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SPECIAL TOPIC

Carotid Angioplasty and Stenting: State of the Art After CREST Study

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KEY WORDS: *stroke; carotid stenosis; carotid endarterectomy; carotid angioplasty; carotid stenting*

Abbreviations
CAS = carotid angioplasty and stenting
CEA = carotid endarterectomy
CRP = C-reactive protein
CT = computed tomography
DW-MRI = diffusion-weighted MRI
EPD = embolic protection device(s)
FDA = (US) Food & Drug Administration
ICA = internal carotid artery
MI = myocardial infarction
MRI = magnetic resonance imaging
PET = positron emission tomography
SPECT = single-photon emission computed tomography
TCD = transcranial Doppler
TIA = transient ischemic attack

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ABSTRACT

Stroke represents the third leading cause of death in the USA and the most common and disabling neurological disorder in the elderly population. A carotid stenosis is responsible for about 30% of the cases. Medical therapy with antithrombotic agents and statins has a role in reducing cardiovascular risk, but randomized trials have shown that carotid endarterectomy (CEA) is superior to medical therapy alone and is considered the gold standard treatment of a carotid stenosis. However, surgery is not without complications; the stroke and death rate at 30 days in these trials ranged from 5.8% to 7.5% in the symptomatic patients and from 2.3% to 4.3% in asymptomatic patients. In higher risk patients, like those with severe coronary artery disease, morbidity and mortality has been reported in up to 18% of patients.

Carotid angioplasty and stenting (CAS) has been proposed as an alternative to surgery, and two initial randomized studies comparing CAS and CEA showed comparable results. However, after these results, numerous studies, both European and American studies, have been published with very different outcomes. Among them the most important is the American study, CREST, which demonstrated that CAS is not inferior to CEA and can now be proposed to the majority of patients suffering from a carotid stenosis. But in contrast to many other endovascular interventions, CAS represents a more challenging procedure requiring complex catheter-based skills and an extensive learning curve that explains the poor results of CAS in some published series and particularly in Europeans studies.

In conclusion, after the CREST study and recent published data, CAS and CEA can be deemed equivalent for the treatment of a carotid stenosis. However, these two treatments may have some contraindications and limitations. We need appropriate patient and lesion selection, proper technique, embolic protection devices, and most importantly experienced operators. Indications for asymptomatic patients have to be discussed considering the benefit of optimal medical therapy.

INTRODUCTION

Stroke represents the third leading cause of death in the US and the most common and disabling neurological disorder in the elderly population.[1] A carotid stenosis is responsible for about 30% of these cases. The majority (>75%) of stroke patients

were asymptomatic before their stroke. Medical therapy (e.g. antiplatelets and lipid lowering agents) have a continuing role in reducing cardiovascular risk, but randomized trials[2-7] have shown that carotid endarterectomy (CEA) is superior to medical therapy alone and have demonstrated the efficiency of CEA in reducing the risk of stroke and death in symptomatic and asymptomatic patients. Based on these trials, CEA was considered as the gold standard treatment of a carotid stenosis. However, this operation is not without drawbacks and risks in high and low risks patients.[8] The stroke and death rate at 30 days in these trials ranged from 5.8% to 7.5% in the symptomatic patients and from 2.3% to 4.3% in asymptomatic patients. In higher risk patients, like those with severe coronary artery disease, morbidity and mortality has been reported in up to 18% of patients.

Carotid angioplasty and stenting (CAS) has been proposed as an alternative to surgery, and two randomized studies comparing CAS and CEA had shown comparable results even without embolic protection devices (EPD).[9,10] However, after these results, numerous studies have been published with very different outcomes; among them several device approval trials[11] with results of CAS at least not inferior to surgery, and several European and American studies. Among the European studies, three stand out: the Endarterectomy Versus Angioplasty in patients with symptomatic severe carotid stenosis (EVA-3S),[12] the Stent-Protected Angioplasty versus Carotid Endarterectomy in symptomatic patients (SPACE Study),[13] and the International Carotid Stenting Study (ICSS).[14] Only the SPACE study has shown similar results between CAS and CEA. Among the American studies, the most recent and the most important one is the Carotid Revascularization Endarterectomy vs Stenting trial (CREST Study),[15] a randomized controlled trial which demonstrated that CAS is not inferior to CEA. In contrast to many endovascular interventions, CAS represents a more challenging procedure requiring complex catheter-based skills and an extensive learning curve that explains the poor results of CAS in some published series and particularly in European studies.

In the present review, we would like to analyze these studies, and try to determine if the CREST Study has changed the current clinical practice in favor of CAS procedures at a time when the enthusiasm for endoluminal repair has been dampened by some studies and in particular European studies.

REGISTRIES – RANDOMIZED STUDIES: RESULTS

1. DEVICE APPROVAL TRIALS[11]

Since 2002, 11 device-approval trials in high-risk patients were reported showing rapidly improving outcomes as demonstrated in Figure 1. The SAPPHIRE study randomized 317 high-risk patients to either CEA or CAS with an EPD (Angioguard, Cordis, Bridgewater, NJ, USA). The 30-day composite index of stroke/death/myocardial infarction (MI) rate was 4.8% for CAS and 9.8% for CEA (P = 0.09) and results at 1 year favored CAS, 12.2% vs 20.1% (P = 0.048). Ten other pivotal registries reported data at least comparable to CEA (Table 1).[11]

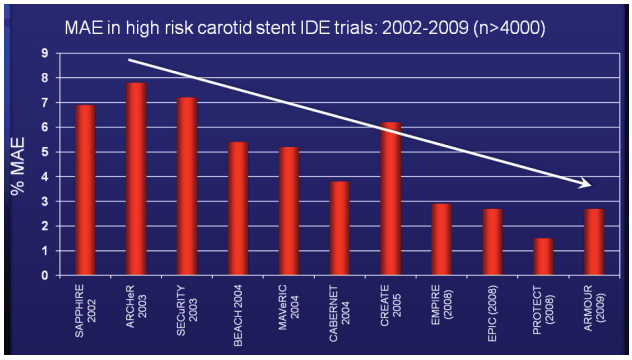

FIGURE 1. Device approval trials.

2. EUROPEAN STUDIES: EVA-3S, SPACE, ICSS STUDIES[12-14]

The 30-day outcomes (stroke/death/MI rate) are summarized in Table 2.

Only the SPACE study showed similar results between the two treatments. However, these studies have a lot of limitations: a high failure rate of CAS of 3 to 5% (EVA-3S, SPACE) which is usually not seen with experienced operators, an emergency conversion of CAS to CEA of 5% (EVA-3S), too many low volume centers, and incomplete antiplatelet drug therapy (EVA-3S). In addition, EPD was not mandatory in 27% in

TABLE 1. Registries Reporting Outcome Data on CAS

Registry	No. of Patients	Stroke/Death/MI Rate (%)
ARCHER 2003	581	8.3
SECURITY 2003	383	8.5
BEACH 2004	480	5.8
MAVERIC 2004	498	5.3
CABERNET 2004	454	3.8
CREATE 2005	543	6.2
EMPIRE 2008	245	3.7
EPIC 2008	237	3
PROTECT 2008	274	1.8
ARMOUR 2009	263	2.7

CAS = carotid angioplasty & stenting; MI = myocardial infarction.

TABLE 2. European Studies: 30-Day Outcomes

	CAS	CEA	P Value
EVA-3S	10%	4%	0.01
SPACE	7%	6%	NS
ICSS	8.5%	5.2%	0.006

CAS = carotid angioplasty & stenting; CEA = carotid endarterectomy; NS = non-significant

SPACE and in 72% in ICSS; there was inaccurate analysis whereby MI was not considered as an endpoint (EVA-3S, SPACE) which is in favor of CEA, and; there was inappropriate patient selection. A major issue relates to inexperienced operators. For example, in order to be enrolled in EVA-3S study, the operator had to justify 12 carotid procedures or at least five CAS plus 30 or more supraaortic trunk procedures. For SPACE study, 25 successful CAS procedures or assistance from a tutor with at least 10 carotid stents were considered adequate and for ICSS to be designated an "experienced" operator the criterion was the performance of 10 carotid stents among 50 endovascular stents. We know that training and experience as we will discuss later are very important to limit the complication rate of CAS. Such lack of experience of investigators performing CAS in these trials can only have tended to put CAS patients at increased risk of complications. Finally, none of these studies fulfills the criteria of good medical practice.

3. CREST STUDY[15]

The most recent published study, the CREST study, is the most important one. It is a prospective multicenter randomized controlled trial comparing CEA and CAS in 2502 patients; 1326 symptomatic patients with a carotid artery stenosis ≥50%, and 1196 asymptomatic patients with a stenosis ≥60%. Surgeons and interventionists were highly qualified. The devices used were the Acculink carotid stent and Accunet EPD (Abbott Laboratories, Abbott Park, IL, USA). All patients also received the best medical management. To compare the safety and efficacy of the two treatments, the primary endpoints studied were any periprocedural stroke/death/myocardial infarction (MI) and any postprocedural ipsilateral stroke at up to 4 years of follow up. Cardiologists performed 42% of the CAS procedures, vascular surgeons 22%, radiologists 16%, neuroradiologists 12% and neurosurgeons 8%.

CAS and CEA appeared similar with regard to the study's endpoint (stroke/death/MI) in symptomatic and asymptomatic patients (Fig. 2). At 30 days, the death/stroke/MI rate was 5.8% for CAS (N = 1131) and 5.1% for CEA (N = 1176) whithout any statistically significant difference (P = 0.52). However, the rate for any stroke was higher in the CAS group: 4.1% vs 1.9% (P = 0.0019) but with higher rate of minor strokes of

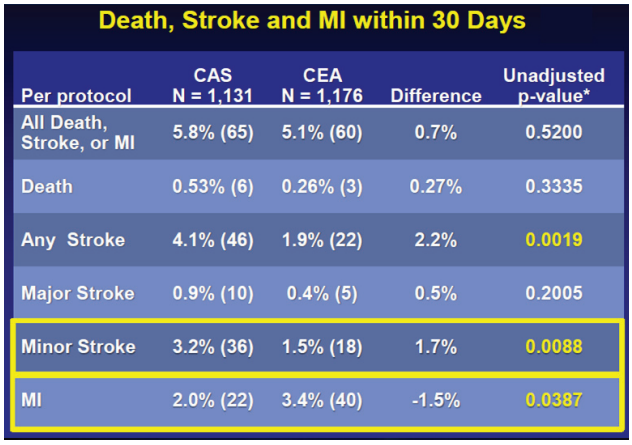

FIGURE 2. Crest study. Periprocedural endpoint components.

3.2% vs 1.5% (P = 0.0088). There was no difference for major stroke: CAS 0.9%, CEA 0.4% (P = 0.2005). The rate for MI was higher in the CEA group: 3.4% vs 2% (P = 0.0387).

It is important to point out that the excess risk of stroke in CAS was mainly due to minor stroke, and this is significant because any disability related to minor stroke typically goes away within 7 days and at 6 months the Neurological Residual Deficit Rates by NIHSS associated with minor strokes are equivalent (0.62% for CAS, 0.60% for CEA). Heart attacks, on the other hand, carry a late consequence that strokes do not, increasing the risk of dying in 2 to 3 years by about 4-fold. When we compare the long-term mortality at 4 years, the freedom from all-cause mortality is 94.8% after minor stroke, 75% after MI (P = 0.02). Moreover, patients who had MI reported a better quality of life after recovery than those who had a stroke.

Concerning the long-term results, in a combination of symptomatic and asymptomatic patients, there are no differences in outcome for CAS and CEA (Fig. 3). At 4 years we observed a similar freedom from ipsilateral stroke of 96.7% for CEA and 96.5% for CAS (P = 0.89). The rates of ipsilateral stroke during a mean follow up of 2.5 years were equal at 2% for stenting and 2.4% for CEA (P = 0.51). We also observed a similar mortality at 4 years. The freedom from all-cause mortality was 89.2% for CEA and 87.9% for CAS (P = 0.23). We also have to mention the problem of cranial nerve injury, never observed after CAS but reported in 5.3% of CEA patients (P = 0.001), unresolved at one month in 3.6% and at 6 months in 2.1%. The access site complication rate is also higher after CEA, 3.7% vs 1.1%, respectively (P = 0.0001).

Considering the age of the patient, CAS gave better results than CEA in young patients, CEA gave better results in elderly patients (Fig. 4). However, a subanalysis of CREST showed that although older patients have worse outcomes, the increase in complications is similar for CAS and CEA. In

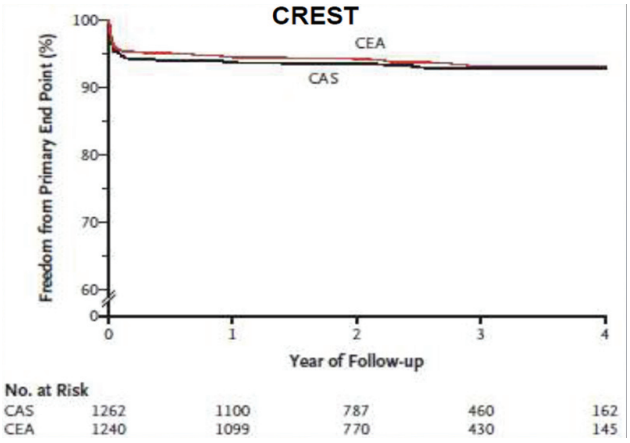

FIGURE 3. Crest study long term outcomes.

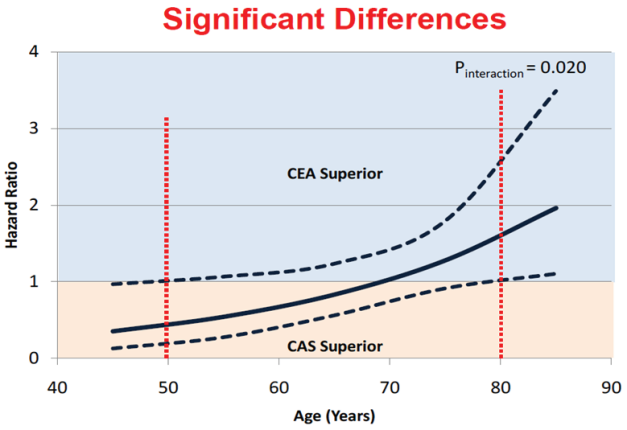

FIGURE 4. Crest study results depending on age.

octogenarians the complication rate is 11.6 % after CAS (N = 106) and 10.8% after CEA (N = 103), which is not statistically significant. Thus, octogenarians do not appear to be a contraindication for CAS.[16] We have to point out that in the CREST study only a single first generation of stent and EPD was utilized and if we consider large recent published series reported in high volume centers with experienced operators, proper indications, choice of the techniques (stents, EPD, approach, etc.), CAS seems as safe as surgery in elderly patients. In the EMPIRE study, the 30-day death/stroke/MI rate was 2.6% in octogenarians and in the ARMOUR study 3.1%. In our own series, the 30-day outcomes are similar in patients >80 years and in patients <80 years (Fig. 5).

What is also remarkable is the restenosis rate. CREST

1164 PROCEDURES	> 80 Y.			< 80 Y.		
	TOTAL	WITHOUT EPD	WITH EPD	TOTAL	WITHOUT EPD	WITH EPD
NBR	177	6	171	987	182	805
T.I.A.	3 (1,3%)	1 (17%)	2 (1,1%)	11 (1,1%)	3 (1,6%)	8 (1%)
MINOR STROKE	1 (0,6%)	1 (17%)	0	6 (0,6%)	3 (1,6%)	3 (0,4%)
MAJOR STROKE	0	0	0	3 (0,3%)	2 (1,1%)	1 (0,1%)
RETINAL EMBOLUS	0	0	0	4 (0,4%)	0	4 (0,5%)
HYPERPERFUSION SYNDROME	0	0	0	3 (0,3%)	0	3 (0,4%)
DEATH FATAL STROKE NON FATAL STROKE	0	0	0	5 (0,5%) 4 (0,4%) 1 (0,1%)	2 (1,1%) 2 (1,1%) 0	3 (0,4%) 2 (0,3%) 1 (0,1%)
M.I.	0	0	0	1 (0,1%)	0	1 (0,1%)
DEATH / STROKE	1 (0,6%)	1 (17%)	0	14 (1,4%)	7 (3,8%)	7 (0,9%)
DEATH / STROKE / M.I.	1 (0,6%)	1 (17%)	0	15 (1,5%)	7 (3,8%)	8 (1%)

E.P.D. : EMBOLIC PROTECTION DEVICES

FIGURE 5. C.A.S. in octogenarians 30 day outcomes.

showed that after 2 years of follow up, restenosis is infrequent and similar whether patients underwent CAS or CEA. The rate of restenosis and occlusion was 6% after CAS and 6.3% after CEA, not statistically different. Women and patients with diabetes or dyslipidemia had higher rates of stenosis, almost doubling the risk. Interestingly, smoking increased restenosis in CEA patients but appeared protective in the stenting group.[17]

REGISTRIES AND RANDOMIZED STUDIES: IMPLICATION FOR CLINICAL PRACTICE

Considering the latest registries and the CREST Study, CAS and CEA are equivalent. These 2 methods of carotid revascularization are safe and efficient for stroke prevention in carotid bifurcation disease. Physicians and patients now have the choice between CEA and CAS. Despite the difference in perioperative stroke prevention at up to 4 years of follow up, CREST lends justifiable support to physicians who choose to treat symptomatic and asymptomatic patients with carotid artery disease by stenting.[18]

CREST reported excellent clinical results for both stenting and surgery with low complication rates. Stenting seems to have similar results with endarterectomy in both symptomatic and asymptomatic patients. Considering the age of the patient at approximately age 69 and younger, stenting results are slightly better with a larger benefit for stenting the younger the age of the patient. For patients older than 70, surgical results are slightly superior to stenting with larger benefits for surgery the older the age of the patient. However, as we have previously discussed, with experienced operators in high volume centers and choice of devices, CAS seems at least not inferior to CEA and can be proposed to elderly patients and octogenarians.

Up to 2010, in the USA, CAS was only indicated for patients at high surgical risk. However, in May 2011, FDA approved expanded use of CAS wwithy the Acculink stenting system to patients at standard risk for adverse events from carotid surgery. The current accepted indications for FDA are symptomatic patients with a stenosis ≥50% or asymptomatic patients with a stenosis ≥60% by angiography. This large population represents about two thirds of all carotid patients. All CAS candidates must have a reference vessel diameter between 4 and 9 mm at the target lesion. The expanded indications are specifically for the Acculink carotid stent used in conjunction with the Rx Accunet EPD. This means that the use of any other EPD in standard risk patient would be off-label. However, there is no evidence of differences in outcomes between the various stents and EPDs.

There are limitations for CEA but also for CAS. We can not stent everyone. Clinicians should use the two therapies, CAS and CEA, in a complementary way so that patients get the lowest risk procedure possible. There will always be some patients who will do better with stenting and some who will do better with surgery. That is the way to reduce stroke rates and confer long-term benefit. We will discuss later the lesions to avoid or to treat with caution. Some lesions should be only treated by very experienced operators. If not, surgery could be the best option but as with CAS, CEA must also be performed by well trained surgeons and not by beginners.

HOW TO AVOID AND REDUCE THE COMPLICATIONS ASSOCIATED WITH CAS[19,20]

1. APPROPRIATE INDICATIONS. PATIENT AND LESION SELECTION

Before determining the indication for carotid revascularization, a procedure assessment with several examinations and tests is indispensable whether the patient is symptomatic or asymptomatic and to recognize the high-risk patients for CAS or CEA. New parameters have been recently reported to define better indications particularly in asymptomatic patients. These examinations include clinical, biological and neurological assessment, ultrasonic plaque morphology examination, transcranial Doppler (TCD), computed tomography (CT) scan and/or magnetic resonance imaging (MRI), diffusion-weighted (DW) MRI, angiographic evaluation, positron emission tomography (PET) and SPECT imaging in some patients, and finally criteria of plaque vulnerability.

1.1. Medical and cardiological assessment

Age is often listed as a high-risk factor, but it is the anatomic challenges and medical co-morbidities that come with age that increase the risk for most patients. A cardiological examination is mandatory to recognize patients with severe coronary artery disease (left main stenosis, triple vessel disease), unstable angina, heart failure, recent MI, patients in need of urgent open heart or vascular surgery, patients with other cardiac, vascular or rhythm abnormalities, or uncontrolled high blood pressure.

A sudden decline in blood pressure and the onset of severe bradycardia during the procedure present major risk for MI and stroke. A careful monitoring of the blood pressure and of the heart rate during the procedure is indispensable to minimize the risk of MI or neurological complications (hypertension syndrome, brain hemorrhage, stroke). The presence of severe peripheral vascular disease could favor brachial or radial access even direct carotid puncture to minimize access site difficulties and complications.

1.2. Neurological assessment

The neurological risk increases with recent large infarction with risk of brain hemorrhage. It is probably preferable to wait for six weeks before intervention in these circumstances, al-

though there is little robust evidence to guide the interventionist. However, newer data over the last 5-7 years have shown that CAS for symptomatic patients with neurological stabilization can be done in a much shorter time window.[21] Other situations of increased neurological risk comprise crescendo transient ischemic attack (TIA), stroke in evolution, and elderly patients due to the lack of vascular reserve.

1.3. Biological assessment

Elderly diabetic patients could be at higher risk for CAS.[22] Also patients with chronic renal insufficiency have a higher risk of neurological complications.[23]

1.4. Echographic plaque characteristics

A good echographic evaluation is mandatory to recognize echolucent plaques which are at higher risk of embolization during CAS.[24]

1.5. Transcranial Doppler (TCD)

Spence et al[25] reported that asymptomatic patients who have microemboli at baseline detected by TCD are more likely to have a stroke during the first year of follow up (15.6% vs 1%) and could benefit from revascularization. This technique may allow for better identification of a particular high-risk group of patients with carotid stenosis and particularity asymptomatic patients.

1.6. CT scan – MRI

Silent infarct is an independent risk factor for future stroke.[26] Thus, the detection of silent brain infarcts on DW MRI or CT scan could reinforce the indications of CAS or CEA especially in asymptomatic patients. Patients with contralateral ischemic symptoms seem also at higher risk for neurological complications.

1.7. Angiographic evaluation

An angiography of the aortic arch, all supra-aortic vessels and of the intracranial arteries is indispensable before a CAS procedure. Some anatomical situations may lead to difficulties to safely perform CAS, due to access problems, increasing the risk of the procedure. CEA could be better in some cases like complex bifurcation disease with long, multifocal lesions, very angulated internal carotid artery (ICA), extensive aortic or brachiocephalic trunk plaque, severe tortuosities, severe calcifications of the aorta and arch vessel, severe ulceration, heavy circumferential calcifications of the carotid bifurcation.

A good knowledge of the vessel anatomy is mandatory in order to decide on the appropriate approach or the best technique to use. A type 3 aortic arch could be challenging, particularly in elderly patients with very atheromatous arch. The aortic arch has its own set of embolic potential and is a substancial source of emboli. We have to avoid excessive catheter manipulation in this type of arch, which could detach atheromatous plaques and lead to showers of emboli to the brain. Distal loops, bends, kinks may be a contraindication to some protection devices. If a clot is suspected, CAS is contraindicated if the interventionist cannot use a proximal protection device.

1.8. Criteria of plaque vulnerability

Baseline C-reactive protein (CRP) was found to be a powerful predictor of outcome in patients undergoing CAS. An elevated CRP value before CAS remained a significant and independent predictor of stroke and death within 30 days after CAS.[27] Similarly an increased preprocedural leukocyte count independently predicted more frequent embolic events during CAS.[28] In the future, virtual histology intravascular ultrasound imaging will perhaps identify vulnerable plaque with embolic potential in patients undergoing CAS.[29]

2. CORRECT TECHNIQUE OF CAS

We have to select the best procedural approach depending on the anatomy. Most of the time we use the femoral approach but in some patients (tortuous arteries, difficult aortic arch, type III aortic arch, bovine arch, etc.) a brachial or radial approach, even a direct puncture of the common carotid artery are the best options to minimize the neurological complications.

3. EMBOLIC PROTECTION DEVICES[19,20,30]

Embolic protection devices (EPD) should be used in any CAS procedure. We have the choice among 3 techniques: distal occlusion with balloon occlusion, filters, and proximal protection devices (Gore Neuroprotection System, W. L. Gore & Associates, Inc., Flagstaff, AZ, USA; or Moma device, Invatec, Medtronic, Bethlehem, PA, USA).

According to the metaanalysis of Garg et al (134 reports),[31] EPD reduced the risk of perioperative stroke with CAS. A total of 12263 protected CAS procedures were compared with 11198 unprotected CAS procedures. The relative risk (RR) for stroke was 0.62 (95% CI: 0.54 to 0.72) in favor of protected CAS. In the CREST study, 24 patients were treated without EPD with a 30-day death, stroke, MI rate of 20.8% compared to 5.3% for patients treated with EPD.

Choosing EPD is crucial and depends on the interventionist, the lesion, the anatomy of the different vessels, the intracranial circulation and the collateral circulation. An occlusion balloon or flow reversal system are contraindicated in cases of poor collateral circulation and contralateral occlusion. Patients presenting with tortuous supraaortic vessels or type 3 aortic arch require a low profile flexible EPD. Flow reversal systems seem inadequate due to their larger profile, but may be beneficial in cases with very tortuous ICA, severely angulated ICA kinks, bends above the carotid stenosis or if thrombi are suspected. Some authors advise proximal occlusion to treat plaques with very high risk of brain embolization (soft plaques,

dyshomogenous, plaques, plaques with gray-scale median (GSM) <25). However, a very low profile filter can be useful to treat lesions in tortuous vessels. New low profile filters with their retrieval catheter which is an aspiration catheter like the FiberNet Filter (Medtronic Inc, Santa Rosa, CA, USA) seem promising to treat high risk plaques.[32]

A question arises whether all protection devices are equivalent in humans. Iyer et al[33] reported a multicenter study analyzing 3160 CAS procedures using 9 different types of EPD. There was no significant difference in the risk of procedural adverse events for any EPD. In the EMPIRE and ARMOUR studies with proximal protection devices, the 30-day death/stroke/MI rates were respectively 3.7% and 2.7%, not different from any other EPD. However, we have to mention that with proximal protection it seems that we observe less microemboli and less new cerebral ischemic lesions on DW-MRI.[34]

4. CHOICE OF THE STENT AND CORRECT IMPLANTATION

Two types of stents can be selected for the carotid bifurcation: closed cell stent design, either the Wallstent (Boston Scientific, Natick, MA, USA) or nitinol stents (Xact stent, Abbott, IL, USA; NexStent, Boston Scentific, MN, USA), and open cell stent design, such as the Precise (Cordis, NJ, USA), Acculink (Abbott, IL, USA), Protege (ev3, MN, USA), or Exponent (Medtronic Vascular Inc., CA, USA) stents.

Bosier et al[35] reported a higher neurological complication rate after implantation of open cell than closed cell stents (11.1% vs 3%). It is also now well demonstrated that the majority of strokes occur post procedure and before discharge. Furthermore, it seems that the free cell area influences the outcome in CAS. In Bosier's report the post procedural rate analysed for different stents varied from 1.2% using a closed cell stent (Wallstent) to 5.9% using an open cell stent (Medtronic Exponent). The late events varied from 1.2% to 3.4% for free cell area <2.5 mm^2 and 7.5 mm^2 respectively (P<0.05). Post procedural event rate was 1.3% for closed cells and 3.4% for open cells. All these differences were highly pronounced among symptomatic patients (p<0.001).

In the SPACE study,[13] the same influence of stent cell design was reported. The neurological complication rate was 5.9% with closed cell stents and 11% with open cell stents. Schillinger et al[36] reported a registry of 1684 patients with results which conflict with those of Bosier's et al. Combined TIA, stroke or death rates and stroke or death within 30 days of treatment were 6.1% (95% CI, 5.0 to 7.2) and 3.1% (95% CI, 2.3 to 3.9) for the closed cell design versus 4.1% (95% CI, 3.2 to 5.0) and 2.4% (95% CI, 1.7 to 3.1) for the open-cell design stents (P=0.077, P=0.38), respectively, without significant differences in asymptomatic and symptomatic patients. These data do not support the superiority of specific carotid stent cell design with respect to neurologic complications stroke and mortality risk. However, if we analyse more carefully these data, we can see that the event rate at day 1 through day 30 in symptomatic patients is 0.3% with closed cell and 1.39 with open-cell stents (P=0.03). Thus, open cell stents could give a better protection against delayed embolic events in symptomatic patients. Hornung[37] reported a series of 845 CAS procedures and found that the acute and subacute results of CAS were not significantly different between open and closed cell stents. There was a trend towards better results with open cell stents in symptomatic patients. Despite these different opinions, we recommend to use closed cell design stents except in tortuous vessels where open cell stents are more appropriate. In that case we advise to use open cell stents with the smallest free cell area. Regarding the size of the stent, the diameter is chosen depending on the diameter of the common carotid artery and the length depending on the length of the lesion.

5. PHARMACOLOGICAL ADJUNCTS

Platelet antiaggregants are mandatory (aspirin, clopidogrel, etc) and it is also most important to control blood pressure and heart rate during and after the procedure.

6. LEARNING CURVE. EXPERIENCED OPERATORS

Increase in operator experience coupled with improvements in techniques and patient selection likely contributed to marked improvements in CAS outcomes as recently reported by W. Gray in 4 studies in high risk patients (Fig. 6) and in the CREST study (Fig. 7). In this latter study, the learning curve and experience played a major role and in particular in elderly patients and octogenarians. In the period between 2000-2004, death and major stroke rate was 6.5% and between 2006-2008 0% (Fig. 8). Lin et al[39] reported clearly that the complication rate is dramatically reduced with experience. In their series, the complication rate was 18% for the first 50 patients, 8% for the group of patients between number 51 and 100, and 2% after the first 100 procedures. It is well known that the poor results published in the EVA3S (88) and SPACE (98) studies are for a large part due to inexperienced operators. All these data demonstrate that CAS is a challenging procedure which should the performed by experienced operators, in high volume centers with a proper choice of different techniques (EPD, stents, etc.).

CONCLUSION

The CREST study and recently published data have shown that CAS and CEA are equivalent for the treatment of a carotid stenosis. However, these two treatments have respective contraindications and limitations. For each intervention, there is a need for appropriate patient and lesion selection, good technique, embolic protection devices and experienced

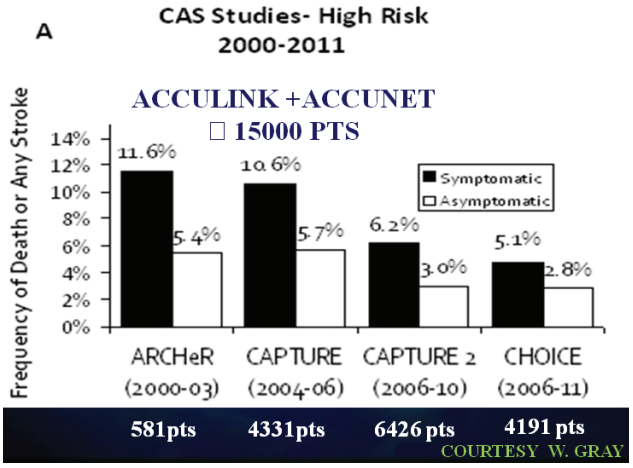

FIGURE 6. C.A.S. under protection 4 studies in high risk patients.

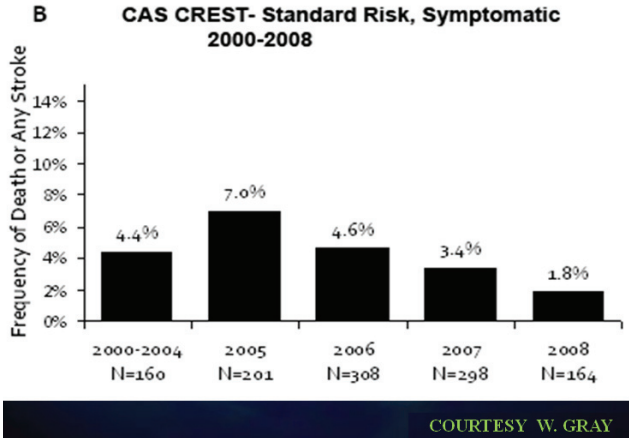

FIGURE 7. Crest study outcomes overtime.

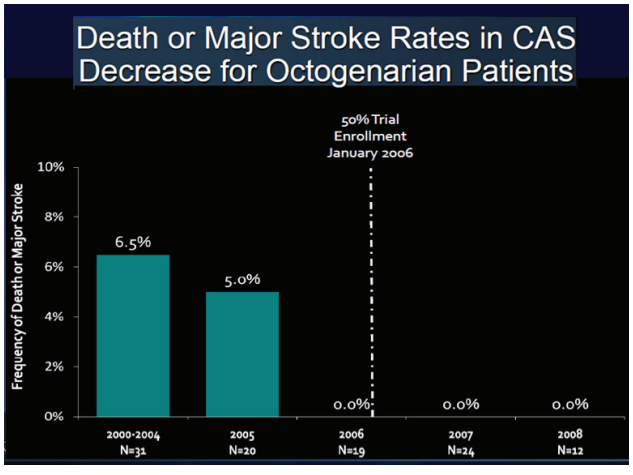

FIGURE 7. C.A.S. Crest study - Elderly patients.

operators. Indications for asymptomatic patients have to be discussed considering the benefit of optimal medical therapy and need a large number of new parameters (Duplex scan, plaque histology, brain perfusion imaging, etc.).

REFERENCES

1. Paraskevas K, Bessias N, Mikhailidis D. Epidemiology and pathophysiology of carotid artery disease. *In:* Henry M, Diethrich E, Polydorou A (eds), The Carotid and Supra Aortic Trunks: Diagnosis, Angioplasty and Stenting.3 OXFORD, WILEY-BLACKWELL, 2011: 3-7.
2. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of the carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med* 1991; 325:445-453.
3. European Carotid Surgery Trialists' Collaborative Group. MRC European Carotid Surgery Trial: Interim Results for symptomatic patients with severe (70-90 %) or with mild (0-29 %) carotid stenosis. *Lancet* 1991; 337:1235-1243.
4. Mayberg MR, Wilson SE, Yatsu F, et al. Carotid endarterectomy and prevention of cerebral ischemia in symptomatic carotid stenosis. Veterans Affairs Cooperative Studies Program 309 Trialists Group. *JAMA* 1991;266:3289-3294.
5. Executive Committee for the asymptomatic carotid atherosclerotic study: endarterectomy for asymptomatic carotid artery stenosis. *JAMA* 1995; 273:1421-1428.
6. MRC Asymptomatic Carotid Surgery Trial (ACST) Collaborative Group Prevention. Prevention of Disabling and Fatal Strokes by successful Carotid Endarterectomy in Patients without recent neurological Symptoms: Randomised Controlled Trial. *Lancet* 2004; 363:1491-1502.
7. Hobson RW, Weiss DG, Fields WS. Efficacy of carotid endarterectomy for asymptomatic carotid stenosis: The Veterans Affairs Cooperative Study Group. *N Engl J Med* 1993; 328:221-227.
8. Ouriel K, Hertzer NR, Beven EG. Preprocedural risks stratification: Identifying an appropriate population for carotid Stenting. *J Vasc Surg* 2001; 33:728-732.
9. Endovascular versus Surgical Treatment in Patients with Carotid Stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS: a randomised trial). *Lancet* 2001; 357:1729-1737.
10. Brooks WH, Mc Lure RR, Jones MR. Carotid Angioplasty and Stenting versus Carotid Endarterectomy: Randomised Trial in a community hospital. *J Am Coll Cardiol* 2001; 38:1589-1595.
11. Jaffery Z, Grant A, Collins T. Critical review of randomized studies and registries. In: Henry M, Diethrich E, Polydorou A (eds), The Carotid and SupraAortic Trunks : Diagnosis, Angioplasty and Stenting: OXFORD: WILEY-BLACKWELL, 2011: 315-325.
12. Mas JL, Chatellier G, Beyssen B, et al. Endarterectomy versus stenting in patients with symptomatic severe carotid stenosis. *N Engl J Med* 2006;355 : 1660-1671.
13. SPACE Collaborative Group, Ringleb PA, Allenberg J, Bruckmann H, Eckstein HH, Fraedrich G, et al. 30-day results from

the SPACE trial of stent-protected angioplasty versus carotid endarterectomy in symptomatic patients: a randomized non-inferiority trial. *Lancet* 2006;368:1239-1247. Erratum in: Lancet 2006; 368:1238.
14. International Carotid Stenting Study Investigators. Carotid artery stenting compared with endarterectomy in patients with symptomatic carotid stenosis. *Lancet* 2010; 375:985-997.
15. Brott TG, Hobson RW, Howard G, et al. CREST Investigators. Stenting versus endarterectomy for treatment of carotid artery stenosis. *N Engl J Med* 2010; 363:11-23.
16. Henry M, Henry I, Polydorou A, Hugel M. Carotid angioplasty and stenting in octogenarians. Is it safe? *Catheter Cardiovasc Interv* 2008; 72:309-317.
17. Lal BK. Restenosis similar with carotid stenting or surgery: CREST. International stroke conference 2012.
18. Diethtrich EB, N'Diaye M, Reid D. The Carotid Revascularization Endarterectomy versus Stenting Trial (CREST): implications for clinical practice. In: Henry M, Diethtrich E, Polydorou A eds, The carotid and Supra Aortic Trunks: Diagnosis, Angioplasty and Stenting. OXFORD, WILEY-BLACKWELL, 2011: 335-338.
19. Henry M, Henry I, Polydorou A, et al. Carotid angioplasty and stenting: How to avoid complications. *Minerva Cardioangiol* 2009; 57:29-56.
20. Henry M, Henry I, Benjelloun A, et al. Carotid angioplasty under protection; limitations, dark side, how to avoid complications. In: Henry M, Diethrich E, Polydorou A (eds), The Carotid and Supra Aortic Trunks: Diagnosis, Angioplasty and stenting. OXFORD, WILEY-BLACKWELL, 2011:208-229.
21. Gurm Ms, Nallamothv BK, Yadav J. Safety of carotid stenting for symptomatic carotid artery disease: a meta-analysis. *Eur Heart J* 2008; 29:113-119.
22. Schluter M, Reimers B, Castriota F, et al. Impact of diabetes, patient age and gender on the 30 day incidence of stroke and death in patients undergoing carotid angioplasty stenting with embolic protection: a post hoc subanalysis of a prospective multicenter registry. *J Endovascular Ther* 2007; 14:271-278.
23. Gruberg L, Laird J, Satler L. Stent supported carotid artery angioplasty: the impact of renal function on the neurological outcome. *J Am Coll Cardiol* 2002: 39(Suppl. A):30A.
24. Biasi GM, Sampaolo A. Computer analysis of ultrasonic plaque echolucency in identifying high risk carotid bifurcation lesions. *Eur J Endovasc Surg* 199: 17(6):476-479.
25. Spence JD, Tamoya A, Lownie SP, et al. Absence of microemboli on transcranial Doppler identifies low-risk patients with asymptomatic carotid stenosis. *Stroke* 2005; 36:2373-2378.
26. Bernick C, Kuller L, Dulberg C, et al. Silent MRI infarcts and the risk of future stroke: the cardiovascular health study. *Neurology* 2001; 57:1222-1229.
27. Groschel K, Ernemann U, Larsen J, et al. Preprocedural C-reactive protein levels predict stroke and death in patients undergoing carotid stenting. *Am J Neuroradiol* 2007; 28:1743-1746.
28. Aronow HD, Shishehbor M, Davis DA, et al. Leukocyte count predicts microemboli Doppler signals during carotid stenting: a link between inflammation and embolization. *Stroke* 2005; 36: 1910-1914.
29. Diethrich EB, Margolis PM, Reid DB, et al. Virtual histology intravascular ultrasound assessment of carotid artery disease: the carotid artery plaque vertebral histology evaluation. (CAPITAL) study. *J Endovasc Ther* 2007; 14:676-686.
30. Henry M, Henry I, Polydorou A, et al. Embolic Protection Devices. In : Henry M, Dietrich E, Polydorou A (eds), The Carotid and Supra Aortic Trunks: Diagnosis, Angioplasty and Stenting. OXFORD: WILLEY-BLACKWELL, 2011:191-207.
31. Garg N, Karagiorgos N, Pisimisis GT, et al. Cerebral protection devices reduce preprocedural strokes during carotid angioplasty and stenting: a systematic review of the current literature. *J Endovasc Ther* 2009; 16:412-427.
32. Henry M, Polydorou A, Henry I. New distal embolic protection device. The FiberNet 3- dimensional filter. First carotid human study. *Cath Cardiovasc Intervent* 2007; 69:1026-1035.
33. Iyer V, Dedonato G, Deloose K, et al. The type of embolic protection does not influence the outcome in carotid artery stenting. *J Vasc Surg* 2007; 46:251-256.
34. Bijulic K. Profi Study. TCT Meeting, San Francisco, CA, USA, 2011.
35. Bosiers M, de Donato G, Deloose K, et al. Does free cell area influence the outcome in carotid artery stenting? *Eur J Vasc Endovasc Surg* 2007; 33:135-141.
36. Schillinger M, Gscgwendtner M, Reimers B, et al. Does carotid stent cell design matter? *Stroke* 2008; 39:905-909.
37. Hornung M, Bode A, Franke J, et al. Open and closed cell stent design for carotid stenting. *Am J Cardiol* 2008; 102 (suppl): 36 I.
38. Lin PH, Zhou W, Kougias P, et al. Assessing the learning curve of CAS. *Endovascular Today* 2006; 5:68-74.