"Medical high risk" designation is not associated with survival after carotid artery stenting

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Background: **While medical high risk (MHR) has been proposed as an indication for carotid artery stenting (CAS), the impact of MHR on long-term survival and stroke after CAS has not been described.**
Methods: **A retrospective chart review of CAS procedures at our institution was performed. One hundred seventy-nine consecutive patients who underwent 196 CAS procedures were classified by MHR status based on cardiac, pulmonary, and renal criteria routinely used in high-risk clinical trials. Survival and stroke rates were compared after 90 CAS procedures in MHR patients vs 106 CAS procedures in normal risk patients. Survival results were also compared with 365 contemporaneous carotid endarterectomy (CEA) procedures in 346 patients.**
Results: **The mean age of CAS patients was 72 years, with 87% having a smoking history, 85% hypertension, 38% diabetes, 39% symptomatic, and 74% documented coronary artery disease. Mean follow-up was 23 months. Recurrent stenosis after CEA comprised 21% of all CAS procedures. During the 30-day post-procedure period, there were five minor strokes, one major stroke, and one death, for a combined stroke/death rate of 3.6%. Kaplan-Meier analysis demonstrated mortality of 5% at 1 year and 21% at 3 years for the entire cohort. Cox regression analysis found that MHR designation was not associated with increased mortality or an increase in a composite end point of death or stroke. MHR patients had mortality of 4% at 1 year and 22% at 3 years. Normal risk patients had mortality of 6% at 1 year and 20% at 3 years. Preoperative age over 80 years old, low density lipoprotein (LDL) ≥160 mg/dL, and serum creatinine ≥1.5 mg/dL conferred statistically significant risk for death (Hazard ratios: 2.9, 4.3, and 2.4, respectively). As a point of comparison, a contemporaneous group of CEA patients were analyzed similarly. After adjusting for age over 80 years old and serum creatinine ≥1.5 mg/dL, there was no survival difference between MHR patients undergoing CAS or CEA.**
Conclusions: **The presence of MHR did not impact long-term survival or stroke rate after CAS, and overall survival of MHR patients in our series was comparable with risk-adjusted controls undergoing CEA. These results suggest the need for more refined predictors of medical risk to optimally guide patients in selecting carotid revascularization strategies.**
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Carotid artery atherosclerotic disease is a major cause of ischemic stroke, being an underlying cause in 10% to 20% of patients presenting with stroke.[1] Randomized controlled trials have demonstrated durable benefit from carotid endarterectomy (CEA) in symptomatic and asymptomatic patients that have been appropriately selected.[2,3,4,5,6,7] In fact, many have deemed CEA to be the "gold standard" in carotid revascularization.[8]

However, some patients with severe coronary, pulmonary, and renal disease are considered to be at medical high risk (MHR) for CEA, and they have been shown to have higher rates of stroke, myocardial infarction, and death after CEA than patients without such risk factors.[9] For these patients, many consider carotid artery stenting (CAS) to be an alternative, and perhaps equivalent, treatment option. Although controversial, the Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy trial (SAPPHIRE) concluded that CAS was not inferior to CEA among patients who were at medical or surgical high risk for carotid endarterectomy.[10] However, the same medical comorbidities that made these patients eligible for CAS raise the concern that these patients might have increased late mortality and might not live long enough to benefit from carotid revascularization. This is especially true when treating asymptomatic patients, who comprise the majority of patients enrolled into many randomized trials and registries.[11]

Therefore, we reviewed the records at our institution of patients who underwent CAS, and examined the effect of MHR designation on midterm survival. To provide a comparison with endarterectomy, we also compared survival after CAS with a contemporaneous group of patients undergoing CEA at our institution.

METHODS

Study design and patient selection. A retrospective review was conducted of all patients who underwent CAS for extracranial carotid bifurcation disease from December 2000 through August 2006. This study was approved by the Institutional Review Board at Dartmouth-Hitchcock Medical Center (DHMC), Lebanon, NH. We included only patients undergoing CAS for bifurcation disease. We excluded those patients who underwent isolated proximal

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Table I. Inclusion criteria for medical high risk for carotid endarterectomy

High-risk category	*Criteria*
Cardiac dysfunction	NYHA class III or IV CHF
	LVEF ≤30%
	CCS class III or IV angina
	Positive cardiac stress test
Pulmonary dysfunction	Chronic oxygen therapy
	pO_2 ≤60 mm Hg
	FEV_1 ≤50% predicted
	DL_{CO} ≤50% of predicted
Renal dysfunction	Serum creatinine ≥3 mg/dL
	Dialysis dependence

NYHA, New York Heart Association; *CHF,* congestive heart failure pO_2, partial pressure of oxygen in arterial blood; *LVEF,* left ventricular ejection fraction; *CCS,* Canadian Cardiovascular Society; *FEV_1,* forced expiratory volume in 1 second; *DL_{CO},* diffusing capacity of the lungs for carbon monoxide.

common carotid artery stenting or carotid interventions for other indications such as dissection, trauma, or aneurysm.

Medical high risk determination. We reviewed the recent literature and current clinical trials in order to identify MHR criteria used in major high-risk CAS studies,[10,12,13] and then used these to define inclusion criteria to designate patients as MHR for this study. These criteria are identified in Table I. Based on medical records available before the procedure, patients were then classified as being at MHR for conventional CEA if they fulfilled any of the cardiac, pulmonary, or renal criteria listed.

Two authors (THY and PPG) independently reviewed patient records and assigned MHR designation according to these criteria. Any designations that were ambiguous or uncertain were arbitrated by a third author (RJP). If these patients did not fulfill any of these criteria, they were deemed to be at normal risk (NR). Anatomic risk factors for CEA, such as previous ipsilateral CEA or a history of cervical radiation therapy, were not considered in this analysis.

CAS procedures. CAS procedures were performed as previously described.[14] Patients generally received clopidogrel, 75 mg/d for 1 week, or a single 300-mg loading dose of clopidogrel orally on the morning of the procedure. In addition, patients were given oral aspirin throughout the periprocedure period. Carotid artery access was obtained via either a femoral or carotid approach, and in most cases, an embolic protection device (EPD) was then deployed before a carotid artery stent was placed. Patients remained in the recovery room for 4 to 6 hours. If no hemodynamic instability occurred, they were transferred to a standard hospital room. The morning after the procedure, a carotid duplex scan was obtained, and patients were subsequently discharged on aspirin and clopidogrel 75 mg/d for 1 month. Carotid duplex scanning was performed at 24 hours, 1 and 6 months, and yearly thereafter.

Embolic protection devices (EPDs) used included the GuardWire in 51% (PercuSurge/Medtronic Vascular, Santa Rosa, Calif), the Accunet in 22% (Guidant, St. Paul, Minn), the Emboshield in 20% (Abbott Laboratories, Abbott Park, Ill), the AngioGuard in 5% (Cordis, Miami Lakes, Fla), and the FilterWire in 1% (Boston Scientific, Natick, Mass). Reversal of flow was used in one case, and no protection method was used in two cases.

Stents used included the Wallstent in 53% (Boston Scientific, Natick, Mass), the Acculink in 21% (Guidant, St. Paul, Minn), the Xact in 15% (Abbott Laboratories, Abbott Park, Ill), the Precise in 7% (Cordis, Miami Lakes, Fla), and the ViVEXX in 4% (Bard Peripheral Vascular, Tempe, Ariz). In one case, a Cypher sirolimus-eluting coronary stent (Cordis, Miami Lakes, Fla) was used for a patient with recurrent intimal hyperplasia. Similarly, an ICast covered stent (Atrium Medical, Hudson, NH) was used in another patient with recurrent intimal hyperplasia.

CEA procedures. We then sought to examine survival across risk strata, between patients undergoing CAS and CEA. Therefore, a contemporary group of patients who had undergone CEA at DHMC between August 2002 and August 2006 was utilized to provide a reference point. We studied 365 CEAs in 346 patients. Chart and database review allowed determination of pre-existing medical comorbidities, such that the patients were then classified as MHR or NR for CEA in a fashion similar to the CAS cohort. A total of 38 (10%) of the CEA procedures occurred in patients who were MHR. Survival status was ascertained in a fashion similar to the CAS patients.

Outcomes definitions. Patients underwent a neurologic examination performed by a general surgery chief resident or vascular fellow in addition to the surgical attending physician on post-procedure day 1 and at each clinic visit thereafter. Patients were not consistently examined by an independent neurologist, though later in our series almost all patients underwent independent neurologist evaluation. Any new neurologic deficits were scored with the National Institutes of Health (NIH) Stroke Scale. A major stroke was defined as a new neurologic event that lasted longer than 24 hours, with an increase in the NIH Stroke Scale greater than or equal to 3. A minor stroke was defined as a new neurologic event that lasted longer than 24 hours and was associated with an increase in the NIH Stroke Scale of less than 3. A transient ischemic attack (TIA) was defined as a new neurologic deficit that lasted less than 24 hours. A neurologic deficit that developed during deployment of the EPD that completely resolved with its removal was not considered a TIA, but as failure of embolization protection.

Follow-up procedures and analysis. Subsequent survival and stroke were ascertained through the use of available medical records, and if recent medical records were not available, the patient, patient's family, or the patient's primary care provider was directly contacted by telephone to determine survival status and establish a follow-up visit in clinic. If the patient could not be contacted, the patient's family or primary care provider was contacted to determine the patient's survival status. Stroke status was not determined through the telephone interview.

Table II. Demographic data and frequency of clinical variables in patients undergoing CAS

Demographic data	*CAS: medical normal risk (n = 106)*	*CAS: medical high risk (n = 90)*	*CAS: all (n = 196)*	P *value*
Number of patients	96	83	179	
Mean age (y)	71.0 ± 0.9	72.5 ± 0.9	71.7 ± 0.7	NS
Male gender	79%	78%	79%	NS
Symptom status				
TIA or amaurosis fugax	24%	32%	28%	NS
Stroke	10%	12%	11%	NS
Asymptomatic	66%	56%	61%	NS
Cardiovascular risk factors				
History of coronary artery disease	57%	94%	74%	<.001
Diabetes mellitus	34%	43%	38%	NS
Hypertension	82%	88%	85%	NS
Dyslipidemia	88%	91%	90%	NS
Smoking history	87%	87%	87%	NS
Preoperative creatinine (mg/dL)	1.13 ± 0.04	1.39 ± 0.08	1.3 ± 0.05	.004
Preoperative LDL (mg/dL)	97 ± 4	88 ± 4	93 ± 3	NS
Vascular history				
History of any previous vascular surgery	50%	40%	45%	NS
History of previous ipsilateral CEA	29%	11%	21%	.002
Presence of anatomic high risk factors	60%	38%	50%	.002
Radiographic ICA stenosis	81%	82%	81%	NS
Contralateral ICA stenosis or occlusion	22%	20%	21%	NS

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *TIA,* transient ischemic attack; *LDL,* low density lipoprotein; *ICA,* internal carotid artery; *NS,* not significant.

Analysis. Data are presented as mean ± SEM, except where noted. Demographic data were analyzed with the use of Student *t* tests or Pearson χ^2 tests, as appropriate. Rates of survival and stroke were estimated using the Kaplan-Meier method for patients undergoing CAS. Differences in survival between various groups of patients were estimated with the use of the Cox proportional hazards regression. Analysis was performed with STATA 9.0 (Stata Corp, College Station, Texas) and Microsoft Office Excel 2003 (Microsoft Corporation, Redmond, Wash).

RESULTS

Patient demographics and results of CAS. Demographic and clinical data for the patients undergoing CAS are presented in Table II. A total of 196 CAS procedures were performed in 179 patients, with 46% of the procedures being done in MHR patients. Mean CAS follow-up was 23 ± 1 months. Mean patient age was similar at the time of the procedure between NR and MHR patients (71 vs 73 years old), as was the prevalence of male patients (79% vs 78%). Clinical presentation was also similar, with 66% and 56% of the patients being asymptomatic, respectively. In terms of cardiovascular risk factors, 57% of the NR group and 94% of the MHR group ($P < .001$) had a documented history of coronary artery disease. The presence of other risk factors, including diabetes mellitus, hypertension, dyslipidemia, and a history of smoking, was comparable between the two groups. Preoperative creatinine was significantly higher in the MHR group (1.1 g/dL vs 1.4 g/dL, $P = .004$). NR patients had a significantly higher chance of having anatomic factors that would confer additional risk for CEA compared with MHR patients (60% vs 38%; $P = .002$). Mean radiographic ICA stenosis was similar in both NR and MHR patients (81% vs 82%), as was the presence of a contralateral ICA occlusion (22% vs 20%).

Table III. High risk categories among CAS patients

Category	*No of procedures*	*% of all procedures (n = 196)*
Medical		
Cardiac	74	38
Pulmonary	20	10
Renal	3	2
Anatomic		
Previous CEA	41	21
Distal extent	19	10
Other[a]	4	2
None	42	21

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy.
Several patients fulfilled criteria for multiple high risk categories.
[a]Other includes contralateral cranial nerve palsy, history of neck irradiation, and tracheal stoma.

Among patients with MHR factors, cardiac comorbidity was the most common criterion for MHR status followed by pulmonary, and then renal comorbidities (Table III). Most patients were MHR in only one category, while six of the procedures were done in patients who had both cardiac and pulmonary comorbidities, and one procedure was done in a patient who had a cardiac and a renal comorbidity.

Outcomes of CAS. During the immediate periprocedural period, there were three minor strokes and two major strokes. During the 30-day post-procedural period, there was one minor stroke and one death, for a combined

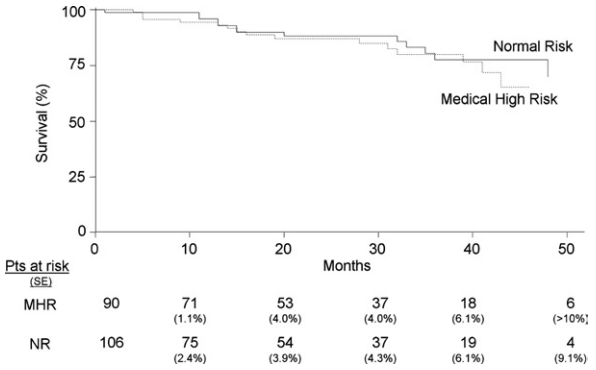

Fig 1. Kaplan-Meier survival estimates comparing medical high risk and medical low risk patients.

30-day stroke/death rate of 3.6%. During follow-up, a total of 28 patients had died, after undergoing 30 CAS procedures. One additional minor stroke was detected during the follow-up period.

Kaplan-Meier analysis for all patients demonstrated mortality of 5% at 1 year and 21% at 3 years. NR mortality was 6% at 1 year and 20% at 3 years, which was similar to the mortality for MHR patients that were 4% at 1 year and 22% at 3 years (Fig 1). Analysis of death rates using Kaplan-Meier and Cox proportional hazards analysis showed no difference in rate of death between MHR patients and NR patients (Hazard ratio [HR] = 0.89, 95% CI: 0.43-1.82). Kaplan-Meier analysis for the composite end point of stroke or death revealed similar findings. For all patients, the rate of stroke or death at 1 year and 3 years was 7% and 24%, respectively. NR stroke or death rates were 7% at 1 year and 23% at 3 years, while the corresponding rate for MHR patients was 7% at 1 year and 25% at 3 years. This composite end point of stroke or death was not increased among MHR patients compared with NR patients (HR = 0.91, 95% CI: 0.47-1.75).

Univariate Cox proportional hazards analysis of available preoperative variables revealed three significant risk factors for reduced survival. These were: age ≥80 years old, serum LDL >160 mg/dL, and serum creatinine ≥1.5 mg/dL. Of note, MHR designation did not predict worse survival (HR 0.89, 95% CI 0.43-1.82). Many other variables were analyzed; however, none other than the three listed above had any significant ability to predict death following CAS (Table IV).

We then examined if age over 80, which has been shown in several prior studies to predict poor outcomes after CAS, also predicts poor survival after CAS. Kaplan-Meier estimate of the survival function comparing patients older than 80 years old with patients younger than 80 years old at the time of CAS demonstrates a higher risk of death (Fig 2) among the patients over age 80. One and 3 year mortality was 4% and 15% among patients younger than 80 years old, compared with 7% and 45% among octogenarians.

Comparison with CEA. Demographic data for CEA patients is compared with CAS patients in Table V. As expected, CAS patients were significantly older (70 years vs 72 years), were significantly more likely to be male (62% vs 79%) and had a significantly higher creatinine level (1.1 mg/dL vs 1.3 mg/dL). A similar percentage of both groups had asymptomatic lesions (57% vs 61%). As expected, CEA patients were significantly less likely to have an identified medical high risk factor (10% vs 46%). Mean CEA follow-up was 22 ± 1 months.

Univariate Cox proportional hazards analysis revealed that CAS patients died at a significantly higher rate than

Table IV. Hazard ratios of potential predictive factors for mortality after CAS

Variable	*Hazard ratio*	*95% confidence interval*	P *value*
Medical high risk*	0.89	0.43-1.82	NS
Age >80 y old	2.86	1.34-6.10	.007
Preoperative LDL >160 mg/dL	4.30	1.23-15.0	.022
Preoperative creatinine ≥1.5 mg/dL	2.37	1.15-4.86	.019
Diabetes mellitus	1.23	0.60-2.54	NS
Hypertension	1.47	0.51-4.23	NS
Dyslipidemia	0.43	0.16-1.14	NS
Male gender	1.09	0.42-2.84	NS
Presence of a symptomatic lesion	1.13	0.55-2.32	NS
History of CAD	0.73	0.32-1.66	NS
History of ipsilateral CEA	0.25	0.06-1.06	NS
Cardiac risk factor*	0.81	0.38-1.70	NS
Pulmonary risk factor*	1.02	0.31-3.38	NS
Renal risk factor*	1.68	0.23-12.4	NS
Coumadin usage	1.64	0.67-4.03	NS
Past or present tobacco usage	0.42	0.17-1.03	NS
LVEF ≤30%	1.04	0.23-4.67	NS
Statin usage	0.59	0.27-1.30	NS
Beta blocker usage	0.83	0.40-1.72	NS
ACE/ARB usage	0.60	0.29-1.23	NS

ACE, Ace inhibitor; *ARB*, angiotensin receptor blocker; *CAD*, coronary artery disease; *CAS*, Carotid artery stenting; *CEA*, carotid endarterectomy; *LVEF*, left ventricular ejection fraction; *NS*, not significant.
*Cardiac, pulmonary, and renal risk factors for high risk for CEA are defined in Table I.

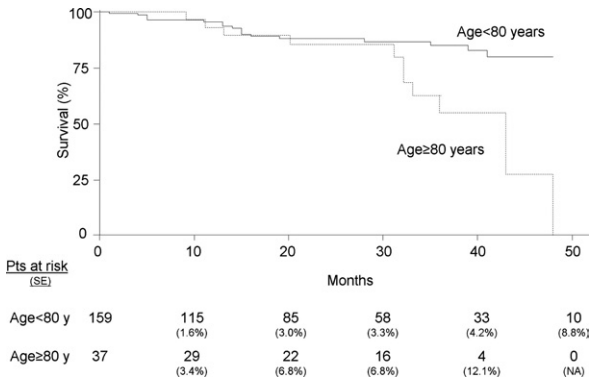

Fig 2. Kaplan-Meier estimates of survival comparing octogenarians with non-octogenarians.

Table V. Comparison of CAS and CEA patient populations

Demographic data	*CEA*	*CAS*	P *value*
Number of procedures	365	196	—
Number of patients	346	179	—
Mean age (y) ± SEM	69.6 ± 0.5	71.7 ± 0.7	.01
Male gender	62%	79%	<.001
Preoperative creatinine (mg/dL) ± SEM	1.1 ± 0.02	1.3 ± 0.05	<.001
Follow-up (mo)	22.3 ± 0.8	23.4	NS
Asymptomatic	57%	61%	NS
High cardiac risk	9%	38%	<.001
High pulmonary risk	1%	10%	<.001
High renal risk	0%	2%	NS
At least one MHR factor	10%	46%	<.001

CAS, Carotid artery stenting; *CEA,* carotid endarterectomy; *MHR,* medical high risk.

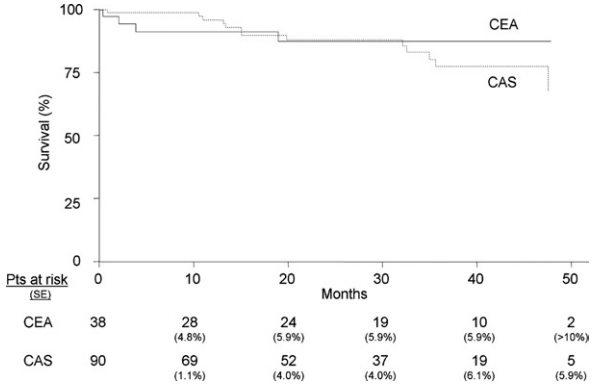

Fig 3. Kaplan-Meier estimates of survival comparing MHR CEA and CAS patients, adjusted for age >80 and preoperative serum creatinine.

CEA patients (HR 2.03, 95% CI 1.20-3.44). One- and 3-year postoperative survival for CEA patients was 96% and 91%, while CAS survival was 95% and 79%, respectively. Additionally, preoperative age ≥80 years old (HR 3.02, 95% CI 1.73-5.25) and preoperative serum creatinine ≥1.5 mg/dL (HR 2.63, 95% CI 1.52-4.55) were associated with an increased risk of death. MHR factors were not found to be significant for death. However, after adjusting for age and preoperative serum creatinine, Cox proportional hazards analysis does not reveal CAS to be significantly associated with death compared with CEA in MHR patients (HR 1.45, 95% CI 0.49-4.49). Survival analysis of MHR CEA patients and CAS patients is shown in Fig 3. Nearly 90% of patients were alive at 1 year, and nearly 80% were alive at 3 years. Despite designation as MHR and undergoing surgical intervention, there was no significant difference in survival between CAS and high or low risk CEA patients, even at 4 years follow-up by life table analysis.

DISCUSSION

Our work demonstrates that, in midterm follow up, the presence of MHR did not impact survival or stroke rate after CAS, and overall survival of MHR patients in our series was comparable with controls undergoing CEA. Many perceive CAS as an alternative to CEA for patients who would be poor surgical candidates, especially those designated as medical high risk.[15] However, while MHR designation may affect periprocedural complication rates in CAS, MHR designation does not appear to be associated with decreased long-term survival following CAS. Given that patients designated as "medically high risk" live just as long as the "normal risk" patients, we find it questionable that any real distinction exists between these groups based on current "medical high risk" criteria. Our data highlights the need for more refined predictors of medical risk to optimally guide patients in selecting carotid revascularization strategies.

Few would argue the role of CAS in the treatment of extracranial carotid occlusive disease has been clearly defined. Randomized controlled trials comparing CEA with CAS that have been reported include SAPPHIRE, which demonstrated that CAS was not inferior to CEA;[15] the Endarterectomy vs Angioplasty in Patients with Symptomatic Severe Carotid Stenosis (EVA-3S) trial, which demonstrated superior outcomes with CEA;[16] and the Stent-Supported Percutaneous Angioplasty of the Carotid Artery vs Endarterectomy (SPACE) trial, which failed to show the noninferiority of CAS compared with CEA in the 30-day perioperative period.[17] Our study refutes the argument that patients with large comorbidity burdens are better served by endovascular therapy than surgery; as we demonstrated no distinct survival advantage. Further, the long-term durability of CAS has yet to be demonstrated. To our knowledge, this present study of CAS patients has the longest follow-up yet described in the North American or European vascular surgery literature. We believe that our finding that MHR patients do not suffer from increased long-term mortality or stroke compared with NR patients after CAS is important, especially when combined with our finding that MHR patients are not at higher risk of mortality after CAS compared with CEA patients. These results suggest that MHR is not a good discriminator of outcomes, though a larger, prospective study of long-term outcomes would be needed to verify this possibility.

The fact that MHR patients had similar outcomes as NR patients after CEA was surprising to us, and we have generated two hypotheses as to why this could be true. First, patients categorized as MHR in our database have, by definition, been identified by their health care providers as having cardiac, pulmonary, or renal disease. The fact that they were identified as MHR could be affecting the intensity of the medical treatment that they are receiving for these comorbid conditions, which could be present, but under treated in the NR group. Guidelines from the National Cholesterol Education Project (NCEP) suggest that patients with significant carotid artery disease have a coronary heart disease equivalent and should be aggressively treated with cholesterol lowering medications to achieve a low density

lipoprotein (LDL) level of less than 100 mg/dL.[18] Our database was not designed to collect data around longitudinal adherence to medication or long-term control of risk factors, but the fact that patients with preoperative LDL levels over 160 mg/dL are at a statistically significantly higher risk of death than patients with better preoperative control suggests that lipid control is an important part of the postoperative care that these patients should receive. Second, these MHR factors were originally devised as a way to identify patients that are at high risk for complications after CEA, not to determine long-term survival. As such, it may be unsurprising that, given appropriate medical care, classification as MHR has no bearing on long-term survival.

Our finding that age over 80 years old is a significant risk factor for CAS supports other findings in the literature that suggest that octogenarians are at heightened risk of death and other complications after CAS.[19,20,21] Our experience suggests that octogenarians may only expect to live about 3 years after CAS on average. As a result, it seems unlikely that asymptomatic patients over 80 years old would significantly benefit from prophylactic CAS given their shorter life expectancy. On the other hand, a broader question raised by our findings is whether or not MHR patients less than 80 years of age should be offered CAS, given similar long-term survival in MHR patients compared with CEA. We believe, based on the survival data demonstrated in our cohort that asymptomatic patients <80 years of age may gain benefit from prophylactic CAS in properly selected cases. Further studies need to be performed to determine the risk-benefit ratio of CAS, most importantly in the asymptomatic patient population.

Our study has several limitations. First, not all patients were examined by an independent neurologist, who may have been able to detect subtle neurologic defects after CAS. In addition, we were unable to clearly identify the cause of death for a significant proportion of our patients. While many of these deaths appeared to be sudden, they may have been neurologic in nature, which could also have led to an undercounting of the number of strokes. Second, our choice of CAS device and EPD varied across patients, encompassing both open-cell and closed-cell designs. Variation across devices may have affected our results,[22] although significant differences in outcomes across designs have not yet been described. Additionally, most of the variation in device and EPD type was encountered early in our series and would be unlikely to have skewed results throughout. Third, myocardial infarction was not tracked as an endpoint. While it would seem that MHR patients would be more likely to suffer from heart attacks or other cardiac events than NR patients, our analysis did not reveal a difference in mortality between the two groups. Similarly, in the comparison between CAS and CEA patients, there was no significant difference in mortality. Therefore, even if there was a difference in cardiac events between any of the groups that we compared, it did not affect mortality. Fourth, while our study has one of the longest follow-up periods published to date, even longer follow-up could demonstrate statistically significant differences in mortality among the studied groups. This effect was seen in NASCET in patients with moderate stenosis; the benefit of CEA was not seen at 2 years of follow-up, but was seen at 5 years.[2,3] Lastly, it is important to note that the MHR criteria were developed to predict periprocedural high risk, not long-term survival. While it seems reasonable that criteria such as age, renal function, and lipid levels would also predict long-term survival, this presumption has not yet been validated.

In summary, the presence of MHR did not impact long-term survival or stroke rate after CAS, and overall survival of MHR patients in our series was comparable with controls undergoing CEA. Patients over 80 years of age had poor survival over 3 years, and are unlikely to gain benefit from CAS if asymptomatic. These results suggest the need for more refined predictors of medical risk to optimally guide patients in selecting carotid revascularization strategies.

AUTHOR CONTRIBUTIONS

Conception and design: TY, JC, RP
Analysis and interpretation: TY, PG, RP, JC
Data collection: TY, PG
Writing the article: TY, PG
Critical revision of the article: PG, RP, JC
Final approval of the article: PG, RP, JC
Statistical analysis: TY, PG
Obtained funding: Not applicable
Overall responsibility: TY

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