Endovascular treatment for carotid artery stenosis after neck irradiation

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Background: **To lower the risk of complications, carotid angioplasty and stenting (CAS) has been proposed as an alternative to open surgery for carotid artery stenosis after neck irradiation. However, there are little postoperative data to support the benefits of this strategy. This study evaluated the outcome of CAS in patients who had undergone neck irradiation.**

Methods: **This retrospective study was conducted at 15 vascular surgery or interventional radiology centers in France between January 1998 and July 2006. A total of 135 patients (115 men) with a mean age of 67 ± 8 years (range, 43-88) underwent CAS for 149 irradiation-induced lesions. The interval between irradiation and discovery of the lesions was 12 ± 8 years. Mean diameter reduction was 81% (range, 50%-95%), and stenosis was symptomatic in 34%. Contralateral carotid lesions were observed in 48% of patients, including thrombosis in 18 and stenosis >50% in 53.**

Results: **Technical failure occurred during CAS in three cases. The overall technical success rate was 98%. A cerebral protection device was used in 59%. No death, one transient ischemic attack, and two strokes occurred during the first postoperative month. Mean follow-up was 30 months. Six patients were lost to follow-up. Survival rates were 93.9% at 1 year and 75.3% at 3 years. Complications after the first postoperative month included neurologic events in six, carotid thrombosis in nine, and restenosis in 18. The rates of freedom from neurologic and anatomic events were, respectively, 96.2% and 93.2% at 1 year and 93.1% and 85.9% at 3 years.**

Conclusion: **The immediate outcome of CAS for irradiation-induced carotid artery stenosis was satisfactory. Medium-term neurologic outcome was acceptable, but the incidence of anatomic events such as thrombosis and restenosis was high. A randomized study is needed to confirm that the outcome of the endovascular and surgical therapy is comparable in this indication. (J Vasc Surg 2008;48:852-8.)**

Carotid angioplasty and stenting (CAS) has been under investigation for two decades and was initially proposed for patients at high risk for open surgery. Several studies using various clinical and anatomic criteria to define high-risk indications[1,2] have shown that CAS and open surgery achieve similar postoperative outcomes for treatment of carotid artery stenosis.[2,3]

Irradiation-induced stenosis of the carotid artery is one of the main high-risk entities for open surgical therapy. Surgical access in these patients can be complicated, and nerve injury or wound-healing problems are frequent. Endovascular treatment has been proposed as an attractive alternative, but little data are available on the short- and long-term outcome of CAS in this indication. Moreover, there are no large series. This study evaluated the outcome of CAS for carotid artery stenosis after neck irradiation by conducting a retrospective review of cases collected from 15 French vascular surgery or interventional radiology centers.

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METHODS

Patients. This retrospective study included symptomatic and asymptomatic patients with tight carotid artery stenosis secondary to neck irradiation. Patients were recruited between January 1998 and July 2006 at 15 French vascular surgery or interventional radiology centers with experience in both surgical and endovascular treatment of carotid artery stenosis (Table I, online only). During the study period, 135 patients with carotid artery stenosis after neck irradiation were selected for CAS. Selection for CAS was by the individual judgement of the treating practitioner, according to clinical experience and learning curve, as well as patient anatomic considerations with regard to CAS feasibility and contraindication for carotid endarterectomy.

Mean age was 67 ± 8 years (range, 43-88 years), and 85% were men. General and cardiovascular risk factors are listed in Table II. Neck irradiation was performed for laryngeal cancer in 60%, oropharyngeal cancer in 26%, and miscellaneous malignancies such as parotid, thyroid,

Table II. Characteristics and risk factors in the patient population

Characteristic	*Value*
Age, mean ± SD years (range)	67 ± 8 (43-88)
Sex, No. (%)	
Male	115 (85)
Female	20 (15)
Risk factors, No. (%)	
Hypertension	98 (73)
Diabetes	12 (9)
Smoking	113 (86)
Hypercholesterolemia	69 (51)
Coronary disease	29 (21)
Peripheral arterial disease	31 (23)

or hematologic disease in 14%. The mean interval between radiotherapy and CAS was 12 ± 8 years (range, 2-33 years). Prior neck surgery had been performed in 103 patients (76%), of which 15 had a permanent tracheostomy.

Procedural details. Bilateral CAS was done in 14 patients, resulting in treatment of a total of 149 carotid arteries. Two high-grade stenoses on the same artery were present in 18 patients. In all, 167 postirradiation carotid lesions were proposed for CAS. The mean diameter reduction, as assessed by duplex scanning, was 81% ± 7% (range, 50%-95%) and was confirmed by reductions of 82% ± 6% (range, 60%-95%) on preprocedural or intraprocedural angiography. The degree of stenosis was assessed on angiography according to North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria.

The side of involvement was the right in 82 (55%) and left 67 (45%). Stenosis was located in the common carotid artery in 46 patients, carotid bifurcation in 31, and internal carotid artery in 90. The contralateral carotid axis exhibited no significant lesions in 78 cases (52%), stenosis between 50% and 95% in 53 (36%), and occlusion in 18 (12%). Unilateral evaluation of ipsilateral carotid lesions, as determined by neurologic consequences, showed 66% of stenoses (n = 98) were asymptomatic and 34% were symptomatic, accounting for transient ischemic attacks (TIAs) in 43 patients and stroke in eight.

Most CAS procedures in this study were performed in a radiology suite through femoral artery puncture under local anesthesia. Long sheaths (6F or 7F) were used more often than guiding catheters (Table III).

Cerebral protection devices were used in 59% of procedures. At the beginning of the study, cerebral protection was not available, but as protection devices became available, their use increased progressively. At the end of the study, cerebral protection was being used routinely according to recommendations of the Endarterectomy Versus Angioplasty in Patients With Symptomatic Severe Carotid Stenosis (EVA-3S) trial steering committee.[4]

Table III. Characteristics of the endovascular procedures

	Percentage
Setting	
Radiology suite	58
Operating room	42
Anesthesia	
Local	86
General	14
Introduction technique	
Femoral percutaneous	94
Femoral cut-down	6
Introducer type	
Long sheath	69
Guiding catheter	31
Cerebral protection	
Yes	59
No	41
Type of protection	
Filter	75
Occlusive balloon	25
Type of stent	
Carotid Wallstent[a]	62
Other	38
Residual stenosis	
10% to 30%	6
>30%	*

[a]Boston Scientific, Natick, Mass.
*3 procedural failures required conversion to successful open surgery.

Table IV. Medical treatment used before and after endovascular treatment

Treatment	*Pre-op, %*	*Post-op, %*
Aspirin alone	35	7
Clopidogrel[a] alone	5	3
Clopidogrel[a] + aspirin	55	85
Warfarin	5	5
Statin	24	. . .

[a]Before 2003, ticlopidine was used instead of clopidogrel.

Whenever possible, self-expandable nonconic stents were implanted. Stent models, diameters, and lengths varied considerably, depending on the features of the carotid lesion and operators' preferences. The procedure was considered successful if stent deployment was achieved. In accordance with NASCET criteria, residual stenosis was defined as narrowing >20% at the end of the procedure.

Preoperative medical treatment included platelet aggregation inhibitors in all patients except seven who had long-term treatment with warfarin. From 2003, 90% of patients received two inhibitors at least 48 hours before the procedure. During the procedure, all patients received intravenous heparin. Atropine was given to 24% of patients, usually as a prophylactic measure (Table IV). After treatment, a combination of clopidogrel (or ticlopidine before 2003) and aspirin was prescribed for at least 1 month in 85% of patients not undergoing long-term treatment with

warfarin (5%). Statins were used in only 24% of patients before the procedure and in 43% after the procedure.

Follow-up. Clinical data, technical features of the intervention, and short- to medium-term results were retrospectively collected, and outcome was analyzed on an intention-to-treat basis. None of the participating centers performed an independent neurologic assessment. All patients underwent postprocedural duplex scanning ≤7 days and at 3 or 6 months, according to individual center practice. The interval between two consecutive duplex scans was generally 6 or 12 months, according to individual center practice. All surviving patients with successful CAS had clinical examination and duplex scan <6 months before the end of the study.

Statistical analysis. Actuarial survival, freedom from neurologic events, and freedom from anatomic events, defined as restenosis or occlusion, were assessed for the entire study population. Restenosis was defined as a diameter reduction >50% measured by duplex scanning. Univariate analysis was performed using χ^2 and Wilcoxon tests. Cumulative survival estimates were assessed using the life-table method. The SPSS computer program (SPSS Inc, Chicago, Ill) was used to perform statistical analysis.

RESULTS

Early outcome. Technical failure occurred in three patients, for a technical success rate of 98%. In one patient it was not possible to pass through the internal carotid artery stenosis with the 0.014-inch wire. The second patient had a type III aortic arch, and it was not possible to catheterize the common carotid artery. These two patients underwent emergency saphenous bypass grafting and had no intraoperative or postoperative neurologic events. In the third patient, dissection of common carotid artery occurred during catheterization. This patient had an intraoperative stroke, underwent emergency saphenous bypass grafting, and recovered with no neurologic sequelae ≤3 days.

One patient had a postoperative stroke 90 minutes after a technically successful procedure secondary to stent thrombosis. He underwent emergency saphenous bypass grafting and kept a minor motor deficit until he died 18 months later from malignancy. Another patient had TIA 1 day after a successful procedure. A duplex scan after the TIA showed patent internal carotid artery without residual stenosis.

No patient died during the 30-day postoperative period. The 30-day combined stroke and death rate was 1.5%. In the other patients with technically successful procedures, intraoperative technical problems included difficulty in catheterization of the common carotid artery in four, inability to deploy the stent in correct position in one, and spasm of the internal carotid artery in five. Overall, the rate of intraoperative technical problems, including the three technical failures, was 8.7% (13 of 149 procedures).

Additional postoperative morbidity was seizure in one patient and groin hematoma in four. One patient with groin hematoma underwent surgical revision with repair of the femoral artery, and the other three were observed. The overall postoperative morbidity rate, including these five patients and the three who had neurologic events, was 5.9%.

Long-term outcome. Follow-up was available for 126 patients (three technical failures and six lost to follow-up). Mean follow-up was 30 months (range, 3-95 months). Thirty patients (22%) died during follow-up. One patient died at 7 months after a stroke associated with ipsilateral carotid in-stent restenosis. This patient had iterative carotid dilatation for restenosis 3 months after the initial procedure. Six patients died of cardiac events. Cancer was the cause of death in 20 patients with a mean follow-up of 27 months: three died of the initial malignancy and 17 of secondary cancer. Mean follow-up between CAS and death was 27 months in patients who died of cancer and 25 months in those who died of other causes. The cause of death was undetermined in three patients. Cumulative survival was 93.9% at 1 year and 68% at 4 years (Table V, online only). The 96 surviving patients with successful CAS were contacted ≤6 months before the end of the study and had a clinical examination and duplex scan.

Six patients had ischemic neurologic events at mean interval of 16 months (range, 2-56 months) consisting of three TIAs and three strokes. Two TIAs were due to carotid thrombosis, and the other four neurologic events were related restenosis. Restenosis was treated by open surgery in one patient and repeat endovascular therapy in one patient. In the remaining two patients, restenosis was not treated due to the patients' poor general condition. Neurologic event-free survival rate was 96.2% at 1 year and 93.1% at 4 years (Table VI, online only).

Occlusion of the treated carotid axis occurred in nine patients (6%) at a mean interval of 18 months (range, 0-72 months). Carotid occlusion was symptomatic in three (1 stroke and 2 TIAs) and asymptomatic in six. The patient who sustained a postprocedural stroke underwent immediate carotid saphenous bypass grafting with subsequent mild neurologic sequelae.

Two patients had early symptomatic thrombosis at 1.5 and 2 months; postoperative duplex scans in these patients did not show residual stenosis. In the six asymptomatic occlusions, diagnosis was made on follow-up duplex scans. Two patients had 60% stenosis on duplex imaging performed 6 and 12 months before thrombosis. Two patients had 40% restenosis 6 and 18 months before thrombosis. Two patients had no restenosis 3 and 9 months before thrombosis.

Restenosis >50% was diagnosed in 18 patients (12%) at mean interval of 30 months (range, 3-84 months). Four patients were symptomatic (2 strokes and 2 TIAs), and 14 were asymptomatic. One patient who died from ipsilateral stroke has already been described. Restenosis was treated by repeat angioplasty in three patients (1 symptomatic) and open surgery in two (1 symptomatic). No recurrent neurologic or anatomic events developed in these

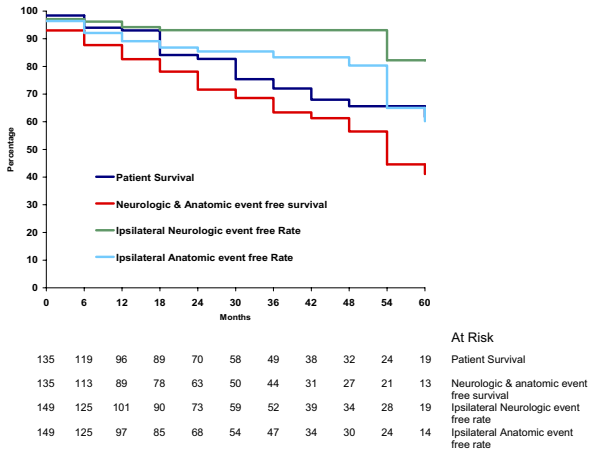

Fig 1. Life-table curves for patient, neurologic event-free, anatomic event-free, and any event-free survival.

five patients in the ensuing 42 months of follow-up. Thirteen patients with restenosis were kept under regular surveillance, and asymptomatic thrombosis developed in two during the following year. Restenosis or occlusion-free survival rates were 92.1% at 1 year and 83.4% at 4 years (Table VII, online only).

Table VIII (online only) reports life-table data related to any event-free survival, including neurologic and anatomic. The Fig 1 summarizes life-table curves for patients, neurologic event-free, anatomic event-free, and any event-free survivals.

Predictive factors for neurologic and anatomic events. Univariant or multivariant analysis was performed to identify predictive factors for neurologic and anatomic (occlusion and/or restenosis) events. The following factors were studied: age, gender, cardiovascular history, vascular risk factors (diabetes, hypertension, hypercholesterolemia, smoking), interval between irradiation and angioplasty, location of treated lesion, degree of stenosis ($<60\%$ vs $\geq 60\%$), symptomatic vs asymptomatic stenosis, contralateral carotid disease, occurrence of procedurally related complications, postoperative residual stenosis, stent type (Wallstent [Boston Scientific, Natick, Mass] vs other), use of cerebral protection device, use of statins before and after CAS, and antiplatelet regimen. Univariant analysis demonstrated that diabetes mellitus, symptomatic stenosis, contralateral carotid disease, and use of statins after CAS were predictive of anatomic events during follow-up. The occurrence of procedurally related complications was the only predictive factor for postoperative neurologic events. Multivariant analysis identified no predictive factors.

DISCUSSION

With a combined stroke and death rate of 1.5% at 1 month, the outcome of CAS after neck irradiation can be considered satisfactory. This result is comparable with that of carotid angioplasty[5] and with results described in studies comparing surgical and endovascular treatment in high-risk surgical patients.[2,3] The early results obtained in this multicenter study are slightly better than those reported in the angioplasty arms of the Stent-Protected Percutaneous Angioplasty Versus Carotid Endarterectomy and EVA-3S[6] trials that demonstrated respective combined stroke and death rates of 7.7% and 9.6%. It should be emphasized, however, that all patients in those two trials presented with symptomatic tight atherosclerotic stenosis that is associated with a higher risk of embolism during endovascular treatment. In our study only 33% of patients were symptomatic, and stenoses were nonatherosclerotic lesions.

The technical success rate of CAS in our study was 98% according to intention-to-treat analysis. This is in agreement with the current data. Endovascular therapy is sometimes unfeasible due to vascular access problems that can result from extensive aortoiliac occlusive disease and complex anatomy of the aortic arch or origin of the supra-aortic branches, or both. It should be emphasized that the present series was not exhaustive, because some patients with carotid stenosis after neck irradiation were not selected for angioplasty. The main reason was because patients with the most favorable anatomy and the highest surgical risk were preferentially selected for CAS. As a result of this limitation, the good immediate success rate can only be interpreted as meaning that CAS is a feasible treatment of postirradiation carotid stenosis.

In addition to demonstrating good clinical results in the first month, this study indicates that the long-term clinical outcome of CAS for postirradiation stenosis is satisfactory. The cumulative neurologic event-free survival rate at 3 years was 93%. Anatomic events, defined as occlusion or restenosis, occurred in 27 carotid axes for an overall anatomic failure rate of 18%. Seven of these anatomic failures (26%) led to neurologic complications (1 early occlusion, 6 secondary anatomic events). In view of this finding, an increased long-term anatomic failure rate should be considered the main drawback of this technique. However, we found that the use of statins after CAS decreased significantly the incidence of anatomic events during follow-up. This confirms the importance of associated medical therapy after interventions for radiation-induced carotid stenosis, as it has been demonstrated for atherosclerotic carotid disease.

Neck irradiation for local malignant disease can cause carotid arterial wall injury by three different mechanisms.[7] The first is ischemic necrosis induced by occlusion of the vasa vasorum, with subsequent gradual replacement of elastic tissue and muscular fibers by fibrous tissue. This replacement process leads to local sclerosis. Another mechanism is adventitial fibroses causing obstruction. In this regard, Muzaffar, et al,[8] observed that neck irradiation induces a significant increase in the thickness of the carotid wall during first year after irradiation treatment. These two mechanisms may explain that

the thrombosis rate after CAS for radiation-induced stenoses is higher than in patients undergoing CAS for atherosclerotic lesions. The third mechanism is acceleration of the atherosclerotic process, even though radiotherapy has been proposed to prevent postangioplasty restenosis. The time interval between irradiation and development of arterial hemodynamic changes varies considerably. In our experience, it ranged from 2 to >30 years. This wide range has been documented in other reports.[9,10]

Cervical irradiation does not always lead to carotid artery stenosis. According to Lam, et al,[11] the incidence of carotid stenosis after irradiation is correlated with the type of cancer treated, with a higher incidence after treatment of head and neck malignancy than hematologic diseases. Nevertheless King, et al,[12] observed a significantly higher incidence of carotid disease in young patients who underwent neck irradiation for Hodgkin lymphoma. Cheng, et al,[7] showed that significant postirradiation carotid artery stenosis is frequent in patients with nasopharyngeal and laryngeal carcinoma. The same authors also showed that significant carotid stenosis was associated with age, smoking, and coronary disease.

Some evidence suggests that irradiation-induced stenosis may correspond to acceleration of the progression of atherosclerotic lesions by local ischemia. However many postirradiation stenoses affect the common carotid artery that is not a "preferred" location of atherosclerotic lesions. In the current series, stenosis involved the common carotid artery in 28% of cases.

It is remarkable that most patients in this series died of cancer and not of a cardiovascular event. Only three of the 20 cancer deaths resulted from the initial cancer, and a new cancer developed in the rest. This is consistent with the experience of Marcel, et al,[13] who found in a series of 41 patients that the only predictor of death was the occurrence of a new malignancy. One might question whether some patients had cancer in evolution at the time of CAS. Although we do not have data on cancer status at the time of CAS, it is remarkable that the mean delay between irradiation and CAS was 10 years in patients who died of cancer and 12 years for the entire population. Furthermore, the mean delay between CAS and death was not different between the patients who died of cancer and the others (27 vs 25 months). When the survival in this population is considered, it seems justified to offer interventional therapy in cases of severe carotid artery stenosis to reduce the potential risk of ipsilateral stroke.

Like previous surgical intervention and history of tracheotomy, irradiation-induced tissue alterations have been associated with difficulties during redo surgery, increased risk of cranial nerve injury, wound-healing problems, and local infection. In addition, irradiation-induced alterations of the arterial wall hamper the performance of endarterectomy. Seven studies[9,10,14-18] have reported 117 cases of surgical treatment of irradiation-induced carotid artery stenosis. The largest series were those of Leseche, et al,[14] and Kashyap, et al,[15] which included 30 and 26 patients, respectively. Five smaller series were also published between 1989 and 2001.[9,10,16-18] In these previous reports, two patients presented with postoperative stroke and one patient died of cerebral hemorrhage for a combined stroke and death rate at 1 month of 2.6%, which is comparable with the 1.5% observed in our experience.

During follow-up in these previous reports, stroke developed in two patients, two patients had symptoms of TIAs, and 10 showed a restenosis >60% or carotid occlusion. Cranial nerve injury was observed in four patients. Wound healing was incomplete in only one patient. With regard to this latter issue, several authors[9,15,17] have closed the wound with musculocutaneous flaps. Despite all technical hurdles, the mean duration of the procedure was generally not significantly increased.[10]

In most surgical reports, stenosis was repaired by means of venous bypass grafting. However, Leseche, et al,[14] recommend the use of polytetrafluoroethylene grafts for bypass surgery because of the high incidence of anastomotic restenosis in venous grafts. Venous patches are preferred to prosthetic patches, but Kashyap, et al,[15] have not encountered complications with polyester patches.

According to our literature search, the early and medium-term results of conventional surgery appear comparable with the results of angioplasty in our experience. From the seven series published between 1989 and 2005, we found that the mean anatomic failure rate after open surgery was about 9%, which is lower than the 18% rate in our series. However, the 4% incidence of neurologic events after CAS in our series compares favorably with the 4.4% that was found from the literature in open surgery. This is because many thromboses and restenoses in our series remained asymptomatic. It does not appear from the above data that the benefit of CAS in terms of reduction of postoperative morbidity is obviated by a greater incidence of neurologic events during follow-up. It therefore seems possible to recommend CAS as primary treatment for stenosis after neck irradiation.

To compare our results with previous experience using endovascular therapy, we compiled data from six previous series[19-24] describing patients with irradiation-induced carotid stenoses treated by CAS (Table IX). The six series comprised 90 carotid arteries in 80 patients, including 59% who were symptomatic. In 20 cases, CAS was performed on two lesions located on the same artery. Cerebral protection devices were used in only 13 angioplasties (14%). By comparison, protection devices were used in 59% of angioplasties in our more recent series. Neurologic events occurred in 4% of patients in the compiled series vs 2% in our experience. The previous series did not mention additional neurologic events during follow-up. We observed six events after the first postoperative month due to occlusion in two cases or restenosis in four at the site of angioplasty.

The overall neurologic complication rate after CAS was satisfactory and comparable with that observed after

Table IX. Outcome of endovascular treatment of carotid artery stenosis after neck irradiation reported in the literature

First author	*Patients, No.*	*Carotid arteries, No.*	*Symptomatic carotid arteries, No. (%)*	*Degree of stenosis, %*	*Technical success rate, %*	*Post-op stroke, No.*	*Mean follow-up, months*	*Restenosis, occlusion during follow-up, No. (%)*
Al Mubarak[19] (2000)	14	15	10 (66)	77	100	1	18	0
Houdart[20] (2001)	7	9	6 (66)	>70	100	0	8	0
Alric[21] (2002)	4	6	2 (33)		95	0	8	0
Ting[22] (2004)	16	18	13 (72)	85	94	1	30	3
Harrod-Kim[23] (2005)	16	19	. . .	84	100	1	28	5
Protack[24] (2007)	23	23	11 (48)	>70	96	1	14	11 (48)
Present series (2007)	135	149	51 (34)	80	98	3	30	27 (18)

conventional surgery. However, the overall incidence of restenosis (n = 30) or occlusion (n = 14) for all 239 published endoluminal treatments (including this report) was high at 18%. After a mean follow-up of 14 months, Protack, et al,[24] reported anatomic complications in 43% of cases treated by CAS, which is obviously much higher than in other series, including our own (13% and 18%, respectively). Despite these discrepancies, it appears that restenosis and occlusion are more frequent after CAS than conventional surgery.

CONCLUSION

The purpose of this multicenter retrospective analysis was to evaluate the outcome of CAS for carotid irradiation-induced stenosis at 15 French vascular surgery or interventional radiology centers and compare the data with those reported in the literature. Long-term clinical results were comparable with previous reports, but anatomic results were not as good as surgical treatment. A prospective randomized study with a follow-up >3 years will be necessary to determine which treatment is better and which clinical and anatomic factors should be taken into account for therapeutic decision making.

AUTHOR CONTRIBUTIONS

Conception and design: JPF, BB, JPB
Analysis and interpretation: JPF, AN, JNA
Data collection: JPF, AD, BB, JPB
Writing the article: JPF, BB, JPB
Critical revision of the article: JPF, AN, AD, JNA
Final approval of the article: JPF, AN, AD, JNA, BB, JPB
Statistical analysis: AN
Obtained funding: Not applicable
Overall responsibility: JPF

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Table I (online only). Centers and lead investigators that participated in this retrospective analysis of endovascular treatment of irradiation-induced carotid artery stenosis

Investigator	*City*	*Patients, No.*	*Carotid arteries, No.*
Beyssen B	Paris	26	28
Becquemin JP	Créteil	20	25
Magnan PE	Marseille	14	15
Watelet J	Rouen	13	13
Favre JP	St Etienne	12	13
Midy D	Bordeaux	10	12
Chevalier J	Lille	8	9
Alric P	Montpellier	7	9
Haulon S	Lille	6	6
Reix T	Amiens	5	5
Feugier P	Lyon	4	4
Hassen-Khodja R	Nice	4	4
Lermuziau P	Tours	4	4
Enon J	Angers	1	1
Chauffour X	Toulouse	1	1
Total		135	149

Table V (online only). Life-table survival of patients who underwent endovascular treatment for carotid artery stenosis after neck irradiation

Interval start time	*No. entering this interval*	*No. withdrawn during interval*	*No. exposed to risk*	*No. of terminal events*	*Proportion terminating*	*Proportion surviving*	*Cumulative proportion surviving at end*	*Probability density*	*Hazard rate*	*SE of cumulative surviving*
.0	135.0	14.0	128.0	2.0	0.0156	0.9844	0.9844	.0026	0.0026	0.0110
6.0	119.0	18.0	110.0	5.0	0.0455	0.9545	0.9396	.0075	0.0078	0.0222
12.0	96.0	6.0	93.0	1.0	0.0108	0.9892	0.9295	.0017	0.0018	0.0241
18.0	89.0	11.0	83.5	8.0	0.0958	0.9042	0.8405	.0148	0.0168	0.0370
24.0	70.0	11.0	64.5	1.0	0.0155	0.9845	0.8274	.0022	0.0026	0.0387
30.0	58.0	4.0	56.0	5.0	0.0893	0.9107	0.7536	.0123	0.0156	0.0473
36.0	49.0	9.0	44.5	2.0	0.0449	0.9551	0.7197	.0056	0.0077	0.0509
42.0	38.0	4.0	36.0	2.0	0.0556	0.9444	0.6797	.0067	0.0095	0.0553
48.0	32.0	7.0	28.5	1.0	0.0351	0.9649	0.6559	.0040	0.0060	0.0583
54.0	24.0	5.0	21.5	0	0	1.0000	0.6559	0	0	0.0583
60.0	19.0	4.0	17.0	1.0	0.0588	0.9412	0.6173	.0064	0.0101	0.0664

SE, Standard error.

Table VI (online only). Life table of neurologic event-free survival rate of patients who underwent endovascular treatment for carotid artery stenosis after neck irradiation

Interval start time	*No. entering this interval*	*No. withdrawn during interval*	*No. exposed to risk*	*No. of terminal events*	*Proportion terminating*	*Proportion surviving*	*Cumulative proportion surviving at end*	*Probability density*	*Hazard rate*	*SE of cumulative surviving*
0	149.0	18.0	138.0	4.0	0.0290	0.9710	0.9710	.0048	0.0049	0.0143
6.0	125.0	23.0	113.5	1.0	0.0088	0.9912	0.9625	.0014	0.0015	0.0165
12.0	101.0	9.0	96.5	2.0	0.0207	0.9793	0.9425	.0033	0.0035	0.0214
18.0	90.0	16.0	82.0	1.0	0.0122	0.9878	0.9310	.0019	0.0020	0.0240
24.0	73.0	14.0	66.0	0	0	1.0000	0.9310	0	0	0.0240
30.0	59.0	7.0	55.5	0	0	1.0000	0.9310	0	0	0.0240
36.0	52.0	13.0	45.5	0	0	1.0000	0.9310	0	0	0.0240
42.0	39.0	5.0	36.5	0	0	1.0000	0.9310	0	0	0.0240
48.0	34.0	6.0	31.0	0	0	1.0000	0.9310	0	0	0.0240
54.0	28.0	8.0	24.0	1.0	0.0417	0.9583	0.8922	.0065	0.0071	0.0444
60.0	19.0	4.0	17.0	0	0	1.0000	0.8922	0	0	0.0444

SE, Standard error.

Table VII (online only). Life table of restenosis- or occlusion-free survival rate of patients who underwent endovascular treatment for carotid artery stenosis after neck irradiation

Interval start time	*No. entering this interval*	*No. withdrawn during interval*	*No. exposed to risk*	*No. of terminal events*	*Proportion terminating*	*Proportion surviving*	*Cumulative proportion surviving at end*	*Probability density*	*Hazard rate*	*SE of cumulative surviving*
0	149.0	19.0	139.5	5.0	0.0358	0.9642	0.9642	.0060	0.0061	0.0157
6.0	125.0	23.0	113.5	5.0	0.0441	0.9559	0.9217	.0071	0.0075	0.0239
12.0	97.0	9.0	92.5	3.0	0.0324	0.9676	0.8918	.0050	0.0055	0.0287
18.0	85.0	15.0	77.5	2.0	0.0258	0.9742	0.8688	.0038	0.0044	0.0322
24.0	68.0	13.0	61.5	1.0	0.163	0.9837	0.8547	.0024	0.0027	0.0347
30.0	54.0	7.0	50.5	0	0	1.0000	0.8547	0	0	0.0347
36.0	47.0	12.0	41.0	1.0	0.0244	0.9756	0.8338	.0035	0.0041	0.0396
42.0	34.0	4.0	32.0	0	0	1.0000	0.8338	0	0	0.0396
48.0	30.0	5.0	27.5	1.0	0.0364	0.9636	0.8035	.0051	0.0062	0.0484
54.0	24.0	6.0	21.0	4.0	0.1905	0.8095	0.6504	.0255	0.0351	0.0792
60.0	14.0	1.0	13.5	1.0	0.0741	0.9259	0.6023	.0080	0.0128	0.0868

SE, Standard error.

Table VIII (online only). Life-table data of any event-free survival, including neurologic and anatomic events, in patients who underwent endovascular treatment for carotid artery stenosis after neck irradiation

Interval start time	*No. entering this interval*	*No. withdrawn during interval*	*No. exposed to risk*	*No. of terminal events*	*Proportion terminating*	*Proportion surviving*	*Cumulative proportion surviving at end*	*Probability density*	*Hazard rate*	*SE of cumulative surviving*
0	135.0	17.0	126.5	5.0	0.0395	0.9605	0.9605	.0066	0.0067	0.0173
6.0	113.0	21.0	102.5	3.0	0.0293	0.9707	0.9324	.0047	0.0050	0.0232
12.0	89.0	8.0	85.0	3.0	0.0353	0.9647	0.8995	.0055	0.0060	0.0291
18.0	78.0	13.0	71.5	2.0	0.0280	0.9720	0.8743	.0042	0.0047	0.0333
24.0	63.0	12.0	57.0	1.0	0.0175	0.9825	0.8590	.0026	0.0029	0.0361
30.0	50.0	6.0	47.0	0	0	1.0000	0.8590	0	0	0.0361
36.0	44.0	12.0	38.0	1.0	0.0263	0.9737	0.8364	.0038	0.0044	0.0416
42.0	31.0	4.0	29.0	0	0	1.0000	0.8364	0	0	0.0416
48.0	27.0	5.0	24.5	1.0	0.0408	0.9592	0.8022	.0057	0.0069	0.0521
54.0	21.0	4.0	19.0	4.0	0.2105	0.7895	0.6333	.0281	0.0392	0.0856
60.0	13.0	1.0	12.5	1.0	0.0800	0.9200	0.5827	.0084	0.0139	0.0925