2 mm	9.9 mm	
Median	10 mm	9.5 mm	
Range	4–20 mm	4–20 mm	
Packing			
Mean	24.2%	18.3%	<.0001
Median	24.5%	19.0%	
Range	11%–32%	9–33%	
SD	4.97%	4.76%	
Σ Aneurysm volumes	10 542 mm ³	10 643 mm ³	
Σ Inserted coil length	2436 cm	3419 cm	
Coil length per mm ³ aneurysm volume	0.23 cm	0.32 cm	
Mean coil length per aneurysm per mm ³	0.233 cm	0.345 cm	<.0001
Total number of coils	145	223	
Mean number of coils per aneurysm	4.5	7.0	.005

Table 2: Clinical and follow-up characteristics of 32 aneurysms treated with GDC 18 coils compared with 32 volume-matched controls treated with GDC 10 coils

	GDC 18	GDC 10	P value (t test)
Number of aneurysms	32	32	
Woman/man	27/5	20/12	
Median age	59.5 years	54.5 years	
Anterior circulation	29	21	
Posterior circulation	3	11	
Ruptured/unruptured	22/10	27/5	
Procedural morbidity	1 (3.1%)	1 (3.1%)	1.0
Procedural rupture	1 (3.1%)	0	1.0
Angiographic follow-up	26 (81%)	28 (88%)	
Mean angiographic follow-up	12.7 months	15.0 months	
Additional treatments	2 of 26 (8%)	4 of 28 (14%)	.74

Mean inserted coil length per aneurysm per cubic millimeter in the aneurysms treated with GDC 18 coils was significantly lower than that for aneurysms treated with both GDC 10 and Trufill/Orbit coils. Mean number of coils used per aneurysm in the aneurysms treated with GDC 18 coils was significantly lower than that for aneurysms treated with both GDC 10 and Trufill/Orbit coils. There were no statistically significant differences in procedural complications, procedural ruptures, initial occlusion rates, occlusion rates at 6-month follow-up angiography, and retreatment rates in any of the groups. In the aneurysms treated with GDC 10, significantly more often a 3D coil was used as a first coil as in aneurysms treated with GDC 18 ($P = .006$).

Discussion

In this study, we found that packing of intracranial aneurysms treated with GDC 18 coils was significantly higher than pack-

Table 3: Aneurysm volume and relevant packing results of 35 aneurysms treated with helical GDC 18 coils compared with 35 volume-matched controls treated with complex Trufill/Orbit coils

	GDC 18	Trufill/Orbit	P value (t test)
Number of aneurysms	35	35	
Aneurysm volume			.98
Mean	297 mm ³	295 mm ³	
Median	400 mm ³	406.5 mm ³	
Range	26–1450 mm ³	27–1504 mm ³	
SD	327 mm ³	383 mm ³	
Largest aneurysm diameter			
Mean	10.3 mm	9.6 mm	
Median	10 mm	10 mm	
Range	4–22 mm	4–17 mm	
Packing			.15
Mean	23.1%	25.1%	
Median	24%	25%	
Range	8%–33%	11%–36%	
SD	5.98%	5.67%	
Σ Aneurysm volumes	14 002 mm ³	14 229 mm ³	
Σ Inserted coil length	2794 cm	4446 cm	
Coil length per mm ³ aneurysm volume	0.20 cm	0.31 cm	
Mean coil length per aneurysm per mm ³	0.224 cm	0.339 cm	<.0001
Total number of coils	157	238	
Mean number of coils per aneurysm	4.5	6.8	.0024

Table 4: Clinical and follow-up characteristics of 35 aneurysms treated with GDC 18 coils compared with 35 volume-matched controls treated with Trufill/Orbit coils

	GDC 18	Trufill/Orbit	P value (t test)
Number of aneurysms	35	35	
Woman/man	27/8	19/16	
Median age	58 years	56 years	
Anterior circulation	32	24	
Posterior circulation	3	11	
Ruptured/unruptured	25/10	27/8	
Procedural morbidity	1	0	1.0
Procedural rupture	2	0	.5
Angiographic follow-up	27 (77%)	29 (83%)	
Mean angiographic follow-up	6.4 months	7.0 months	
Additional treatments	5 of 27 (19%)	4 of 29 (14%)	.9

ing of aneurysms treated with GDC 10 coils. Packing of aneurysms treated with GDC 18 coils was not different from packing of aneurysms treated with Trufill/Orbit coils. The mean volume of the selected aneurysms treated with GDC 18 and their matched volume controls was approximately 300 mm³. This is relatively large because GDC 18 coils are mainly used in medium- and large-sized aneurysms. In a previous study with 235 consecutively coiled aneurysms,⁵ mean aneurysm volume with 150 mm³ was much lower.

Mean inserted coil length per aneurysm per cubic millimeter in the aneurysms treated with helical GDC 18 coils was significantly lower than that for aneurysms treated with helical GDC 10 coils. Apparently, increased coil thickness of GDC 18 is associated with less inserted coil length per cubic millimeter. Because inserted coil volume is the product of coil length and coil thickness, though less coil length is inserted, the increased

thickness still leads to higher inserted coil volume. This outcome may not be surprising because coil thickness influences coil volume by the second power.

What is more interesting, in previous studies,^{4,5} no difference in inserted coil length per cubic millimeter was found between helical GDC 10 coils of 0.010-inch thickness and complex Trufill/Orbit coils of 0.012-inch thickness. The better packing of Trufill/Orbit coils compared with GDC 10 coils was, therefore, explained by the increased coil thickness only because equal coil lengths could be inserted. Apparently, the complex shape of the Trufill/Orbit coil allows better concentric filling and creates less dead space. In an experimental study, Piotin et al⁶ found a higher packing by higher inserted coil lengths of complex-shaped Trufill/Orbit coils compared with helical Trufill/Orbit coils of the same thickness. This study showed that inserted coil volume per cubic millimeter of aneurysm is dependent on coil shape for these particular types of coils and that a complex shape allows more inserted coil length. This increased packing of complex Trufill/Orbit coils compared with helical Trufill/Orbit coils could not be confirmed for GDC coils: we found no difference in packing performance in aneurysms treated with either helical GDC 10 coils or complex-shaped GDC 360° coils.⁸ Apparently, other physical properties of the coils such as softness and shape memory play a role in packing performance. Future research should aim at the best possible combination of coil thickness, coil shape, and other physical properties.

We found no differences in procedural complications, procedural ruptures, and retreatment rates in aneurysms coiled with any of the 3 types of coils. The incidence of these events is low, and larger numbers of patients are needed to detect possible differences. However, a positive relation between high packing and less reopening with time was established in previous studies with more patients.^{3,5}

In the present study, the number of coils needed per aneu-

rysm was significantly lower for GDC 18 coils than for both GDC 10 coils and Trufill/Orbit coils. This finding means that in relatively large aneurysms, the use of GDC 18 coils not only results in higher packing but is also more cost-effective, providing the price per coil is equal. Packing of GDC 10 coils, the most widely used coil, is lower than packing of Trufill/Orbit coils for all aneurysm sizes and also lower than packing of GDC 18 coils in aneurysms of 4 mm or larger.

Conclusion

In aneurysms of 4 mm or larger, packing performance of helical GDC 18 coils (0.0135–0.015 inch) is superior to that of helical GDC 10 coils (0.010 inch) and equal to that of Trufill/Orbit complex-shaped coils (0.012 inch).

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