5 Current Devices and Uses

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Abstract

The prevalence of saccular intracranial aneurysms is about 1–3% in the general population. The introduction of the Guglielmi detachable coil system, three decades ago, provided a new approach for treating aneurysms without the need for a craniotomy. In the new era of technological advancements, several devices have been developed to aid endovascular treatment such as flow diverters, flow disrupters, and stent- or balloon-assisted coil embolization. Herewith, we provide a summary of the latest innovations in the endovascular treatment of cerebral aneurysms.

Keywords

Cerebral aneurysm · Endovascular surgery
Coil · Stent · Embolization · Device

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5.1 Introduction

The prevalence of saccular intracranial aneurysms (IA) in the general population is approximately 1–3%, with most being asymptomatic until the moment of rupture. Rupture of an aneurysm and the following subarachnoid hemorrhage (SAH) is an emergency event that is linked with a high mortality rate (25–45%) as well as with possible significant permanent neurological impairment. The quality of life is dramatically reduced in patients with ruptured IA. Numerous risk factors for IA development have been suggested, such as Ehlers-Danlos syndrome, autosomal dominant polycystic kidney disease (ADPKD), neurofibromatosis, and positive family history of IA. The risk of IA rupture is higher in women, with the sex ratio being 1,5 [1–3].

Clipping of the aneurysm neck with craniotomy was the optimal treatment of IA. All that changed 30 years ago with the introduction of endovascular approaches for the treatment of IA and especially the Guglielmi detachable coil system's entry. Dr. Fedor Serbinenko is considered the father of endovascular neurosurgery, as it was him who in 1974 first proposed the use of a detachable balloon for the management of intracranial aneurysms and vascular lesions. Early technical difficulties, such as the device's cumbrousness, were the main reason for this method

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being discontinued, but the era of endovascular neurosurgery had just begun [2–4].

The initial dilemma of "clip vs. coil" after the widespread use of the Guglielmi device led to the conduction of two large studies, the International Subarachnoid Aneurysm Trial (ISAT) and the International Study of Unruptured Intracranial Aneurysms (ISUIA). Ultimately, these studies' results supported the use of coil over clip in terms of overall morbidity and mortality (ISAT: 30% vs. 23%, ISUIA: 13% vs. 10%). Open approaches are still utilized in selected cases of IA (e.g., in the presence of complex or giant aneurysms, aneurysms of the posterior circulation, or failure of endovascular approaches) [2, 3, 5, 6].

Currently, novel devices have been developed for IA's endovascular treatment, such as balloon-assisted coiling system (BAC), stent-assisted coiling system (SAC), Flow Diverters, Flow Disrupters, and Medina embolization system (Table 5.1). All these devices were designed to treat IA, which cannot be feasibly treated with the standard coil method and otherwise would require an open approach [2, 3]. Herewith, we provide a summary of the latest innovations in the endovascular treatment of cerebral aneurysms. The indications, efficacy, and complications associated with the use of each device will be discussed.

5.1.1 The Guglielmi Detachable Coil System (GDC)

The filling of the aneurysmal cavity for IA treatment had been initially described by Werner et al. back in 1940 when via an extravascular approach they attempted to puncture the aneurysmal cavity and introduce a wire into the aneurysm [7]. During the next 50 years, several other authors described various extravascular and intravascular (including Serbinenko) approaches to occlude the aneurysmal cavity. The success rates of those methods varied, with many technical difficulties. These issues, together with the widespread use of aneurysmal clipping, were the main reason these methods did not find widespread implementation. Nevertheless, endovascular treatment's previous efforts resulted in the innovation of new delivery systems such as microcatheters of variable stiffness ("Trackers"), which can pass through the arterial bifurcations. The development of trackers was a step forward, but two significant problems persisted, namely the lack of appropriate occluding embolization materials and a mechanism for material detachment from the catheter. Finally, in 1990, Guglielmi gave a solution to the aforementioned problems, with the development of appropriate coil materials and a detachment mechanism based on electrolysis. To date, GDC has been systematically used

Table 5.1 Devices that have been developed for intracranial aneurysms endovascular treatment

Technique/device	Mechanism	Main indication	Complications
GDC	Embolization	Berry aneurysms	TE, IOR, RC, RB
BAC	Embolization	Wide neck (over 4 mm), dome/neck ratio < 1,5)	TE, IOR, RC, RB
SAC	Embolization, flow diversion	Wide neck (over 4 mm), dome/neck ratio < 1,5), Unruptured aneurysms	TE, IOR, stent stenosis and migration
Flow diverters	Flow diversion	Large/giant aneurysms, or very small aneurysms, Unruptured aneurysms	TE, rupture in the latent phase, cerebral hemorrhage
Flow disrupters	Flow disruption	Large/giant aneurysms, no need for antiplatelet regimen	TE, IOR, rupture in the latent phase
Medina	Hybrid (embolization and flow diversion)	Wide neck aneurysms	Stroke in 6 months, IOR

TE thromboembolism; *IOR* intraoperative rupture; *RC* recanalization; *RB* rebleeding worldwide and is considered the "gold-standard" for the management of brain aneurysms [8, 9].

The entirety of GDC embolization procedure is accomplished under fluoroscopic guidance while the patient is under general anesthesia, or if possible, sedation. The next step is to confirm access to the femoral artery with a femoral French (F) sheath. The delivery system is promoted via the sheath. The sheath size is usually 6F or 7F, with 7F sheaths preferred when there is a possibility to use a stent or a balloon [10]. The Seldinger technique is utilized to access the femoral artery [11]. When access to the femoral artery has been ensured, a guide catheter is navigated toward the aneurysm's parental artery with the help of a guidewire. The latter is followed by the insertion of a microcatheter via the initial catheter. When the microcatheter is at the level of the aneurysmal cavity a microwire is placed inside the microcatheter, and the microcatheter–microwire complex is guided into the aneurysmal cavity. Confirmation of microcatheter appropriate location (close to the aneurysm dome) is followed by guidewire removal and coils' introduction into the aneurysm. Three types of coils are currently used, the classic platinum-based GDC coil, the Matrix coil, which is a coil similar to GDC but with a polymer coverage (with the ability to induce thrombosis), and hydrogel coated coils. Initially, a 3-D "basket" coil is placed into the aneurysmal cavity to prevent the migration or bulging of the next placed coils in the parent vessel. After the initial 3-D coil placement, the procedure continues with the placement of additional softer coils until the cavity is occluded. The success of the method is confirmed with angiography (with no inflow into the aneurysm). Finally, by electrolysis, there is a detachment of the coil from the microcatheter [8–10, 12, 13] (Fig. 5.1).

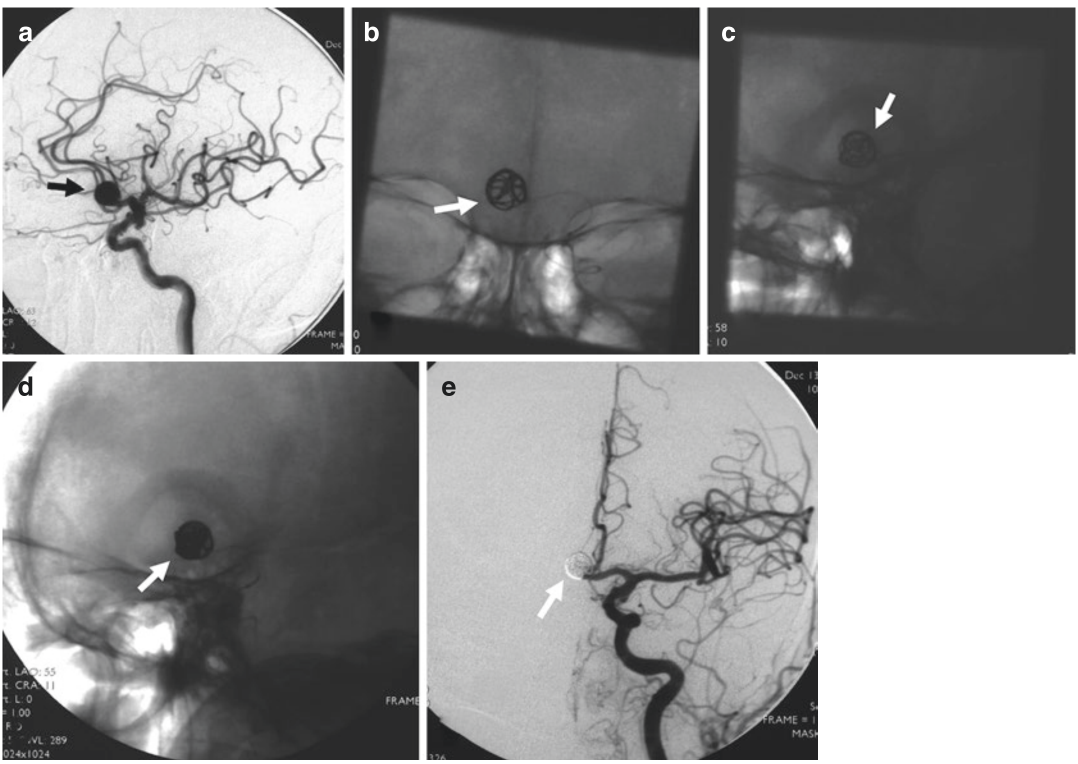

Fig. 5.1 A 76-year-old woman with an anterior communicating artery aneurysm was coiled. (**a**) Lateral view of the left internal carotid artery injection showing the aneurysm of the anterior communicating artery (arrow). (**b**) Frontal view of the unsubtracted image showing the first 3-D coil. (**c**, **d**) Lateral view of the unsubtracted images showing subsequent coils were inserted (arrows). (**e**) Frontal view of the left internal carotid artery injection after aneurysm coiling showing complete occlusion of the aneurysm (arrow)

The two major and life-threatening complications of coil embolization are thromboembolic events and intraoperative rupture. The frequency of thromboembolic events during coil embolization is approximately 5–30%, with the higher frequencies observed in embolization of ruptured aneurysms, wide-neck aneurysms, or in the case of large-giant aneurysms (Fig. 5.2). Nevertheless,

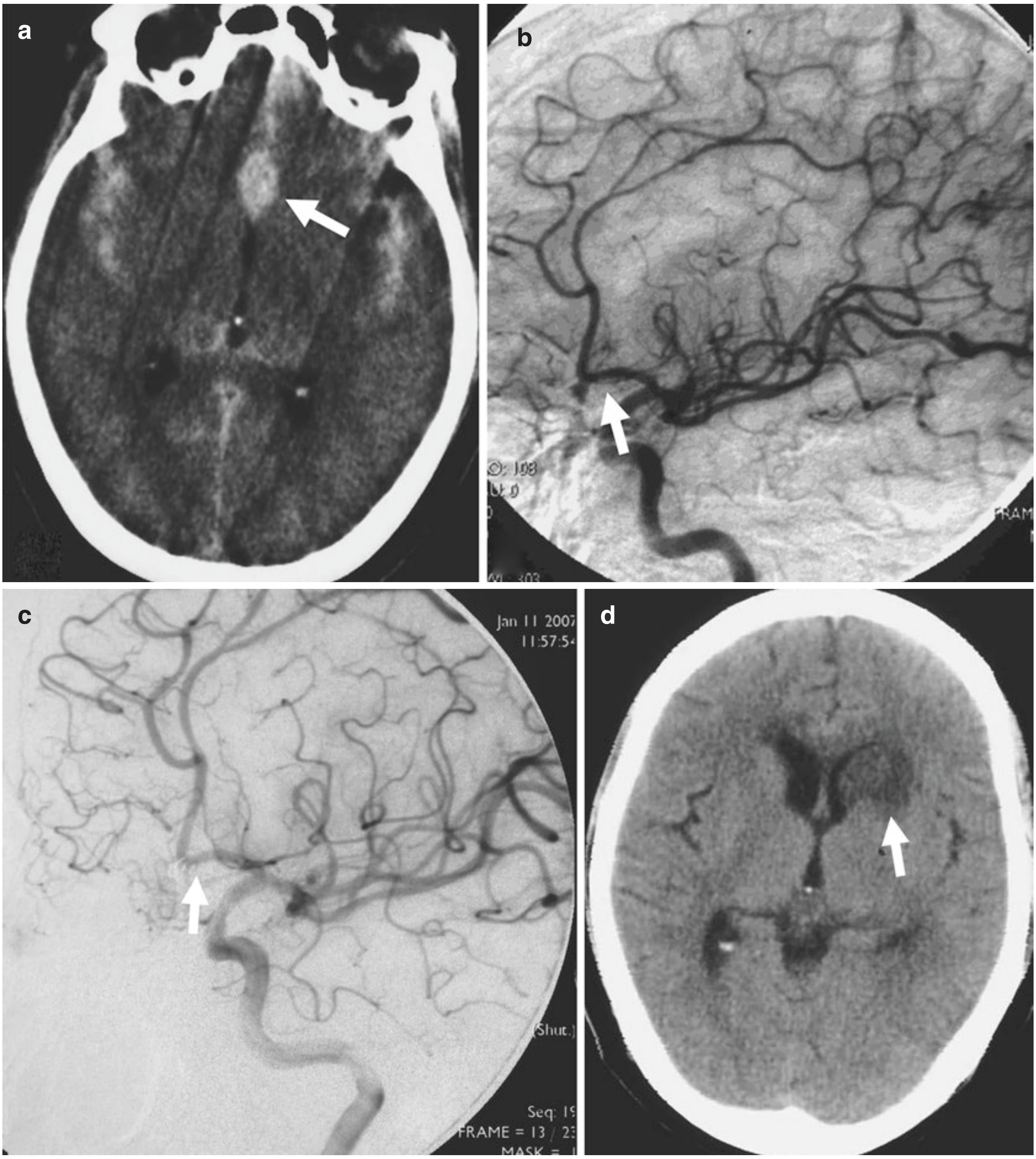

Fig. 5.2 A 44-year-old woman. (**a**) Cranial CT scanning showing subarachnoid hemorrhage from an anterior communicating artery complex aneurysm. (**b**) Oblique view of the left internal carotid artery angiogram showing a left dominant filling of the anterior communicating artery complex and aneurysm. Noting the Heubner's artery arising from the aneurysm neck (arrow). (**c**) Working angle view of the left internal carotid artery angiogram after aneurysm occlusion showing the disappearance of the Heubner's artery due to the retrograde thrombosis (arrow). (**d**) Cranial CT on day 4 after treatment showing the infarction of the head of the caudate nucleus on the left side (arrow)

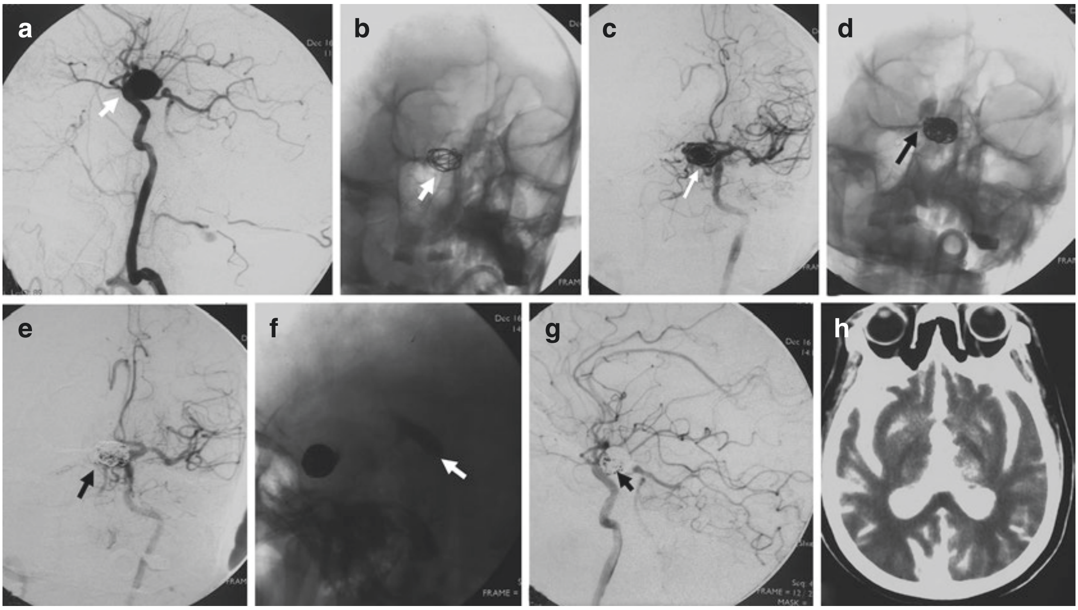

Fig. 5.3 A 68-year-old woman with an incidental paraclinoid aneurysm of the left internal carotid artery. (**a**) Lateral view of the left internal carotid artery injection showing a large paraclinoid aneurysm (arrow). (**b**) Oblique projection of the unsubtraction image showing the first 3-D coil in the aneurysm sac. (**c**) Intraoperative angiogram of the left internal carotid artery. (**d**) Intraoperative unsubtraction image showing the coil mass in the aneurysm sac and contrast extravasation (arrow). (**e**) Frontal projection of the final angiogram image showing no contrast extravasation and incomplete occlusion of the aneurysm (arrow). (**f**) Lateral projection of the unsubtraction image showing the coil mass in the aneurysm sac and contrast extravasation (arrow). (**g**) Lateral projection of the final angiogram image showing no contrast extravasation and incomplete occlusion of the aneurysm (arrow). (**h**) Postprocedural CT image showing diffuse contrast medium extravasation and an enlarged ventricle

some authors propose that the real rate of thromboembolism could be as high as 50–70%, but only a small percentage of them will occur with neurological deficits and will lead to fatal events. The introduction of Diffusion-Weighted Images (DWI)/MRI gave the ability to highlight "small" silent strokes early after the procedure. Thromboembolism is a well-known complication, and a dual-antiplatelet regimen (in unruptured aneurysms) and low molecular weight heparin is administered in the patients before the operation to prevent this complication. Typically, an arterial blood flow obstruction is seen in angiography. Treatment of thromboembolism includes intra-arterial use of antiplatelet, anticoagulant, or other thrombolytic agents such as urokinase with an aim of artery recanalization. Another common treatment option during operation includes mechanical thrombectomy with a stent [2, 10, 14–16].

Intraoperative rupture is the second most common (2–4%) and deadliest complication of IA coil embolization (Fig. 5.3). The mortality rate of intraoperative rupture is approximately 15%. As in thromboembolism, the intraoperative rupture rate is higher in previously ruptured aneurysms. The extravasation of contrast medium suggests aneurysm rupture. The first step after the rupture diagnosis is the injection of protamine to reverse the anticoagulative effect of heparin. Administration of mannitol is required to reduce the raised intracranial pressure. The coil that caused the perforation should remain in the site as it may tamponade the perforation. Instead of removing it, a second microcatheter should be inserted in the aneurysmal cavity to place more coils until the extravasation stops. In the case of an early rupture, the inflation of a non-detachable balloon in the aneurysm's parental artery may limit the extent of bleeding [10, 16, 17].

Aneurysm recanalization (or regrowth) is another well-known complication of coil embolization and may occur in approximately 2–10% of patients at some point after the operation. Despite that, the recanalization would not be significant and not require treatment in half of the patients with this complication. The wide neck (over 4 mm) of the aneurysm is considered a major risk factor for aneurysm regrowth and may lead to recurrence in 85% of the patients treated with the GDC system. The latter is one of the main reasons novel endovascular devices were developed to treat such aneurysms (Fig. 5.4). Rebleeding of the aneurysm is another complication after IA embolization and occurs in approximately 1% of the patients [16, 18].

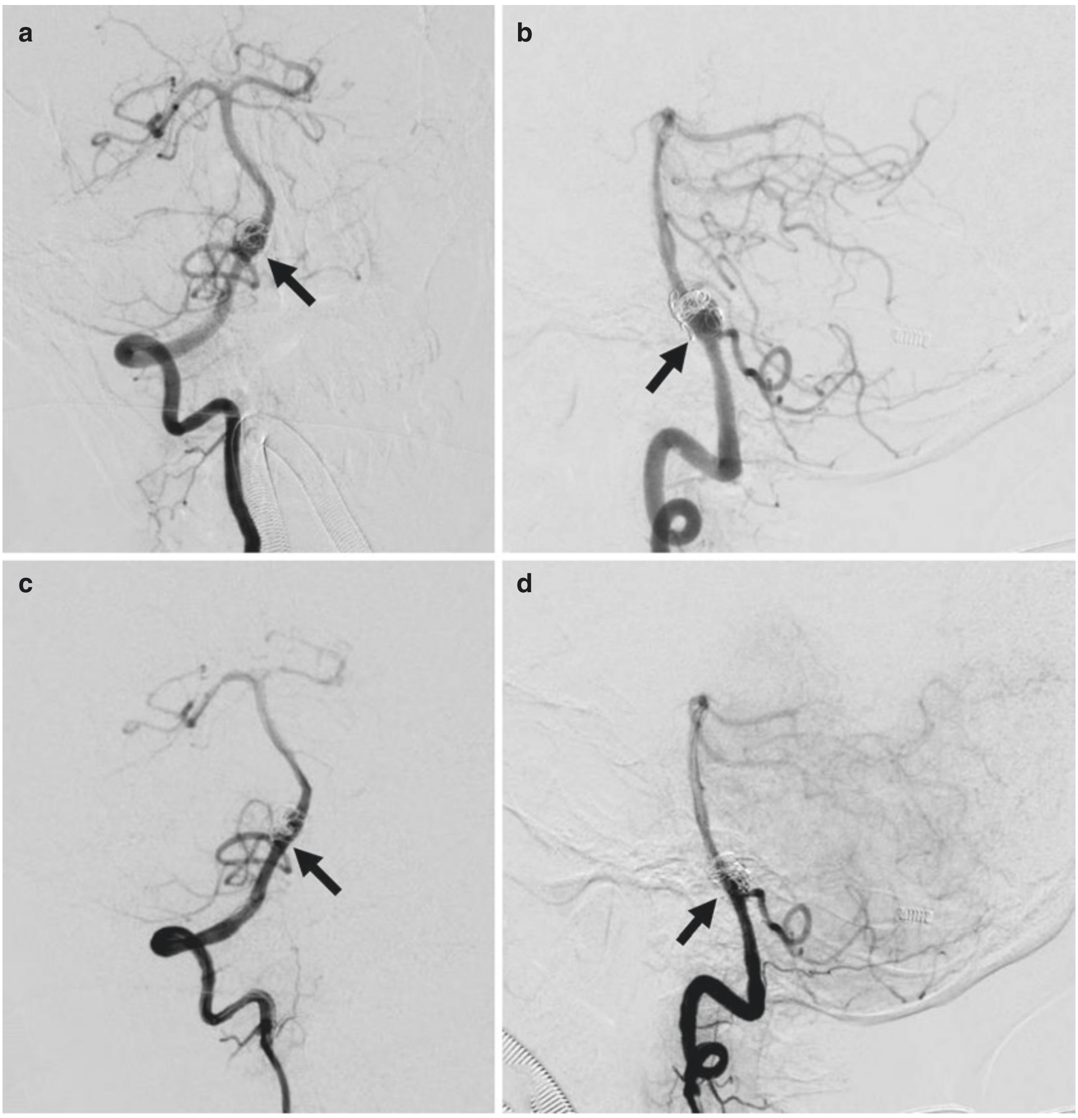

Fig. 5.4 A 50-year-old woman presented with a recurrent vertebral artery-posterior inferior cerebellar artery dissecting aneurysm. Frontal view (**a**) and lateral view (**b**) of the right vertebral artery injection showing a recurrent dissecting aneurysm after LVIS stent-assisted coiling (arrows). Frontal view (**c**) and lateral view (**d**) of the right vertebral artery injection showing the aneurysm was retreated with 3.5 mm × 35 mm Tubridge flow diversion (Microtherapeutic, Shanghai, China) and coils (arrows)

5.1.2 Balloon Assisted Coiling (BAC)

The GDC system for the treatment of berry aneurysms soon became the procedure of choice, but results were poor for aneurysms with a wide neck or giant aneurysms. The main reasons for failure were the aneurysm recanalization and coil herniation. Soon it was visible that a coil stabilization mechanism was necessary for the treatment of wide-neck aneurysms [18, 19]. Moret et al. in 1997 described a method of stabilization with the use of a non-detachable balloon, the so-called "Remodeling technique" (or "Balloon assisted coiling"). They placed a non-detachable balloon next to the aneurysm before the coils' insertion, intending to stabilize the coils and keep them inside the aneurysmal cavity. The initially deflated balloon is directed in the parental artery of the aneurysm. Then, the balloon is inflated to cover the aneurysm neck. After balloon inflation, coil insertion may begin. After each coil placement, the balloon is deflated and coil stability and aneurysm occlusion are evaluated with angiography. The circle of inflation-coil placement-deflation continues until the aneurysm is occluded, and the coils are stabilized (Fig. 5.5) [19].

The main indication for BAC is the treatment of wide-neck aneurysms (over 4 mm), but today it is clear that the dome/neck ratio rather than the absolute value of neck diameter can better predict the success rate of GDC. A dome/neck ratio lower than 1.5 is considered a good indication for BAC (Fig. 5.6). Today BAC is additionally utilized in the classic GDC procedure in cases of intraoperative rupture as previously discussed. The total or subtotal occlusion rate after BAC was over 90% in Moret et al. series and other series [19, 20].

The complication rates and comparison with the standard GDC procedure have been analyzed in two multicenter trials, the "CLARITY" and "ATENA" conducted by Pierot et al., and concern ruptured and unruptured aneurysms, respectively. The results from both of these studies found similar or slightly higher complication rates (thromboembolism and intraoperative rupture) compared to the standard GDC procedure [2, 21, 22].

5.1.3 Stent-Assisted Coiling (SAC)

Another technique used in the treatment of "complex" or "wide" neck aneurysms involves using a stent. The idea behind the use of stents in the SAC procedure is similar to that of a balloon in BAC. In both techniques, a wall-like structure prevents the herniation or migration of coils in the parental artery. Additionally, in the SAC technique, the stent remains in the parental artery after the operation and offers long-term prevention of coil herniation. Theoretically, the stent limits the blood inflow into the aneurysm and thus the aneurysm's regrowth. Currently, the stents applied in the treatment of IA are specialized for delivery and placement in the intracranial vessels, contrary to the previously used coronary stents. "Open" and "Closed" types of stents are used in the SAC technique, with the open type being more flexible and preferred in bifurcated aneurysms. "Neuroform" and "Enterprise" stents are the most frequently used stents for SAC (Fig. 5.7) [2, 23]. Accero is a novel, very promising braided self-expandable stent, which can easily be directed through the intracranial vessels and may overcome some challenges observed with the laser-cut stents [24]. In order to prevent stent thrombosis, a dual antiplatelet regimen is required in patients following. Consequently, the SAC technique was initially limited to unruptured aneurysms, but today is also utilized in ruptured aneurysms in some institutions [2, 23, 25].

In the standard SAC procedure, the stent is implanted in the parental artery before the microcatheter placement. This method's main disadvantage is that sometimes the microcatheter cannot pass through the tiny stent struts. For this reason, an alternative method has been developed, the so-called "Jailing-technique." In jailing technique, the coil microcatheter is placed into the aneurysmal cavity before stent delivery. When the stent is well placed and deployed, the

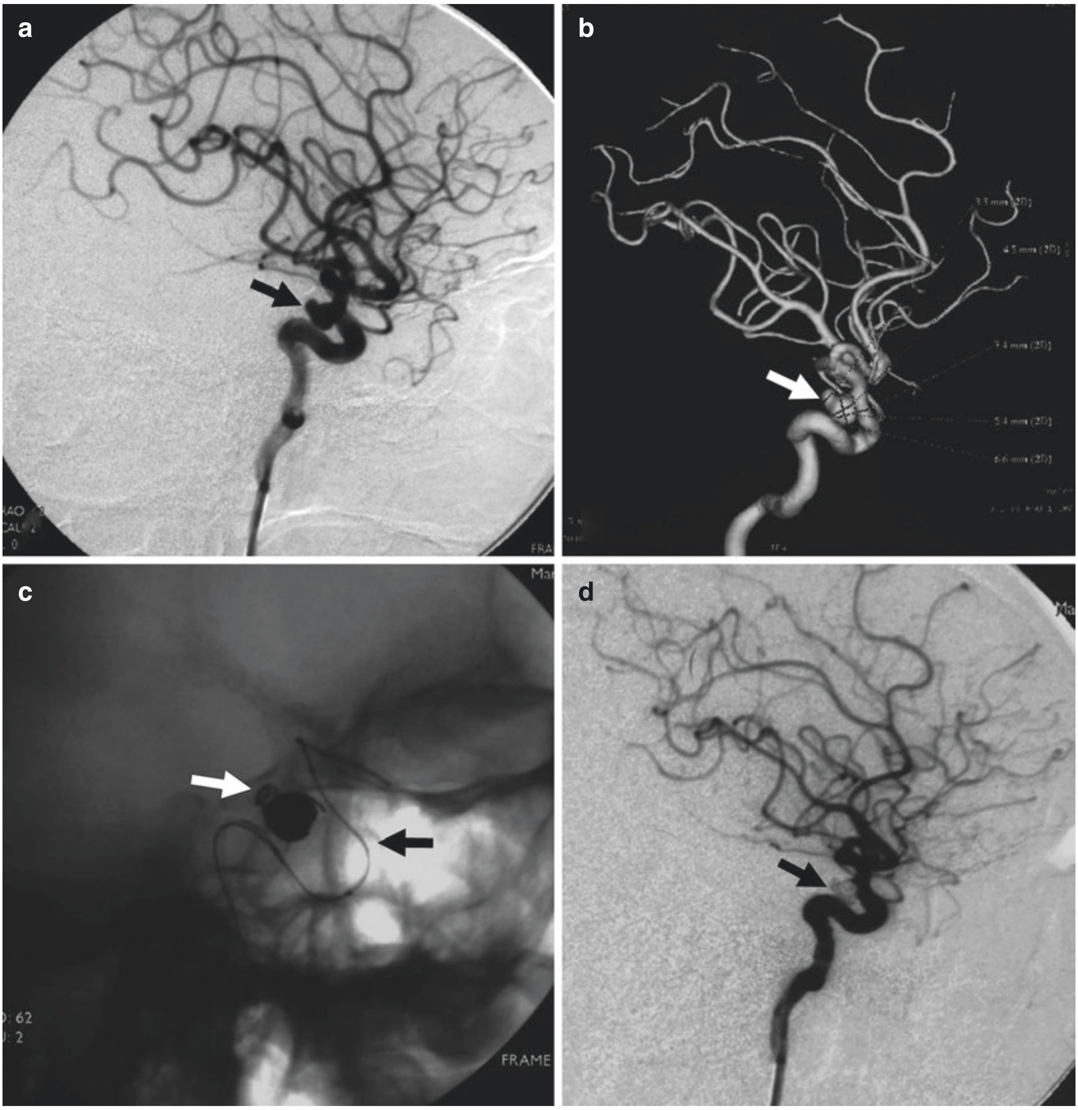

Fig. 5.5 A 54-year-old man presented with a ruptured posterior communicating artery aneurysm. (**a**) Oblique view of the left internal carotid artery injection. (**b**) 3-D reconstruction of the left internal carotid artery injection. Showing a 5 mm × 6 mm aneurysm of posterior communicating artery segment (arrows). (**c**) Unsubtracted image showing the aneurysm was coiled (white arrow) with the assistance of a 4 mm × 20 mm Hyperglide balloon catheter (Medtronic ev3, USA) (black arrow). (**d**) Lateral view of the left internal carotid artery injection showing the aneurysm was completely occluded (arrow)

coil introduction via the microcatheter can begin. The disadvantage of this method is the limitation of microcatheter maneuvers after stent deployment. The “Y-technique” is another method used for aneurysms of the basilar tip (or other bifurcated aneurysms) and includes the use of two stents (stent inside stent). The first stent is placed into the main artery and one of the two branches, while the other stent is placed inside the first stent up to the level of bifurcation and then continues to the other branch. Finally, the neck of the aneurysm is fully covered, and the insertion of the coils follows. Lately, another method combining BAC and SAC procedures has been

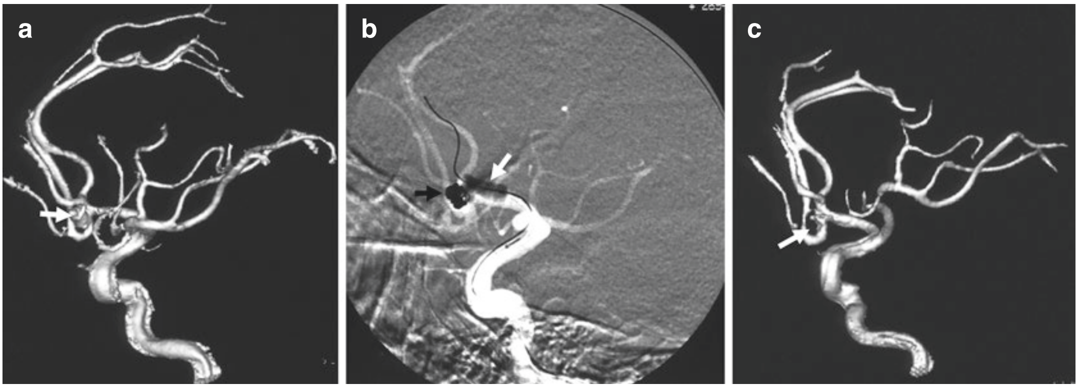

Fig. 5.6 A 48-year-old woman presented with an anterior communicating artery aneurysm. (**a**) 3-D reconstruction of the left internal carotid artery injection showing an anterior communicating artery aneurysm (arrow). (**b**) Roadmap image showing the aneurysm was coiled (black arrow) with the assistance of a 4 mm × 7 mm Hyperform balloon catheter (Medtronic ev3, USA) (white arrow). (**c**) 3-D reconstruction of the left internal carotid artery injection after embolization showing disappearance of the aneurysm (arrow)

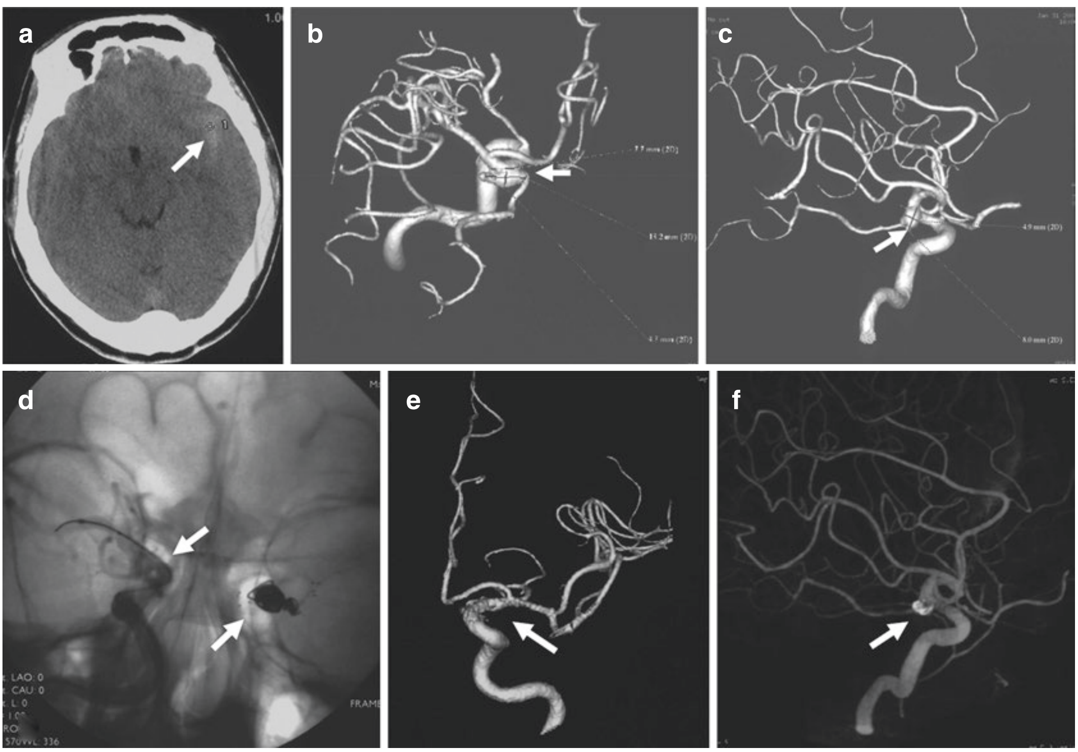

Fig. 5.7 A 62-year-old man presented with a ruptured posterior communicating artery aneurysm. (**a**) CT scanning showing subarachnoid hemorrhage of the left Sylvian fissure. (**b**) 3-D reconstruction of the left internal carotid artery injection showing a 13 mm × 5 mm posterior communicating artery aneurysm (arrow). (**c**) 3-D reconstruction of the right internal carotid artery injection showing a 5 mm × 8 mm posterior communicating artery aneurysm (arrow). (**d**) Frontal view of the unsubtracted image showing bilateral aneurysms were all treated with Neuroform stent-assisted coiling (arrows). (**e**) 3-D reconstruction of the left internal carotid artery injection after treatment showing the disappearance of the aneurysm (arrow). (**f**) 3-D reconstruction of the right internal carotid artery injection after treatment showing the coil mass in the aneurysm (arrow)

developed. Initially, a typical BAC procedure is performed, and then a stent is placed in the neck of the aneurysm. The stent stabilizes the coil mass and blocks the blood inflow into the aneurysmal cavity, while there is no limitation in the microcatheter maneuvers because the stent is implanted after the placement of coils [2, 23]. The theoretical advantage of the last method has been supported by the results of the Spiotta et al. study [26].

The total occlusion rate in SAC is approximately 75% in wide-neck aneurysms. The rate of thromboembolic events is approximately 10%, significantly higher compared to the standard GDC procedure. Recanalization rate is approximately 5–6%, while stent stenosis is observed in 1% of the patients. Up to date, it is unclear whether the SAC procedure is superior to BAC or vice versa. Park et al. performed a study to compare these techniques but did not find significant differences in efficacy, complications, and mortality rates [2, 27, 28].

5.1.4 Flow Diverters

The observation that the stents induce a reduction in blood inflow into the aneurysmal cavity led to the creation of stents specially made for this purpose. However, the high porosity of the stents limited the efficacy in terms of restricting the blood inflow. The development of new devices of low porosity gave the solution to this problem. These devices are called "flow-diverters"(Fig. 5.8). Flow diverters are "stent-like" devices with low porosity and high pore density, which divert blood flow away from the aneurysm leading to blood stasis and clot formation inside the aneurysm similar to a coil. The endothelization observed in the device surface further obstructs blood flow. Some of the devices used as flow diverters are the "Pipeline," "Silk," "Stryker," and "FRED." Currently, Pipeline (Medtronic-ev3, USA) and Surpass (Stryker, USA) are the only devices with US (United States)/FDA (Food and Drug Association) approval. Another advantage of the flow diverters over other devices is the absence of perioperative maneuvers within the aneurysm, ultimately leading to a reduction of intraoperative rupture (Fig. 5.9). The risk of rupture is increased in giant aneurysms whose wall is very vulnerable (Fig. 5.10) [2, 28].

For this reason, flow diverters are predominantly utilized in the treatment of such large-giant aneurysms. Wide neck or tiny aneurysms may also be treated with flow diverters. As with stents, a dual antiplatelet regimen is necessary. Thus, the use of flow-diverters in ruptured aneurysms is controversial. Unlike the standard method of coil embolization, thrombus induction within the aneurysm may not be achieved immediately. It is estimated that only 10–20% of the

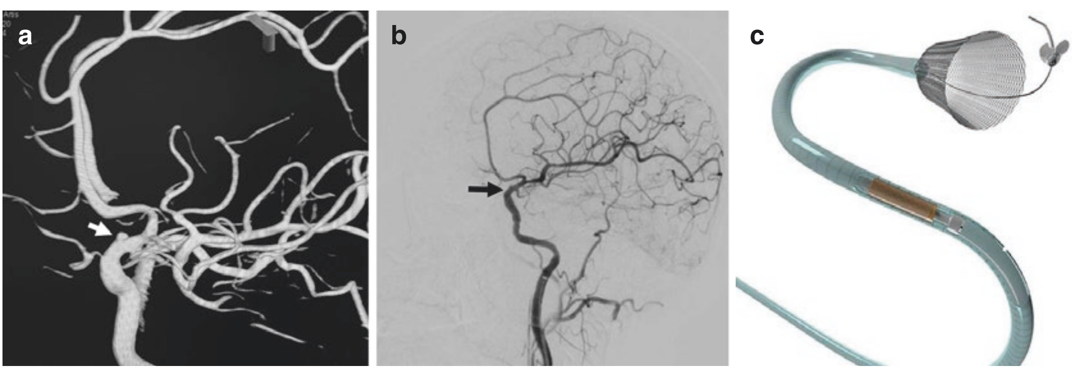

Fig. 5.8 A 50-year-old woman presented with Hunt–Hess grade 1 subarachnoid hemorrhage. (**a**) 3-D reconstruction of the left internal carotid artery injection showing a 1.5 mm × 1.5 mm blood-blister like aneurysm (arrow) of the supraclinoid internal carotid artery. (**b**) Oblique view of the internal carotid artery injection showing the aneurysm was treated with 3.5 mm × 20 mm Pipeline flow diversion and a 1.5 mm × 2 cm coil (Nano, Stryker, USA) (arrow). (**c**) Picture showing the Pipeline flow diversion system (Medtronic, USA)

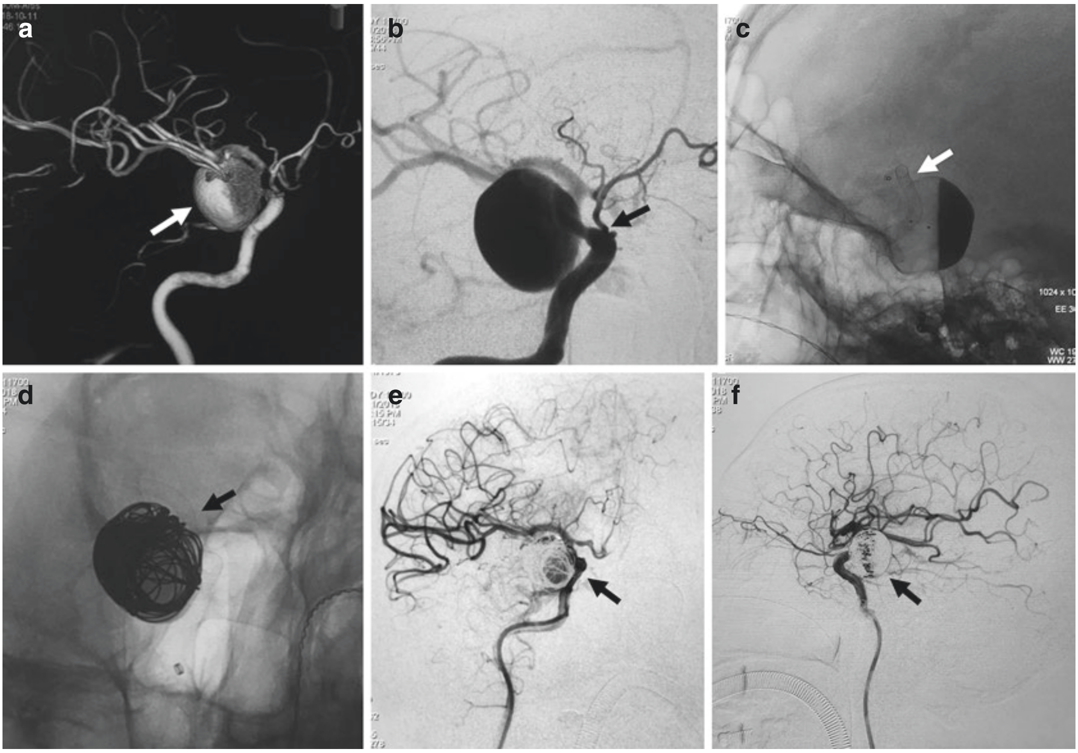

Fig. 5.9 A 42-year-old man presented with an incidental giant aneurysm of the internal carotid artery. (**a**) 3-D reconstruction of the right internal carotid artery injection showing a giant aneurysm of the posterior communicating artery segment of the internal carotid artery (arrow). (**b**) Oblique view of the right internal carotid artery injection showing the giant aneurysm (arrow). (**c**) Unsubtracted image showing the Pipeline flow diversion (arrow). (**d**) Unsubtracted image showing additional coils were placed (arrow). (**e**) Oblique angiography showing the patent internal carotid artery (arrow). (**f**) Lateral view of the angiography showing the aneurysm was partially occluded

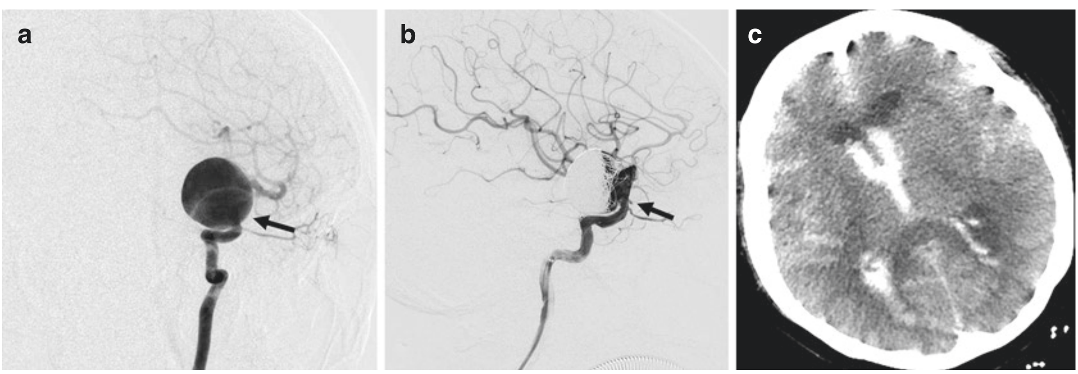

Fig. 5.10 A 39-year-old woman presented with a blurred vision of the left eye. (**a**) Oblique view of the left carotid artery injection showing a giant aneurysm of the supraclinoid segment of the internal carotid artery (arrow). (**b**) Oblique view of the left internal carotid artery injection showing the aneurysm was partially thrombosed after flow diversion and additional coils treatment. (**c**) CT scanning showing aneurysm rupture 20 h after treatment and the patient died

aneurysms will be occluded entirely after applying these devices. In total, it can take up to a year to achieve complete occlusion and shrinkage of the aneurysm. However, it should be mentioned that giant aneurysms have a very high risk of intraoperative rupture compared to other aneurysms. Therefore, the optimal treatment should be assessed case-by-case by weighing the risk of rupture in the latent phase (flow-diverters) with the risk for intraoperative rupture (other endovascular approaches and surgical clipping) [2, 28–30].

Thromboembolic events and device migration are not unusual after flow diverter implantation. The risk of intraoperative rupture still exists despite the lack of maneuvering inside the aneurysm. Obstruction of the parental artery's perforators is another complication of this technique. The obstruction usually concerns the paraclinoid carotid artery and ophthalmic artery branches, although it seems that a significant degree of coverage is required to cause ischemia in the perforator territory [28].

Early and late (after 1–2 months) ruptures may occur, with early ruptures being more common. The pathophysiological mechanism of late rupture is still unclear, but the aneurysm wall's inflammatory response to elements secreted from the clot is considered a possible cause. The overall rupture frequency is about 2–4%. Prognosis post aneurysm rupture is poor, but this is probably related to the nature of the aneurysms (large/giant aneurysms) treated with this technique. Late intraparenchymal cerebral hemorrhage (not related to aneurysm rupture) is another paradoxical event after the treatment with flow-diverters with a frequency of 3–4%. The majority of intraparenchymal hemorrhages are located in the ipsilateral parenchyma in which the device is implanted. Thus, the correlation of the device with this event is unavoidable. Other authors suggest that the hemorrhagic transformation of small ischemic lesions in the brain-territory (caused by the device) of the parental artery is a possible pathophysiological mechanism, while others suggest that hemodynamic alterations are the primary mechanism. Antiplatelets' role in this event is unclear, but the occurrence of the hemorrhage predominantly in ipsilateral parenchyma discredits them as a cause [28–31].

5.1.5 Flow Disrupters

Although flow diverters provided several advantages, their intraluminal location generates a high risk of thromboembolic events and a necessity for a prophylactic antiplatelet regimen. Flow disrupters are devices whose mechanism is similar to flow diverters, with the difference that they possess an intrasaccular location instead of intraluminal. Thus, they overcome the need for an antiplatelet regimen and the restriction of application only in unruptured aneurysms. The "WEB" (Woven Endo Bridge) is a nitinol-based flow disrupter, available in a spherical or cylindrical shape. One or two layers of wire are available, with the efficacy being similar in both versions. The feasibility is very high (95–100%), with the device being preferred in wide-neck bifurcated aneurysms such as basilary tip aneurysms or aneurysms located in anterior and middle cerebral arteries. "Artisse" is another oval-shaped disrupter like WEB and is mainly used for the management of small aneurysms. These devices have yet to be certified by US-FDA and are currently used in European countries. Despite their intrasaccular location, thromboembolic events may occur in 10% of the patients and the risk of rupture in the latent period still remains [32, 33].

5.1.6 Hybrids and Other Novel Devices

Currently, many variations of the devices mentioned above have been developed for the endovascular treatment of IA. Medina embolization device (MED) is a woven cage that combines an embolization device and a flow disrupter. It is essentially a coil with the ability to transform into a 3D structure when fully deployed inside the aneurysmal cavity. The barrel stent is another device used in bifurcated aneurysms with an expanded middle part to fully cover the neck circumference. The "eCLIPS" and "PulseRider" are also endovascular devices used in bifurcated aneurysms. eCLIPS has an anchor segment to stabilize the structure into the main vessel and a leaflet segment used for the placement of coils into the aneurysm. This is another hybrid device because the leaflet segment blocks the blood inflow into the aneurysm. The Pulserider is a "Y" or "T" shaped structure that helps the coiling of bifurcated aneurysms with concurrent protection of artery branches. Finally, many other experimental devices are being developed and are expected to be used for IA's endovascular treatment in the coming years [3, 25].

5.2 Conclusion

Endovascular treatment of IA is an effective and relatively safe method that has replaced, to a great extent, classic surgical clipping. The development of novel techniques and devices such as BAC, SAC, and flow diverters/disrupters for the treatment of wide-neck or giant/large aneurysm has expanded the use of endovascular approaches beyond the exclusive treatment of berry aneurysms. Finally, other hybrid devices are being developed to treat challenging aneurysms such as basilary tip aneurysms and are expected to be used in the upcoming years.

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