Initial Experience with Intracranial Stent-Graft Use Technical Notes

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Summary

We describe our initial experience with the placement of two premounted balloon expandable intracranial Jostent stent-grafts within the intracavernous internal carotid artery for the treatment of a symptomatic large intracavernous aneurysm in one case and a post-traumatic carotidocavernous fistula in the second. Among the initial technical complications we encountered were stent-graft migration and rapidly progressive intragraft thrombosis, with delayed sealing of the stent-graft coverings and exclusion of the pathologies relating to the use of abciximab in both cases. Despite these initial problems both cases had excellent short-term clinical outcomes with angiographic exclusion of both lesions by day three and good clinical and angiographic outcomes at one and two months respectively.

Introduction

The concept of endovascular grafting was first described by Charles Dotter in 1969¹. The first clinical reports of the use of endovascular grafts, stent-grafts or covered stents emerged in the early to mid 1990's^{2,3,4}. These involved the endovascular treatment of abdominal, thoracic and peripheral aneurysms and arteriovenous fistulas and later the extracranial vessels⁵. The initial devices used for the treatment of non-aortic vessels consisted of "home-made" stent-

grafts usually consisting of a piece of PTFE, Dacron or autologous vein tied onto a balloon-expandable stent (usually a Palmaz stent). Later commercially manufactured stent-grafts became available for use in peripheral vessels including the Corvita device (Corvita Inc., Miami Beach, FL), Wallgraft (Schneider, Boston Scientific, Natick, MA), Haemobahn (WL Gore, Flagstaff, AZ) and Jostent (Jomed GmbH, Rangendingen, Germany). Smaller coronary stent-graft devices were developed for use in treating coronary arteries and coronary saphenous vein bypass stenoses. These include the Jostent coronary stent-graft and Symbiot (Boston Scientific Scimed, Maple Grove, MN). To date there are no commercially manufactured stent-grafts specifically available (or registered) for use in the intracranial vessels. We herein describe our initial experience with the intracranial use of the Jostent coronary stent-graft in two cases and discuss some important general aspects of stent-graft usage.

Case 1

A 55-year-old woman had suffered from intermittent left-sided temporal headaches for several years. More recently she had developed 6th nerve palsy on the same side. A magnetic resonance (MR) scan showed a large left-sided intracavernous aneurysm. Cerebral digital subtraction angiography showed this aneurysm to

measure 19 mm by 12 mm with a 10 mm neck arising from the middle of the C5 horizontal intracavernous carotid segment (figure 1A). Also discovered at angiography were two other aneurysms being a much smaller contralateral intracavernous aneurysm and a 3 mm ipsilateral superior hypophyseal aneurysm. Of note was the lack of any significant tortuosity within the ipsilateral extracranial and proximal intracranial internal carotid artery (ICA). Various treatment options were considered at this stage. Despite good cross-filling from the contralateral ICA, parent vessel occlusion (PVO) was not considered initially mainly due to the presence of the contralateral intracavernous aneurysm. Direct coiling of the aneurysm was considered feasible, but a large number of coils would be required rendering this option too expensive given the limited amount of funding available together with the high probability of future coil compaction and possible need for a second coiling procedure. With the favorable access anatomy it was decided to attempt exclusion of the aneurysm by means of stent-graft placement. The patient was placed under general anaesthesia and systemically heparinized so as to keep the activated clotting time (ACT) at around 300 seconds. No antiplatelet agents were given initially. An 8F guiding catheter (Lumax Northstar, Cook, Bloomington, IL) was placed in the distal left extracranial ICA. Through this a Renegade microcatheter (Target Therapeutics/ Boston Scientific, Fremont, CA) was manipulated into a branch of the left middle cerebral artery (MCA) over a Transcend Soft-Tip guidewire (Target Therapeutics).

The Transcend wire was then replaced by a relatively stiffer Luge coronary guidewire (Boston Scientific). Over this a 5 mm x 19 mm Jostent pre-mounted balloon-expandable stent-graft was manipulated into the horizontal intracavernous segment across the aneurysm opening and deployed to a diameter of 5 mm. An immediate endoleak was noted upon deflation of the balloon. Being uncertain as to whether this represented an endoleak through the thin graft material or one around the proximal or distal ends of the graft we decided to re-inflate the balloon and to further expand the stent-graft diameter to 5.4 mm. In so doing, however, the stent-graft migrated proximally with the distal end of the stent-graft collapsing into the aneurysm (figure 1B). A second stent-

graft measuring 5 mm x 16 mm was then placed over the Luge guidewire. Great difficulty was encountered in manipulating the second stent-graft through the first, particularly at the level of the distal outlet which had partly prolapsed into the aneurysm sac. What helped was to partly inflate the balloon creating a "dogbone" appearance to the anterior part of the balloon which helped to displace the distal end of the deployed stent-graft down back into the ICA thereby allowing the second stent-graft to pass through the first. The second stent-graft was then deployed fully sealing the vessel with no further endoleak at this stage. Despite an ACT of over 300 seconds a repeat arteriogram some 15 minutes later showed progressive thrombotic occlusion of the stent-graft (figure 1C).

The Renegade microcatheter was then placed in the stent-graft lumen and a bolus of 15 mg of abciximab (ReoPro, Eli Lilly, Alexandria, VA) was then injected slowly at this point. As only a partial response to this infusion was noted at 20 minutes, a further 7.5 mg (being the balance of the abciximab intended for further 12 hour infusion) was also slowly injected intra-arterially. At 40 minutes most of the visible thrombus had dissolved. No distal emboli were seen. The patient was awoken and transferred to the intensive care unit. No clinical neurological deficits were encountered. A follow-up arteriogram done on the second day showed complete resolution of the thrombus within the stent-graft but persistent filling of the aneurysm due to leakage through the stent-graft PTFE cover (figure 1D). Treatment with low-molecular weight heparin was commenced at this stage. An arteriogram on day three showed good patency of the stent-graft with no contrast opacification seen within the aneurysm lumen (figure 1E). Clinically the patient complained of an ipsilateral temporal headache although the nature of this differed from that experienced before the procedure. This we attributed to traction by the stent-graft on the dural openings of the sinus. This headache persisted for several days but was well managed with minor analgesics and non-steroidal anti-inflammatory drugs. The sixth nerve palsy had by now also much improved with only a partial residual deficit seen with far lateral gazing.

After the arteriogram on day three the femoral sheath was removed and oral antiplatelet therapy commenced with Plavix 75 mg

and Disprin 150 mg tablet daily. She was discharged two days later. A follow-up arteriogram was done one month later which showed full patency of the stent-graft and complete exclusion of the aneurysm. She had a very mild residual sixth nerve deficit with diplopia only with far lateral gazing. When contacted telephonically one month thereafter she had no more double vision and no further headaches.

Case 2

A 27-year-old male motor-vehicle accident polytrauma victim developed clinical evidence of a right-sided carotidocavernous fistula shortly after admission. He was intubated and ventilated due to pulmonary complications but nevertheless awake. A computed tomographic (CT) scan showed proptosis and a distended superior ophthalmic vein. His vision was fully intact. Cerebral arteriography showed a single-hole tear of the anterior wall of the proximal genu (C4/C5 junction) of the intracavernous right internal carotid artery (ICA) (figure 2A). The fistula drained primarily through the ipsilateral superior ophthalmic vein but also retrogradely through the superficial middle cerebral vein. It was decided to attempt closure of the fistula using a stent-graft which was done at ten days after the initial accident. The decision to use a stent-graft in this case was largely a logistical one, due primarily to the non-availability at the time of the procedure of suitable detachable balloons anywhere in our country together with little likelihood of further supply of balloons in the foreseeable future. We also felt that there was a degree of urgency in closing the fistula given the presence of the cortical venous reflux.

A 9F guiding catheter (Northstar Lumax, Cook, Bloomington, IL) was placed in the proximal right ICA through which a Renegade microcatheter (Target Therapeutics) was manipulated into one of the M2 branches of the right middle cerebral artery (MCA). A Luge exchange coronary guidewire was then placed through this and the microcatheter removed. A 5 mm x 16 mm, Jostent stent-graft was manipulated over the Luge exchange wire into a suitable position spanning the proximal genu and the adjacent C4 and C5 carotid segments across the opening of the fistula. Some spasm was encountered in the extracranial ICA during stent-graft manipulation but this did not require specific treatment. The stent-graft was deployed

and expanded to a diameter of 5 mm. A slow endoleak through the fistula was noted 15 minutes after deployment. Fearing a possible distal endoleak we re-inflated the balloon to 5.29 mm but the leak persisted. We then decided that the leak was actually occurring through the graft material and decided at that stage to remove the balloon. During removal of the balloon the stent-graft displaced slightly proximally but was still left covering the opening of the fistula. Heparin had been given during the procedure with the activated clotting time (ACT) maintained at around 300 seconds. After a further 15 minutes a slow endoleak was still present but now with early thrombosis seen within the distal aspect of the stent-graft (figure 2B). 30 minutes later further slowly progressive intrastent-graft thrombus development was noted but not to the degree that we felt warranted urgent intervention. The patient was awoken from the anaesthetic and other than indicating a right sided headache appeared otherwise well.

We had struggled to maintain the ACT at 300 seconds requiring the administration of over 15000 units of heparin during the procedure. We had intended to continue the heparinization after the procedure but the heparin resistance seemed to worsen and we made the decision to stop the heparin and commence abciximab instead. A loading bolus of 30 mg of abciximab was given intravenously followed by an overnight infusion of the calculated maintenance dose of 15 mg. A follow-up arteriogram done the following day showed a worsened endoleak with resumption of flow, albeit slower, through the fistula (figure 2C). No intra-graft thrombosis was seen however. On day two he was also put onto a regime of low molecular-weight heparin of which he received two doses during this 24 hour period. A second follow-up arteriogram was performed on day three which now showed good flow through the stent-graft with no intraluminal thrombosis and finally with complete closure of the fistula (figure 2D). No distal cerebrovascular emboli were seen. The patient was no longer complaining of headache and was otherwise well at this stage. His orbital swelling had completely resolved.

He was transferred back to his base hospital for further management of the other injuries. We placed him on oral Plavix 75 mg and Disprin 150 mg daily, and he was eventually rehabilitated and discharged. He only presented for a follow-up arteriogram nine weeks later. Be-

Figure 2 (Case 2): A) Selective right internal carotid digital subtraction arteriogram, early arterial phase, showing the position of the arterial wall tear. B) After deployment and dilatation of the stent-graft, also further complicated by proximal displacement during balloon removal, there is a persistent endoleak (probably type 4) and evidence of intraluminal thrombosis. C) Follow-up arteriogram done the following day showing a worsened endoleak with resumption of flow, albeit slower, through the fistula. No evidence of intragraft thrombosis. D) Second follow-up arteriogram performed on day three shows good flow through the stent-graft and complete closure of the fistula.

ing now able to communicate fully he also described having had slight diplopia prior to treatment of the fistula that had also completely resolved shortly thereafter. He had had no further headaches. Follow-up arteriography showed complete patency of the stentgraft and exclusion of the fistula.

Discussion

There are only a limited number of reports to date concerning the intracranial use of stent-grafts. Alexander et Al described the successful treatment of pseudoaneurysm of the petrous segment of an internal carotid artery using a

Symbiot covered stent⁶. Chiaradio et al. described the use of a Jostent stent-graft in the treatment of a fusiform (dissecting) aneurysm of the intracranial segment of the right vertebral artery in a patient who presented with acute subarachnoid haemorrhage. This was preceded by initial angioplasty and stenting of a stenotic left vertebral artery⁷. Kocer et al reported on the use of a Jostent coronary stent-graft for the treatment of an iatrogenic injury of the intracavernous internal carotid artery in a patient who underwent transphenoidal pituitary adenoma removal. The injury resulted in the development of both local haemorrhage and a carotico-cavernous fistula (CCF), and the patient had a successful clinical outcome after placement of the stent-graft⁸. Islak et al. described the use of a covered-stent-within-a-stent technique in the treatment of two patients with giant aneurysms, again with good short term outcome⁹. A similar case to that of Kocer et al was reported by Vanninen et al again treated with a Jostent coronary stent-graft. This case was complicated by the development of a transient right hemiparesis and dysphasia which resolved once systemic heparinization was optimized¹⁰. Finally Felber et al reported the treatment of eleven patients with aneurysms or arteriovenous fistulae of the cranio-cervical vessels with stent-grafts. These included one intracranial vertebral dissecting aneurysm, one intracavernous ICA giant aneurysm, one ICA pseudoaneurysm and five direct CCF's in a further four patients. Complications encountered in five of the patients included transient hemipareses², increased hemiparesis¹, ICA dissection¹ and one fatal gastrointestinal haemorrhage (in a patient with Ehlers-Danlos syndrome)¹¹.

The use of stent-grafts for the management of intracranial vascular pathologies is an attractive proposition and as shown to date is certainly feasible in certain settings. However the use of current stent-graft devices, none of which are currently approved for cerebrovascular use, presents a number of significant technical problems in the intracranial vessels. Desirable characteristics of an optimal stent-graft include small device size, biocompatibility, good flexibility, rigidity (where relevant), good radio-opacity, good functionality (i.e. be impervious to blood or be capable of sealing within a short and reproducible period of time) and demonstrate constant predictability regarding

the behavior of the delivery system as well as in the sizing or degree of expansion of the stent-graft¹². At present we have only two small stent-graft types available to ourselves being the balloon-expandable Jostent coronary stent-graft and the self-expanding Symbiot coronary stent-graft.

The Jostent stent-graft consists of a thin layer of polytetrafluorethylene (PTFE) sandwiched between two 316L stainless steel Jostent flex stents. The stent-graft comes pre-mounted on a balloon. The stent-graft wall thickness is 0.3 mm and the stent-grafts come in a range of lengths from 12-26 mm and are able to cover vessels with diameters ranging from 2.5 to 5 mm. The optimal deployment expansion pressure is 14-16 bar. The system is tracked over a wire in a "monorail" fashion. The shaft size is 2.8F enabling it to be placed through an 0.068" inner diameter guiding catheter. In contrast, the Symbiot although having the more desirable characteristic of being self-expanding, does have a distal shaft diameter of 3.5F and a thicker crossing profile of 0.079" making it a somewhat more rigid device. Thus one of the major drawbacks of currently available devices is their relative rigidity and inflexibility resulting in difficulty in tracking these devices through the petrous and cavernous carotid segments and beyond. In both our cases manipulation of the entire device resulted in spasm within the extracranial internal carotid arteries which resolved with time and which did not require direct treatment with vasodilators. In case one the cavernous segments of the ICA presented a relatively straight line facilitating passage of the device which only became stuck when trying to get around the ophthalmic bend. In case two we had managed to get the device around the posterior genu of the intracavernous ICA before deployment, but even this required a considerable amount of forward pressure on the device. It is vitally important not to force the device for fear of dissecting the vessel. The range of available stent-graft sizes seems adequate for intracranial use even in the region of the skull base. Maintaining accurate positioning during deployment was not an issue, but in both of our cases we experienced proximal displacement of the stent-graft during removal of the deflated balloon, a problem less likely to occur with self-expanding stent-grafts, unless balloon remodelling is required after their deployment. In case one

this displacement resulted in prolapse of the distal end of the stent-graft into the aneurysm. We then had great difficulty in trying to place a second stent-graft though the first because of the absence of a patent "tunnel" through the stent and into the efferent part of the vessel. We overcame this problem by partly inflating the balloon of the second device in order to create a partial "dogbone" expansion of the balloon which elevated the distal end of the first stent-graft enough so as to allow us to pass the second device into the carotid artery beyond the aneurysm. Although not an issue in our cases the recommended deployment pressures are 14 to 16 bar that could potentially lead to rupture of the target vessel if great care is not taken.

One other major problem we encountered after deployment of the device concerned the biocompatibility and functionality of the stent-grafts, specifically relating to problems with coagulation. Neither of our patients was treated with antiplatelet agents prior to the procedure. We routinely heparinize all our cases at the onset of an elective neurointerventional procedure strictly maintaining an activated clotting time of over 300 seconds. We have tended to maintain the use of antiplatelet agents, namely abciximab, as a "bail-out" treatment for acute intraprocedural thrombotic complications. The PTFE covering is porous allowing blood to flow through the covering immediately after deployment. Sealing of the pores requires some degree of activation of the clotting mechanism. We have had considerable experience within the placement of stent-grafts in extracranial and peripheral vessels as well as aortic stent-graft placement and have become accustomed to the phenomenon of continued endoleak due to stent-graft covering porosity for several minutes after deployment until the material seals. Most of these cases are done under cover of systemic heparinization whereas some are not. In all cases there is eventual closure of the leak without (in our experience) the runaway progressive platelet deposition seen in case one and to a lesser degree in case two. Fearing parent vessel occlusion or distal embolization we treated both cases with intra-arterial (Case 1) and intravenous (Case 2) abciximab with good clinical

outcome being no development of any neurological signs or symptoms but which also resulted in the prolongation of the sealing of the PTFE cover for at least 24 hours in each case. The only reason we observed the relatively late progressive closure of the stent-graft in case one is that we decided to monitor the patient angiographically for 30 minutes after placement of the stent-graft whereas in peripheral stent-graft procedures we would probably have stopped the procedure shortly after successful deployment of the stent-graft with a single immediate follow-up arteriogram. This delayed and progressive platelet build up within the stent-graft may explain some of the neurological complications described in the paper by Feller et al who also used heparin during the procedure and only instituted anti-platelet therapy afterwards¹¹. Based upon our experience we feel that control of platelet function before, during and after intracranial stent-graft deployment is mandatory and in future cases we would strongly consider the use of abciximab as a prophylactic agent rather than heparin. The cost, however, for treating this rapid and exaggerated platelet deposition within the stent-grafts, was the delay in sealing of the stent-graft covering and thus in exclusion of the aneurysm and fistula respectively. This was no doubt exacerbated initially by the concurrent administration of both heparin and abciximab, but once the levels of activity of the abciximab had tapered spontaneously no further thrombotic complications were encountered and the stent-graft material was then able to seal effectively. There is thus a critical balance to be achieved between control of thrombogenicity and potential thrombo-occlusive and embolic

Table 1: Classification of Endoleaks

Classification	Cause
Type I	Proximal or distal attachment zone leak
Type II	Collateral flow retroleak due to filling from collateral vessels, not related to leakage through or around the stent-graft itself
Type III	Leaks due to a tear in the stent-graft covering material or leaks due to an inadequate seal between overlapping stent-grafts
Type IV	Porosity of the stent-graft covering material
<i>Adapted from White GH et Al. J Endovasc Surg 5: 305-309, 1998.</i>	

complications and the functionality of the stent-graft i.e. closure of the leak or fistula or exclusion of the aneurysm. The stent-graft covering material eventually seals permanently by endothelialization of the PTFE membrane.

In addition to initial porosity of the graft material, further causes for stent-graft "endoleaks" (practically defined as the persistent accumulation of contrast or blood outside the wall of the graft) include proximal and distal endoleaks caused by inadequate sealing at either end of the stent-graft, leaks due to an inadequate seal between overlapping stent-grafts, leaks due to collateral vessels and finally leaks due to a tear or other defect in the wall of the stent-graft. A useful classification for these different types of endoleak initially described by White et al is given in Table 1¹³. Although initially applied to leaks occurring in aortic stent-grafts, the same classification could be practically applied to stent-grafts elsewhere within the body.

Differentiating between the various types of endoleak can be somewhat difficult. As mentioned we have previously found Type IV endoleaks through the stent-graft material to be very common. Although this leak does usually stop after a wait of between five and 15 minutes, it may well persist longer depending upon the degree of anticoagulation. We strongly recommend waiting up to 15 minutes at least after observing any endoleak before embarking upon any further manipulation within the stent-graft which could lead to displacement of the graft as occurred in case one. This resulted in conversion to a definite Type 1 (distal) endoleak. Proximal and distal Type 1 endoleaks can be treated initially by remodelling and further expansion of the graft ends using a balloon. Failing this a second overlapping stent-graft may be required to seal the leak. The same strategy could be employed in trying to seal a leak between overlapping stent-grafts that would require deployment of yet another one within the lumen. The strategy for Type II endoleaks could involve either observation only in the hope that any relevant collateral supply may thrombose after reversal of any anticoagulation, or alternatively embolization of any reachable collateral vessel. This may not be very relevant in intracranial stent-graft usage.

Our series is naturally far too small and too short to comment upon long-term patency of intracranial stent-grafts. We do not know whe-

ther patency rates for coronary or peripheral stent-graft implantation can be extrapolated to cerebrovascular cases. Felber et al reported ongoing patency of the grafts in nine of their cases followed-up between three months and five years¹¹. Kocer et al showed good patency with no intimal hyperplasia or vessels stenosis at three months, and Islak et al showed similar angiographic outcomes at three and four months respectively for each of their two cases^{8,9}. Of great concern in the use of these devices in the intracranial vessels are the long-term patencies and whether or not these can be prolonged by pharmacological or other means such as drug-eluting stents. Furthermore the prevention of late thromboembolic events, occasionally seen after implantation of coronary stent-grafts is another potential complication that would require ongoing clinical monitoring and pharmacological treatment¹⁴. The use of stent-grafts coated with heparin or other anti-coagulant agent may go some way to preventing early stent or stent-graft thrombosis¹⁵. The type of covering material is also critical, with Dacron and polyethylacrylate / polymethylmethacrylate coverings being seen to produce a higher rate of intragraft thrombosis and occlusion than PTFE^{16,17}. The presence of stents or stent-grafts in a vessel elicits neointimal hyperproliferation that can lead to delayed vessel stenosis or occlusion¹⁵. The covering of a stent-graft prevents direct intimal tissue growth into the stent-graft but intimal hyperplasia does nevertheless occur at the edges of the stent-graft. Different methods employed to try and control the degree of neointimal hyperplasia in coronary stents have included intraluminal brachytherapy drug-eluting stents (using agents such as sirolimus, paclitaxel and rapamycin) and oral agents (sirolimus), all with varying degrees of success^{18,19,20,21}. A recent study by Levy et al has shown no neurotoxic effects due to sirolimus-eluting stents implanted in the canine basilar artery²². It remains to be seen whether these antiproliferative methods would be as effective in stent-grafts as well.

Finally with regard to the usefulness of covered stents or stent-grafts in the intracranial vessels, their use would naturally be confined to segments of the vasculature not giving rise to critical side branches, thereby significantly restricting their application in neurovascular disease, particularly given the current level of technology. Despite this apparent limited scope

for application, however, newer stent-graft devices are currently under investigation for use in the intracranial vasculature. Nishi et Al recently described the implantation of heparin-coated microporous stent-grafts for the exclusion of experimental carotid arterial aneurysms in dogs¹⁵. They described immediate termination of blood inflow and closure of the

aneurysm necks. All parent carotid arteries remained patent with no significant stenosis seen up to three months after stent-graft placement. Thus for a few highly selected cases the deployment of stent-grafts within the intracranial vessels is a feasible and potentially highly useful technique to add to the armamentarium of the neurointerventionalist.

References

- Dotter CT: Transluminally-placed coil spring endarterial tube-grafts. *Investigative Radiol* 4: 329-332, 1969.
- Parodi JC: Endovascular repair of abdominal aortic aneurysms and other arterial lesions. *J Vasc Surg* 21: 549-557, 1995.
- Marin ML, Veith FJ et Al: Transluminally placed endovascular stented graft repair for arterial trauma. *J Vasc Surg* 20: 266-473, 1994.
- Dake M, Miller C et Al: Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. *N Engl J Med* 331: 1729-1734, 1994.
- Singer RJ, Dake MD et Al: Covered stent placement for neurovascular disease. *Am J Neuroradiol* 18: 507-509, 1997.
- Alexander MP, Smith TP, Ducci DL: Treatment of an iatrogenic petrous carotid artery pseudoaneurysm with a Symbiot covered stent. *Neurosurgery* 50: 658-662, 2002.
- Chiaradio JC, Guzman L et Al: Intravascular graft stent treatment of a ruptured fusiform dissecting aneurysm of the intracranial vertebral artery: Technical case report. *Neurosurgery* 50: 213-216, 2002.
- Kocer N, Kizilkilic O et Al: Treatment of iatrogenic internal carotid artery laceration and carotid cavernous fistula with endovascular stent-graft placement. *Am J Neuroradiol* 23: 442-446, 2002.
- Islak C, Kocer N, Albayram S, et Al: Bare stent-graft technique: A new method of endoluminal vascular reconstruction for the treatment of giant and fusiform aneurysms. *Am J Neuroradiol* 28: 1589-1595, 2002.
- Vanninen RL, Manninen HI, Rinne J: Intracranial iatrogenic carotid pseudoaneurysm: Endovascular treatment with a polytetrafluoroethylene - covered stent. *Cardiovasc Intervent Radiol* 26: 298-301, 2003.
- Felber S, Henkes H et Al: Treatment of extracranial and intracranial aneurysms and arteriovenous fistulae using stent-grafts. *Neurosurgery* 55: 631-639, 2004.
- Katzen BT: Current status of endovascular stent-grafts: An overview of applications and devices. In: Adam A, Dondelinger RF, Mueller PR. *Textbook of Metallic Stents*. Oxford, Isis medical media 73-84, 1997.
- White GH, May J et Al: Type III and Type IV endoleak: Toward a complete definition of blood flow in the sac after endoluminal AAA repair. *J Endovasc Surg* 5: 305-309, 1998.
- Elsner M, Auch-Schweik W et Al: Coronary stent-grafts covered by a polytetrafluoroethylene membrane. *Am J Cardiol* 84: 335-338, 1999.
- Nishi S, Nakayama Y et Al: Occlusion of experimental aneurysm with heparin-loaded, microporous stent-grafts. *Neurosurgery* 53: 1397-1405, 2003.
- Palmaz JC: Intravascular stents: Tissue-stent interactions and design considerations. *Am J Roentgenol* 16: 613-618, 1993.
- Tepe G, Duda SH et Al: Covered stents for prevention of restenosis. Experimental and clinical results with different stent designs. *Investing Radiol* 31: 223-229, 1996.
- Link J, Feyerabend B et Al: Dacron - covered stent-grafts for the percutaneous treatment of carotid aneurysms : Effectiveness and biocompatibility - Experimental study in swine. *Radiology* 200: 397-401, 1996.
- Sindermann JR, Verin V et Al: Biological aspects of radiation and drug-eluting stents for the prevention of restenosis. *Cardiovasc Res* 63: 22-30, 2004.
- Beyar R: Novel approaches to reduce restenosis. *Ann N Y Acad Sci* 1015: 367-378, 2004.
- Hausleiter J, Kastrati A et Al: Randomized, double-blind, placebo-controlled trial of oral sirolimus for restenosis prevention in patients with in-stent restenosis: the Oral Sirolimus to Inhibit Recurrent In-stent Stenosis (OSIRIS) trial. *Eur Heart J* 25: 1330-1340, 2004.
- Levy EI, Hanel RA et Al: Sirolimus-eluting stents in the canine cerebral vasculature: A prospective, randomized, blinded assessment of safety and vessel response. *J Neurosurg* 100: 688-694, 2004.

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