

# Balloon remodeling technique in endovascular treatment of intracranial aneurysms

## *Técnica de remodelagem com balão no tratamento endovascular de aneurismas intracranianos*

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### RESUMO

**Objetivos:** O tratamento endovascular de aneurismas intracranianos demonstra baixas taxas morbidade e mortalidade, entretanto, aneurismas complexos e de colo largo permanecem um desafio terapêutico. O objetivo deste estudo é avaliar o manejo endovascular de uma série de aneurismas intracranianos utilizando-se a técnica de remodelagem com balão.

**Método:** Realizou-se uma avaliação retrospectiva de pacientes com aneurismas intracranianos submetidos a tratamento endovascular com a técnica de remodelagem com balão no Instituto de Neurologia de Curitiba (Outubro de 2006 a Junho de 2011).

**Resultados:** Foram analisados 34 pacientes. A média de idade era de 55,12 anos e 78,79% eram do sexo feminino. Treze pacientes apresentavam aneurismas rotos (38,24%) e em 8 havia vasoespasm (23,53%). A maioria dos aneurismas (61,76%) tinham entre 5-15 mm de tamanho e 41,18% apresentavam colo maior ou igual a 4 mm. Uma oclusão total foi obtida em 29 aneurismas (85,29%) e parcial em 2 aneurismas (5,88%). Ocorreu óbito por hemorragia subaracnóidea relacionada ao procedimento em 1 caso.

**Conclusão:** O tratamento endovascular com a técnica de remodelagem com balão mostra-se segura e eficaz para o tratamento de aneurismas intracranianos, especialmente naqueles complexos e com colo largo.

**Palavras Chave:** aneurisma intracraniano, tratamento endovascular, técnica de remodelagem.

### ABSTRACT

**Objectives:** Endovascular treatment of intracranial aneurysms demonstrates low rates of morbidity and mortality. However, aneurysms with complex forms and wide neck remain a therapeutic challenge. The aim of this study is to evaluate the endovascular management of a series of intracranial aneurysms using the balloon remodeling technique.

**Method:** A retrospective evaluation was performed on patients with intracranial aneurysms having undergone endovascular treatment with balloon remodeling technique at the Instituto de Neurologia de Curitiba (from October, 2006 to June, 2011).

**Results:** Thirty-four patients were evaluated. The mean age was 55.12 years and 78.79% were female. Thirteen patients had ruptured aneurysms (38.24%) and 8 had vasospasm (23.53%). The majority of the aneurysms (61.76%) had dome measurements between 5 to 15mm and 41.18% had a neck size of greater than or equal to 4mm. Total occlusion was obtained in 29 aneurysms (85.29%) and partial occlusion in 2 (5.88%). One patient died from a procedure-related hemorrhage.

**Conclusion:** Endovascular treatment with balloon remodeling techniques seems to be a safe and effective treatment for intracranial aneurysms, especially those with complex forms and wide neck.

**Keywords:** intracranial aneurysm, endovascular treatment, remodeling technique.

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## INTRODUCTION

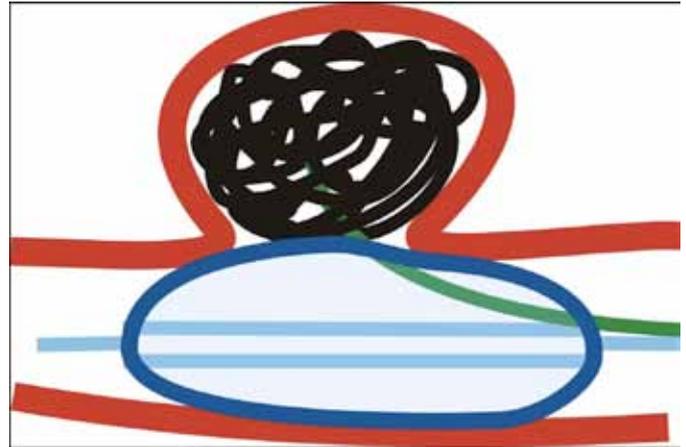
Aneurysms are vascular malformations of extreme importance in the group of cerebrovascular diseases, given that they represent the most common cause of spontaneous subarachnoid hemorrhage and are responsible for nearly a quarter of all intracranial hemorrhages<sup>12</sup>. The treatment of intracranial aneurysms may be performed by microsurgical clipping or endovascular coil embolization.

Surgical management of intracranial aneurysms consists of the exclusion of the aneurysmal sac from the circulation. Clipping of aneurysm neck has been the method of choice for aneurysm obliteration. For decades it was the only option in treatment of ruptured and unruptured aneurysms<sup>12</sup>.

A study published in 1991 became one of the major references in the evolution of endovascular treatment for intracranial aneurysms<sup>2</sup>. Guglielmi developed a system of soft platinum coil soldered to a stainless steel delivery wire that was detachable by electrolysis. The system called GDC (Guglielmi detachable coil) began to be employed initially for aneurysms with difficult surgical access, such as in the vertebrobasilar system, or in patients with unfavorable clinical conditions<sup>3</sup>. Soon, the indications were expanded and endovascular treatment became a very good option in the management of intracranial aneurysms<sup>5,6</sup>.

The endovascular treatment of intracranial aneurysms demonstrates low morbidity and mortality<sup>5,6</sup>. However, aneurysms with complex form and wide neck still remain a therapeutic challenge with a greater risk of recurrence and complication.

In the endovascular treatment by coiling aneurysms with wide necks, two strategies may be employed. The placement of a stent at aneurysm neck (stent remodeling technique or stent-assist coil embolization) allows for adequate coil detachment and might help prevent aneurysm recanalization by redirecting flow and facilitating endothelialization at the aneurysm neck. The balloon remodeling technique (or balloon-assisted coil embolization), which is evaluated in this study, consists on the use of a balloon that is inflated to compress and shape the coil inside the aneurysm, preventing coil protrusion into the parent vessel (Fig.1).



**Figure 1:** Balloon remodeling technique.

In this article we report a 5-year experience in endovascular management of intracranial aneurysms using balloon remodeling technique. The aim of this study is to evaluate the clinical, technical, and angiographic results in this series of aneurysms.

## MATERIALS AND METHODS

A retrospective evaluation was performed in 34 patients presenting with saccular cerebral aneurysms submitted to endovascular treatment using balloon remodeling technique at the Neurological Institute of Curitiba between October, 2006 and June, 2011.

Collected data included: demographic information (age and gender), characteristics of the aneurysm (location, size and the presence or not of rupture), technical complications (presence of vasospasm and thrombosis after embolization), treatment strategy (technique, number of coils), angiographic results (rate of the aneurysm occlusion), and clinical outcome after the treatment.

All procedures were performed by a team of 2 or 3 specialists on a monoplane angiographic system (PHILIPS Integris HM3000®).

The procedures were performed under general anesthesia, endotracheal intubation, and with surgical sterilization care. Right femoral access is usually accomplished with the Seldinger technique, and carotid or vertebral catheterization is performed with the aid of a detailed pre-embolization angiography.

A 6F guide catheter or one with a larger diameter is allocated in the parent lumen vessel, proximal to the aneurysm, avoiding ex-

cessive manipulation that may provoke or worsen vasospasm. The guide catheter should allow access beyond the passage of a micro guide catheter, the passage of a catheter with a balloon, or a stent for the remodeling technique.

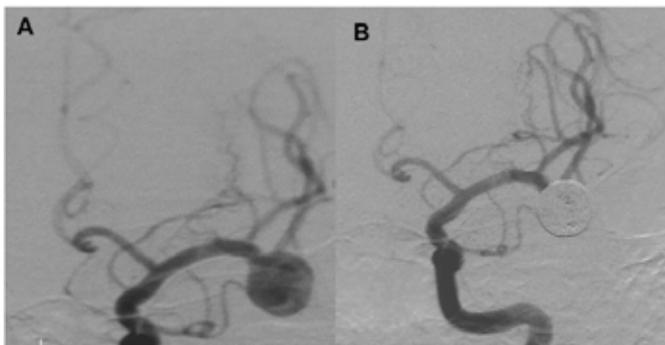
Systemic anticoagulation is performed with a bolus injection of heparin (5000 IU), and then 1000 IU every hour. When treating ruptured aneurysms, heparinization is started only after the detachment of the first coil, while in cases of unruptured aneurysms it is initiated soon after the introducer is set in the femoral artery.

In the balloon remodeling technique, especially used in treatment of complex and wide neck aneurysms, a balloon is inflated to compress and shape the coil inside the aneurysm (Fig.2).



**Figure 2.** A: Diagnostic angiogram demonstrating a basilar tip aneurysm. B: Angiogram, obtained after initial balloon remodeling and embolization. C: Postembolization angiogram exhibiting complete occlusion of the aneurysm.

Finally, an angiography is performed and the catheters are removed. The introducer is removed after an anticoagulation control, with manual compression and compressive dressing for 24 hours. An angiographic control is indicated 6 months after the procedure and repeated after 2 years of treatment, checking the rate of occlusion ( Fig.3).



**Figure 3.** A: Initial diagnostic angiogram demonstrating a left middle cerebral artery aneurysm. B: Postembolization angiogram exhibiting complete occlusion of the aneurysm.

## RESULTS

In the present study, 34 patients were evaluated, including 27 (78.79%) female and 7 (21.21%) male patients. The average age was  $55.12 \pm 13.54$  years. Divided into age groups: 2.94% of the sample were 29 years or below; 8.82% were from 30 to 39 years of age; 23.53% from 40 to 49 years; 26.47% were from 50 to 59 years; 20.59% from 60 to 69 years; and 17.65% were 70 years old and above. Thirteen patients harbored ruptured aneurysms, corresponding to 38.24% of the series. There were 8 cases of vasospasm, representing a rate of 23.53% (Table 1).

Age group	
<29 years	1 (2.94%)
30 to 39 years	3 (8.82%)
40 to 49 years	8 (23.53%)
50 to 59 years	9 (26.47%)
60 to 69 years	7 (20.59%)
≥70 years	6 (17.65%)
Gender	
Female	27 (78.79%)
Male	7 (21.21%)
Ruptured / Uruptured	
Unruptured	21 (61,76%)
Ruptured	13 (38.24%)
Vasospasm	
Absence	26 (76,47%)
Occurrence	8 (23,53%)

**Table 1.** Patients.

According to location, 22 aneurysms involved the internal carotid artery (64.71%) and 13 included the posterior communicating segment (38.24%), 5 the cavernous segment (14.71%) and 4 the ophthalmic segment (11.76%). Four aneurysms involved the middle cerebral artery (11.76%), 4 the anterior communicating artery (11.76%), 2 the basilar artery (5.88%), and 2 involved the pericallosal artery (5.88%) (Table 2).

Internal carotid artery	
- Cavernous segment	5 (14.71%)
- Communicating segment	13 (38.24%)
- Ophthalmic segment	4 (11.76%)
<b>Middle cerebral artery</b>	4 (11.76%)
<b>Anterior communicating artery</b>	4 (11.76%)
<b>Basilar artery</b>	2 (5.88%)
<b>Pericallosal artery</b>	2 (5.88%)

**Table 2.** Location.

Aneurysm dome measurements were less than 5 mm in 11 instances (32.35%), 5 to 15 mm in 21 instances (61.76%), and larger than 15 mm in 2 instances (5.88%). The aneurysm dome diameters ranged from 2.5 to 15 mm. Neck sizes ranged from 1.5 to 10 mm, and there were 14 aneurysms with neck size greater than or equal to 4 mm (41.18%). The neck size was less than 4 mm in 20 aneurysms (58.82%), however, there was a major risk of coil protrusion into the parent vessel in these cases. Dome/neck ratios were greater than or equal to 0.8 in 8 instances (23.53%) and less than 0.8 in 26 instances (76.47%) (Table 3).

Size	
Large	2 (5.88%)
Medium	21 (61.76%)
Small	11 (32.35%)
Neck	
≥4 mm	14 (41.18%)
<4 mm	20 (58.82%)
Dome-to-neck ratio	
≥0.8	26 (76.47%)
<0.8	8 (23.53%)

**Table 3.** Size.

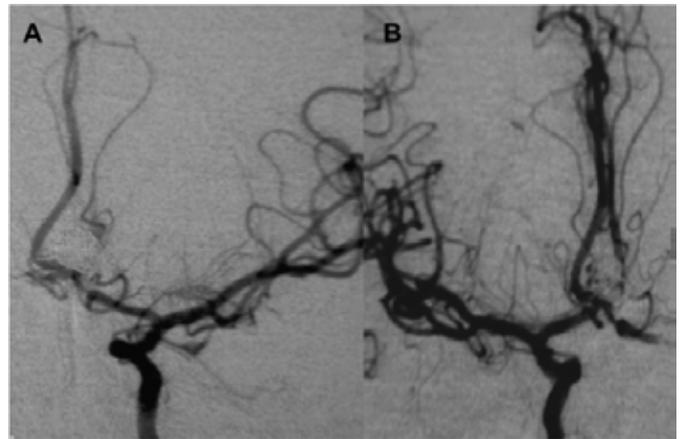
In four patients (11.76%) the balloon remodeling technique was associated with the stent remodeling technique due to the occurrence of coil protrusion into the parent vessel. The average of coils used per procedure was  $4.0 \pm 2.8$ .

According to the angiographic results, total occlusion was obtained in 29 aneurysms at the end of the procedure (85,29%), and partial occlusion in 2 aneurysms (5.88%). In 2 aneurysms coil insertion was not possible (5.88%), and one procedure was interrupted due to rupture of the aneurysmal sac (Table 4).

Total	29 (85,29%)
Partial	2 (5.88%)
Non occlusion	2 (5.88%)

**Table 4.** Occlusion Rate.

Technical complication included one case of distal vessel thromboembolism in an anterior communicating artery aneurysm embolization using balloon remodeling technique, which reverted after abciximab (ReoPro®) infusion, and resulted in no neurological deficits (Fig.4).



**Figure 4. A:** Immediate posttreatment angiogram demonstrating occlusion of the post-communicating segment of left anterior cerebral artery **B:** Vessel recanalization after abciximab (ReoPro®) infusion.

In this series, one patient died from a procedure-related hemorrhage. There were 4 deaths related to complications of the subarachnoid hemorrhage in patients with ruptured aneurysms at admission. One patient died due to massive pulmonary thromboembolism, and one due to acute abdomen hemorrhage. These last two patients also presented with ruptured aneurysms on admission.

Twenty-one patients underwent angiographic follow-up 6 months after the procedure. Total aneurysm occlusion was observed in 20 patients, and partial occlusion in 1 patient. Eight patients underwent control with cerebral computed angiotomography 6 months after the procedure and complete occlusion was evidenced in all cases.

## DISCUSSION

In 1994, Moret et al<sup>7</sup> described the remodeling technique for extending the indications and feasibility of the endovascular treatment to wide neck aneurysms. This technique involves the temporary inflation of a non-detachable balloon in front of the aneurysm neck during each coil placement. At the end of the procedure, the remodeling balloon is removed and no device is left in place in the parent vessel.

In 1997<sup>8</sup> the same author published the angiographic results and clinical follow-up in 56 cases. Total occlusion was possible in 40 cases (77%), subtotal occlusion in nine cases (17%), and incomplete occlusion in three cases (6%). Angiographic evidence of thrombosis was observed during the procedure in three cases, resulting in one permanent deficit. Rupture of the aneurysmal sac occurred during the procedure in three cases, all of which were asymptomatic in the follow-up.

After the description of the balloon remodeling several single-center series were published analyzing clinical and anatomic results of this technique. Aletich et al<sup>1</sup> reported a retrospective analysis of 72 patients with 75 aneurysms who underwent endovascular procedures using the remodeling technique. The authors found that 50 (78%) of 64 aneurysms were completely or subtotally (> 95%) occluded and eight (12%) of 64 were incompletely (< 95%) occluded. Morbidity was limited to four patients and there were three deaths directly related to the procedure.

Malek et al<sup>4</sup> analyzed 20 patients with 22 aneurysms (19 unruptured aneurysms and 3 ruptured aneurysms) who underwent coil embolization with the balloon remodeling technique. In this study, the balloon-assisted technique performed in the same treatment session after conventional coil embolization failed in 55% of cases (12 of 22 cases) and was the primary treatment in 45% of cases. Technical success was achieved in 77% of cases (17 of 22). The rate of aneurysm obliteration at the end of the procedures was  $97\% \pm 3.8\%$ . Technical complications included two cases of asymptomatic distal vessel thromboembolism and one case of intraprocedural rupture of an arteriovenous malformation-related feeder artery aneurysm, which resulted in no neurological deficits and required no further treatment. There were no deaths and no procedure-related 30-day or permanent morbidity. In our series, total occlusion was obtained in 85.29% of the cases, partial occlusion in 5.88%, and coil insertion was not possible in 2 aneurysms (5.88%). There was one case of

distal vessel thromboembolism, which reverted and resulted in no neurological deficits, and there was one death related to the procedure.

Sluzewski et al<sup>13</sup> evaluated the risks associated with balloon-assisted coil embolization of intracranial aneurysms. The authors analyzed the results in 71 cases in which the remodeling technique was performed and compared the data with those from a group of 756 aneurysms in which coil embolization alone was used. The remodeling technique was more frequently utilized in larger aneurysms with broad necks, unruptured lesions, and lesions in the posterior circulation. They observed that balloon-assisted techniques had a higher procedural complication rate of 14.1% compared with the 3% rate in the conventional interventions and suggested that the remodeling technique should be used only if standard coiling was impossible or had failed.

A direct comparison of the standard coiling technique and balloon remodeling was recently conducted in both ruptured and unruptured aneurysms in 2 large multicentric prospective studies<sup>9,10</sup>.

As part of the ATENA (Analysis of Treatment by Endovascular Approach of Nonruptured Aneurysms) Study<sup>9</sup>, a comparison of safety of balloon remodeling technique and standard treatment with coils for treatment of unruptured intracranial aneurysms was published in 2009. In this large multicenter series 547 patients with 572 aneurysms were analyzed and the remodeling technique was associated with a similar rate of adverse events and combined morbidity and mortality compared with the standard treatment with coils.

In 2011 CLARITY study (Clinical and Anatomic Results in the Treatment of Ruptured Intracranial Aneurysms)<sup>10</sup> compared the safety and efficacy of the remodeling technique with that of conventional coil embolization in a large multicenter series involving ruptured intracranial aneurysms. A total of 608 (79.2%) patients with ruptured aneurysms were treated with conventional coil embolization and 160 (20.8%) with the remodeling technique.

In this study, the rate of treatment-related complications was similar in both groups (17.4% using coil embolization and 16.9% remodeling) ( $P = 0.999$ ). There was no statistically significant difference in the rates of thromboembolic events, intraoperative rupture, and early repeat bleeding between the treatment groups. The cumulative morbidity and mortality rate related to the treatment in the remodeling group (3.8%) was similar to that in the coil embolization group (5.1%) ( $P = 0.678$ ). Equally, the global cumulative morbidity and mortality rates related to both the treatment and the initial hemorrhage did not differ

significantly (16.2% remodeling and 19.6% coil embolization) ( $P = 0.366$ ). However, the rate of adequate aneurysm occlusion was significantly higher in the remodeling group (94.9%) than in the coil embolization group (88.7%) ( $P = 0.017$ ). In summary, the authors found that the remodeling technique was as safe as conventional coil embolization and more efficacious in terms of the rate of adequate postoperative occlusion.

A literature review of safety and efficacy of balloon remodeling technique during endovascular treatment of intracranial aneurysms was published in 2011<sup>11</sup>. The authors noticed that all except one publication<sup>13</sup> showed a similar safety profile in the standard coiling and the remodeling techniques. Another literature review comparing the anatomic results in aneurysms treated by standard coiling and remodeling shows that immediate and follow-up results are better in the remodeling group and these results are partially confirmed in the CLARITY series<sup>10</sup>, showing that adequate occlusion is significantly more frequent in the remodeling group. They concluded that despite the fact that aneurysms treated by the remodeling technique are different from aneurysms treated with standard coiling, the safety of both techniques is similar with a higher anatomic efficacy of the remodeling technique.

Our article has some limitations as it is a retrospective study and has a small number of patients. The remodeling technique seems to be an excellent option in complex and wide neck aneurysms management, with a low rate of morbidity and a high rate of aneurysm occlusion. A large and prospective study should be performed in order to determine accurately the safety and efficacy of balloon remodeling technique in our population.

## REFERENCES

1. Aletich V, Debrun GM, Misra M, Charbel F, Ausman JI. The remodeling technique of balloon-assisted Guglielmi detachable coil placement in wide-necked aneurysms: experience at the University of Illinois at Chicago. *J Neurosurg.* 2000 Sep;93(3):388–96.
2. Guglielmi G, Vinuela F, Sepetka I, Macellari V. Electrothrombosis of saccular aneurysms via endovascular approach. Part 1: Electrochemical basis, technique, and experimental results. *J Neurosurg.* 1991;75(1):1–7.
3. Guglielmi G, Vinuela F, Dion J, Duckwiler G. Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: Preliminary clinical experience. *J Neurosurg.* 1991;75(1):8–14.
4. Malek AM, Halbach VV, Phatouros CC, Lempert TE, Meyers PM, Dowd CF, Higashida RT. Balloon-assist technique for endovascular coil embolization of geometrically difficult intracranial aneurysms. *Neurosurgery.* 2000 Dec;46(6):1397–1407.
5. Molyneux A, Kerr R, Stratton I, Sandercock P, Clarke M, Shrimpton J, Holman R, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. *Lancet.* 2002;360(9342):1267–74.
6. Molyneux AJ, Kerr RSC, Yu LM, Clarke M, Sneade M, Yarnold JA, et al. International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised comparison of effects on survival, dependency, seizures, rebleeding, subgroups, and aneurysm occlusion. *Lancet.* 2005;366(9488):809–17.
7. Moret J, Pierot L, Boulin A, Castaings L. “Remodelling” technique of the arterial wall in the endovascular treatment of intracranial aneurysms. *Neuroradiol.* 1994 36(suppl 1): S83.
8. Moret J, Cognard C, Weill A, Castaings L, Rey A. The “remodelling technique” in the treatment of wide neck intracranial aneurysms. Angiographic results and clinical follow-up in 56 Cases. *Interv Neuroradiol.* 1997 Mar 30;3(1):21–35.
9. Pierot L, Spelle L, Leclerc X, Cognard C, Bonafé A, Moret J. Endovascular treatment of unruptured intracranial aneurysms: comparison of safety of remodeling technique and standard treatment with coils. *Radiology.* 2009 Jun;251(3):846–55.
10. Pierot L, Cognard C, Anxionnat R, Ricolfi F. Remodeling technique for endovascular treatment of ruptured intracranial aneurysms had a higher rate of adequate postoperative occlusion than did conventional coil embolization with comparable safety. *Radiology.* 2011 Feb 1;258(2):546–53.
11. Pierot L, Cognard C, Spelle L, Moret J. Safety and efficacy of balloon remodeling technique during endovascular treatment of intracranial aneurysms: critical review of the literature. *Am J Neuroradiol.* 2011 Feb 24;33(1):10–3.
12. Schumacher M, Weber J. Aneurysm treatment – a neuroradiologic success story. *Clin Neuroradiol.* 2008;(4):203–15.
13. Sluzewski M, Rooij WV, Beute G. Balloon-assisted coil embolization of intracranial aneurysms: incidence, complications, and angiography results. *J Neurosurg.* 2006 Sep;105(3):396–9.

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