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Comorbidities and Health-Related Quality of Life Following Revascularization for Asymptomatic Critical Internal Carotid Artery Stenosis Treated with Carotid Endarterectomy or Angioplasty with Stenting

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Study Design A
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Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
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Background: This study aimed to evaluate the relationship between existing comorbidities and the effectiveness of revascularization of asymptomatic critical internal carotid artery (ICA) stenosis treated with carotid endarterectomy (CEA) or carotid artery stenting (CAS) and short-term and long-term outcome in terms of health-related quality of life (HRQoL).

Material/Methods: Patients with asymptomatic critical ICA stenosis (n=62) included a group treated with CEA (n=31) and a group treated with CAS (n=31). A Health Assessment Questionnaire designed for this study was used to assess ten comorbidities, and the Short Form 36 Health Survey Questionnaire (SF-36) was used to evaluate HRQoL following CEA and CAS.

Results: Three comorbidities significantly influenced the effectiveness of revascularization in all patients studied who underwent CEA and CAS, which included symptomatic atherosclerosis in other vascular areas (p=0.048), coronary artery disease (CAD) (p=0.004), and previous myocardial infarction (MI) (p=0.004). In the CEA group, CAD and previous MI were significant comorbidities (p=0.002), when compared with the CAS group (p=0.635). In the CAS group, chronic obstructive pulmonary disease (COPD) was a significant comorbidity in terms of outcome (p=0.025).

Conclusions: The comorbidities of atherosclerotic vascular disease, CAD, and previous MI had a significant influence of the effectiveness of the revascularization and postoperative HRQoL in all patients studied with asymptomatic critical ICA stenosis who were treated with CEA and CAS. When the two groups were compared, CAD and previous MI were significant comorbidities in the CEA group, and COPD was a significant comorbidity in the CAS group.

MeSH Keywords: **Angioplasty • Arteriosclerosis • Coronary Disease • Endarterectomy • Myocardial Infarction • Pulmonary Disease, Chronic Obstructive**

Abbreviations: **ICA** – internal carotid artery; **CAS** – carotid artery stenting; **CEA** – carotid endarterectomy; **HRQoL** – Health Related Quality of Life; **SF-36** – Short Form Outcome Study (SF-36)

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Background

For more than 30 years, carotid artery stenting (CAS) has been an alternative to carotid endarterectomy (CEA) for carotid artery stenosis revascularisation [1–3]. However, there have been increasing technical developments in arterial stents and neuroprotection, as well as in the experience of interventionalists. Comparative studies have shown varying results in patient quality of life (QoL) that follows both CEA and CAS. The results from randomized trials and registry data have also resulted in conflicting results regarding the effectiveness of the CAS and CEA and patient outcome, including health status, major and minor complications [2–13], and health-related quality of life (HRQoL) [14].

Review of the literature has shown that there is still controversy regarding the choice between CEA and CAS in terms of improved postoperative cognitive outcome, HRQoL, treatment costs, and effectiveness [15]. Some studies have reported worse patient outcome following the CAS procedure when using the Short Form 36 Health Survey Questionnaire (SF-36) to evaluate HRQoL when compared with the CEA procedure [16,17]. However, patient outcome in terms of HRQoL is difficult and complex to evaluate due to comorbidities that are often present in patients with carotid artery atherosclerosis, and because patients may be symptomatic or asymptomatic. There is also the additional complexity of differences in the perioperative and postoperative procedures and the methods of neuroprotection used in CEA and CAS procedures.

Some authors have attempted to resolve these issues by evaluating pre-procedural indicators, with particular emphasis on patient comorbidities. It is important to highlight that modern medicine increasingly involves the diagnosis and treatment of diseases of increased affluence and longevity, including arterial atherosclerosis, but not all recent developments in treatment have had a significant impact on patient survival [18]. However, the prevalence of comorbidities has made the evaluation of treatment outcomes more complex, including for outcomes following cerebral reperfusion following CAS and CEA.

With the increase in atherosclerosis, carotid artery stenosis has become increasingly common, and usually results in symptoms during middle age and beyond. Studies have shown that atherosclerotic carotid artery stenosis occurs in individuals with coronary artery and aortic atherosclerosis and that isolated critical carotid artery stenosis is rare [19,20].

Therefore, this study aimed to evaluate the relationship between existing comorbidities and the effectiveness of revascularization of asymptomatic critical ICA stenosis treated with CEA or CAS and short-term and long-term outcome in terms of health-related quality of life (HRQoL).

Material and Methods

Ethics statement

The patients participating in this study were informed in detail about the procedures involved and they provided written consent, in accordance with the guidelines of the Helsinki Declaration, 2008. The study protocols received ethical approval from the Ethical Committee of the Regional Medical Chamber (KB6/16)

Patients and follow-up

From a group of 560 patients with critical stenosis of the internal carotid artery (ICA) treated in the Department of Vascular Surgery with Endovascular Interventions Unit, The John Paul II Hospital, Cracow, Poland, who had carotid endarterectomy (CEA) and angioplasty with carotid artery stenting (CAS) between January 2015 and June 2017, a total of 62 patients with asymptomatic critical internal carotid artery (ICA) stenosis and common comorbidities were identified. One group (n=31) underwent CEA, and the second group (n=31) underwent CAS. All patients had anti-embolic brain protection treatment. The patients were carefully selected for the study according to the inclusion and exclusion criteria, and all patients signed informed consent. The mean age of the patients in the CEA group was 74. 91±5.81 years, which was 71.86±6.72 years for women, and 75.82±5.56 years for men. The mean age of the patients in the CAS group was 69.63±7.41 years, which was 68.14±4.49 years for women, and 71.24±7.55 years for men. Patients included in the study were evaluated four times, including before revascularization, at two or three days after CAS or CEA, at three-month follow-up, and 12-month follow-up.

Inclusion and exclusion criteria

The study inclusion criteria were asymptomatic patients aged between 54–78 years at the time of the study, who had critical ICA stenosis >80% without incidents of stroke or transient ischemic attacks (TIAs) in the six months before the CEA or CAS procedure was performed.

Exclusion criteria included simultaneous contralateral stenosis or occlusion of the ICA, a low Mini-Mental State Examination (MMSE) score (<24 points), mental illness, hemiplegia, aphasia, or anosognosia that excluded the possibility of an objective self-evaluation of health. Patients were also excluded who had documented brain injury in the previous six months, patients who had a myocardial infarction (MI) <3 months before surgery, or those with diagnosed intracranial aneurysm.

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Table 1. Intergroup differences in the age range of the subjects.

Mean age (mean rank)		U	p	The size of the r effect
CEA	CAS			
72.29 (34.92)	69.55 (28.08)	374.5	0.134	0.190

Source: own research.

Table 2. Presentation of the incidence of comorbidities in patients undergoing CEA and CAS methods.

Comorbidities	CEA		CAS		χ^2	p	Nature of differences
	n	%	n	%			
Hypertension (II and III degree)	29	93.5	31	100.0	2.067	0.151	–
Symptomatic arteriosclerosis in other vascular areas	16	51.6	19	61.3	0.590	0.442	–
Coronary Disease	14	45.1	20	64.5	2.345	0.126	–
Ischemic heart disease	12	38.7	19	61.3	1.646	0.200	–
Diabetes	14	45.1	12	38.7	0.265	0.607	–
Chronic Kidney Disease	10	32.5	6	19.3	1.348	0.246	–
History of coronary artery bypass graft (CABG)	10	32.5	4	12.9	3.321	0.068	–
Chronic Obstructive Pulmonary Disease (COPD)	0	0.0	8	25.8	9.185	0.002	CAS>CEA
Myocardial infarction three months before ICA revascularization	2	6.5	8	25.8	4.292	0.038	CAS>CEA
History of the revascularisation of the contralateral internal carotid artery	5	16.1	0	0.0	5.439	0.020	CEA>CAS

Source: own research.

Methods of treatment

Patients were selected for CEA and CAS procedures according to the 2011 consensus guidelines [21] as adapted by our department [19]. The decision regarding the method of treatment was made by a team of experts and was dependent on the clinical condition and medical history and on Doppler ultrasound and computed tomography angiography (CTA) scans of the carotid arteries. The personal treatment preferences of the patients were also considered.

Evaluation of treatment outcomes

A structured Health Assessment Questionnaire that was designed for the study was used to assess patient comorbidities. The questionnaire data were supported by information obtained from the patient medical records and by structured interview. The evaluation of health-related quality of life (HRQoL) was performed using the Short Form 36 Health Survey Questionnaire (SF-36) [22]. The SF-36 scale consisted of a 36-item, patient-reported survey of the patient's health, and their measures of health status. The results were evaluated in eight scaled scores, which were the weighted sums of the questions in each section. Each subscale resulted in scores between 0–100 points, and the value of the scores was directly proportional to the number of comorbidities. The more patient comorbidities and limitations that were present, the higher the score, and fewer complaints and limitations were reflected by a lower score.

Results

Patients demographic characteristics

There were no significant differences in age between the study group who underwent carotid endarterectomy (CEA) and the study group who underwent carotid artery stenting (CAS) for asymptomatic critical internal carotid artery (ICA) stenosis. Due to the lack of normal distribution, to compare the age of the study groups, a non-parametric Mann-Whitney U test was used (Table 1). In both groups, the gender distribution was the same and included 14 women and 17 men. Due to the lack of

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significant differences in age and gender, a further analysis was performed without taking gender parameters into account.

Comorbidities in patients undergoing CEA and CAS

To determine the frequency and effects of comorbidities in the CEA group and the CAS group, Pearson's correlation coefficient (r) and the chi-squared (χ^2) test were used (Table 2). Ten comorbid diseases were analyzed that included second-degree or third-degree hypertension, symptomatic atherosclerosis in other vascular areas, coronary artery disease (CAD), ischemic heart disease (IHD), diabetes, chronic kidney disease, coronary artery bypass surgery (CABG), chronic obstructive pulmonary disease (COPD), myocardial infarction (MI) >3 months before surgery, and previous revascularization of a contralateral ICA.

All 12 comorbidities occurred in the study participants who underwent CEA or CAS, except COPD, which occurred only in the group treated with CAS (p=0.002). This finding was because patients with COPD were not eligible for general anesthesia, used in CEA, and all patients with COPD underwent CAS, which used local anesthesia. The most common comorbidities were atherosclerosis in other vascular areas, CAD, and IHD. Diabetes and chronic kidney disease were less common (Table 2).

Comorbidities in patients with CEA and CAS and health-related quality of life (HRQoL)

The results from the Short Form 36 Health Survey Questionnaire (SF-36) were compared between the two treatment groups and between the 12 comorbidities. Due to the non-normal distributions and small subgroup sizes, the Mann-Whitney U test was used. The occurrence of comorbidities that affected the outcome of asymptomatic critical stenosis of the ICA following revascularization in all subjects, including CEA combined with CAS, as well as comparison of the patients who underwent CEA with the patients who underwent CAS are shown in Table 3.

The occurrence of atherosclerosis in other vascular areas before the study affected the outcome of revascularization in patients with asymptomatic critical ICA stenosis evaluated using the general QoL SF-36 scores in all study participants who underwent CEA or CAS. Patients with this comorbidity were characterized by a significantly lower improvement in HRQoL (p=0.048) (Table 3). These patients reported more complaints about their health. No intergroup differences were present in patients who underwent CEA compared with patients who underwent CAS in terms of this comorbidity.

The occurrence of CAD prior to the study had an effect on the efficiency of revascularization in patients with asymptomatic critical ICA stenosis evaluated using the general QoL SF-36 scores in all study participants who underwent CEA or CAS. Patients with CAD were characterized by a lower QoL measured by this index (p=0.004), and were characterized by more complaints about their health. Intergroup differences between patients who underwent CEA compared with patients who underwent CAS were also found as this comorbidity significantly reduced the QoL of patients in the CEA group (p=0.002), but did not affect the QoL in the CAS group.

The incidence of MI that occurred at least three months treatment had an effect on the efficiency of the revascularization of asymptomatic critical ICA stenosis evaluated using the general QoL SF-36 scores in all study participants who underwent CEA or CAS. Patients with MI were characterized by reduced outcome as determined by the general index of the QoL in SF-36 (p=0.004). Patients with MI were characterized by more complaints about their health and reduced QoL. Intergroup differences between patients who underwent CEA compared with patients who underwent CAS were found. The comorbidity of MI significantly reduced the QoL of patients in the CEA group (p=0.002), but did not affect the QoL in the CAS group (p=0.635).

Differentiation in the effectiveness of asymptomatic ICA critical stenosis revascularization of patients who underwent CEA compared with patients who underwent CAS due to the occurrence of COPD was not possible, as patients with this comorbidity mainly underwent CAS procedure due to the high associated with general anesthesia. However, it was found that patients without COPD showed significant improvement in the effectiveness of the revascularization of asymptomatic ICA critical stenosis measured by general QoL index of the SF-36 (p=0.025) (Table 4).

Discussion

Patients with asymptomatic critical internal carotid artery (ICA) stenosis treated with carotid endarterectomy (CEA) or carotid artery stenting (CAS) usually have carotid artery atherosclerosis. However, coexisting conditions, including cardiovascular events associated with atherosclerosis are common and cause more than 50% of deaths in developed countries [23,24]. Atherosclerosis has common mechanisms of stenosis in both the carotid and coronary arteries [25,26]. The frequency of comorbidities increases with age [19,20]. As shown in the study by Barnett et al. [27], which included 1.7 million patients in Scotland and the UK, 30.4% of patients aged between 45–64 years reported at least two additional chronic diseases, rising to 64.9% of patients between 65–84 years, who reported at least five additional chronic diseases, and over 80% of patients more than 85 years who reported multiple comorbidities. Similar results have been described in the patient population using Medicare in the USA [28,29].

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Table 3. Occurrence of comorbidities (arteriosclerosis, diabetes, coronary disease, history of myocardial infarction) changing the effectiveness of CAS and CEA in the aspect of changing the general quality of life index.

SF-36 scale	Yes Mean (Mean rank)	No Mean (Mean rank)	U	p	The size of the r effect
Differences in the CEA group – Symptomatic arteriosclerosis in other vascular areas					
General index of quality of life for **arteriosclerosis**	81.37 (13.44)	88.66 (18.73)	79.0	0.105	0.291
Differences in the CEA group – Coronary disease					
General index of quality of life for **coronary disease**	77.71 (10.50)	90.82 (20.53)	42.0	**0.002**	0.549
Differences in the CEA group – Myocardial infarction					
General index of quality of life for **myocardial infarction (occurred more than 3 months before)**	77.69 (10.50)	90.81 (20.53)	42.0	**0.002**	0.549
Differences in the CAS group – Symptomatic arteriosclerosis in other vascular areas					
General index of quality of life for **arteriosclerosis**	54.42 (15.03)	60.66 (17.54)	95.5	0.453	0.134
Differences in the CAS group – Coronary disease					
General index of quality of life for **coronary disease**	55.40 (15.43)	59.45 (17.05)	98.5	0.635	0.085
Differences in the CAS group – Myocardial infarction					
General index of quality of life for **myocardial infarction (occurred more than 3 months before)**	55.49 (15.43)	59.46 (17.05)	98.5	0.635	0.085
Differences in the CEA+CAS group – Symptomatic arteriosclerosis in other vascular areas					
General index of quality of life for **arteriosclerosis**	66.74 (27.51)	76.22 (36.67)	333.0	**0.048**	0.251
Differences in the CEA+CAS group – Coronary disease					
General index of quality of life for **coronary disease**	64.58 (25.53)	78.50 (38.75)	273.0	**0.004**	0.364
Differences in the CEA+CAS group – Myocardial infarction					
General index of quality of life for **myocardial infarction (occurred more than 3 months before)**	64.51 (25.53)	78.51 (38.75)	273.0	**0.004**	0.364

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Table 4. Presence of COPD and improvement in quality of life.

The aspect of quality of life	COPD		U	p	The size of the r effect
	Yes Mean (Mean rank)	No Mean (Mean rank)			
The physical dimension of quality of life	42.11 (30.46)	43.55 (32.25)	441.0	0.700	0.048
The mental dimension of quality of life	28.15 (31.44)	27.75 (31.54)	466.5	0.983	0.002
General index of quality of life	70.26 (30.96)	71.30 (31.89)	454.0	0.842	**0.025**

Source: own research.

These findings are not surprising because longevity is associated with an increased prevalence of diseases. While many chronic diseases are potentially lethal, they have a chronic course, which means that multiple comorbidities can exist until late in life. The incidence profile of diseases in aging populations may vary. One patient may have two diseases share similar pathogenesis or outcome, other diseases may have common risk factors, and the presence of one chronic disease may be a risk factor for another disease [30]. In the present study, the mean age of the patients was less than 80 years (75.82±5.56 years), where each patient had several of these complex disease profiles (Table 2), which supports the findings of epidemiological studies [30,31] and explains the impact on the quality of life (QoL) of the patients in the present study.

From the many causes of comorbidity that occurred in the present study population, we chose the top ten to assess their association with the effectiveness of the revascularization in patients with asymptomatic, critical ICA stenosis in terms of health-related QoL. To assess QoL, we chose the Short Form 36 Health Survey Questionnaire (SF-36) scale, which is widely used worldwide and is recognized by the World Health Organization (WHO) and is also used as a measure of surgical outcome [32–35]. The findings of the present study showed that only three comorbidities were related to the functional condition after carotid artery stenosis revascularization, symptomatic atherosclerosis in other vascular areas (p=0.048), ischemic heart disease (IHD) (p=0.004), and myocardial infarction (MI) within three months before surgery (p=0.004). There was no significant relationship between the other seven comorbidities, which included second-degree or third-degree hypertension, coronary artery disease (CAD), diabetes, chronic kidney disease, a history of coronary artery bypass surgery (CABG), chronic obstructive pulmonary disease (COPD), and previous surgery involving the contralateral ICA. However, there was a general tendency for worse results in the effectiveness of revascularization in patients with these other comorbidities.

The findings of the present study are difficult to compare directly with those from previous studies as most studies have evaluated the effectiveness of revascularization in terms of major postoperative complications, such as ischemic stroke, MI, and patient mortality, and have analyzed long-term observational data [36–38]. In this study, two study groups that were treated with CEA and with CAS, both in the group operated on by the CEA and CAS methods, the complications of ischemic stroke, MI, and mortality did not occur either in the early postoperative period or at one-year follow-up. This lack of major complications has also been observed in previous studies conducted by our team of experienced vascular surgeons and interventionists [19,20]. This finding may be explained by the patient selection criteria used to determine the choice of revascularization procedure for carotid artery stenosis [39,40], as well as the analysis of the functional status of the patients.

The findings of the Carotid Revascularization Endarterectomy versus Stenting Trial (CREST) randomized trial to compare CAS and CEA showed a higher risk of periprocedural ischemic stroke following CAS, and data in symptomatic patients show combined periprocedural mortality from stroke following CEA of 3.2–6.7% [41] and in asymptomatic patients of 1.4–3.1% [42]. However, after CAS, both for asymptomatic and symptomatic patients, periprocedural mortality and stroke were reported to be between 4.1–7.7% [43]. The prevalence of perioperative strokes and deaths after a stroke following revascularization procedures was 2.3–3.6% for CEA and 2.1–4.4% for CAS [34,35,44]. The total frequency of perioperative MI was 0.8–6.6% for CEA and 0.0–1.9% for CAS [15,16,37,39,43]. However, the annual rates of stroke per year from CAS revascularization were 7.7–9.8%, and 5.5–5.8% for CEA [44,45].

A novel finding in this study was the lack of major complications, including perioperative mortality, which might be explained by the fact that we used our own clinical guidelines, which were more selective than the guidelines available at the time of the study [46,47]. For example, the clinical team used an embolic protection device (EPD) during the CAS procedure

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and a shunt during the CEA procedure under general anesthesia. Only in the past few decades have there been reports of reduced risk of mortality and an increased risk of perioperative complications in both CEA and CAS due to compliance with new clinical guidelines [48]. Reduced patient mortality and reduced perioperative complications for CEA and CAS may be explained by the obligatory introduction of new neuroprotection methods allowing for direct access through the common carotid artery that prevents atheroemboli from the aortic arch, which is particularly important during right angioplasty of the internal carotid artery [49–54]. Technological developments have been made in the equipment used for carotid artery angioplasty (stents), including the introduction of a new generation of stents [55–57]. Also, there has been the development of new eligibility criteria for CEA and CAS [19,40,58–61]. New eligibility for CAS surgery include patients with multilevel and multifocal atherosclerotic disease [62–65], with symptomatic carotid artery stenosis [19,20] and with symptoms, because for CAS, it is possible to perform simultaneous coronary angiography or even coronary angioplasty or to reclassify the patient for coronary artery bypass graft (CABG) surgery [66–68], to reduce perioperative MI. Patients with COPD have more chronic comorbidities, between four and six on average, when compared with patients without COPD when matched for age [41,69]. When COPD is considered as an index illness, common comorbidities exist, including cardiovascular diseases, and coronary angiography and angioplasty may be necessary during carotid revascularization. Patients with COPD should remain in a supine position for as short a time as possible during the procedure, as the duration of the CAS procedure is shorter than for CEA. CAS is performed under local anesthesia, which could be more beneficial to patients with respiratory disorders than general anesthesia [19,20]. If a patient cannot be disconnected from the ventilator and extubated after surgery, patients undergo CEA while under general anesthesia [70].

Another important factor in this study was the analysis of the functional status of patients assessed with the use of disease-specific research tools [71], including the use of the Short Form 36 Health Survey Questionnaire (SF-36), a tool widely recognized as the best instrument for measuring QoL in vascular surgery [32,40,46]. A recent meta-analysis of the QoL and functional state after carotid revascularization published by Shan et al. [30], identified 12 studies on the effectiveness of CEA and CAS revascularization but identified only two studies that assessed functional status using the SF-36 [35,45]. The use of study-specific questionnaires that have not been previously verified and standardized may result in bias [72–75]. However, previous studies have not considered the correlation with an increased number of comorbidities and the impact of individual diseases, such as COPD [76,77]. In this study, we evaluated the impact of the ten most common comorbidities on the effectiveness of revascularization methods for CEA and CAS individually, as well as CEA compared with CAS. These comparisons have rarely been made in previous studies, including the CREST clinical trial [46,35]. Previous studies that have analyzed the influence of individual coexisting diseases on the effectiveness of CEA compared with CAS as assessed by the SF-36 QoL index did not assess several important comorbidities [78], which were identified as relevant in the present study. In the CREST cohort study, which included about 50% of patients with asymptomatic carotid artery stenosis, the role of symptomatic status on QoL was not investigated [35,61]. The authors discussed only periprocedural stroke and MI as a risk for long-term mortality in CREST [35,61]. Involvement of the contralateral carotid artery and the effectiveness of CEA compared with CAS for revascularization has not been previously demonstrated [79].

The third important fact that could have influenced the results of this study was the use of the SF-36 scale for functional assessment. Previous studies have shown that to facilitate comparisons between worldwide studies coherent, disease-specific, formal validation should be used, including QoL assessment instruments in longitudinal studies, including the SF-36 scale. In many longitudinal studies, the SF-36 questionnaire is sent to be completed at the patient's home [30]. In our study, each patient was evaluated four times by the same assessor who was in direct contact with the patient [19]. However, the use of the SF-36 scale has certain limitations that include the evaluation of psychological factors, biological factors that included health before and after revascularization, postoperative complications, previous health experiences, and reliable information from the treatment staff, and sociocultural factors. Answers to question on wellbeing and QoL associated with disease in the perioperative and postoperative period may be variable [30]. Therefore, a patient with a higher health deficit will assess their QoL after the procedure to be higher than a patient with a lower health deficit. The SF-36 scale is not only subjective but is also insufficiently sensitive to assess changes that can be caused by multiple morbidities and carotid artery surgery. Each person has a different interpretation of their health [80].

This study has highlighted the need to pay close attention not only to the patient's clinical condition and surgical management in carotid artery stenosis but also to additional comorbidities present before surgery. This approach may allow selection of the most appropriate surgery, CEA or CAS, the use of additional diagnostic methods, and additional treatments used in interventional cardiology or cardiac surgery, and protection against complications associated with comorbidities, especially in the elderly. These considerations can potentially protect the patient from perioperative and postoperative complications that reduce QoL and increase morbidity and mortality. The assessment of patient QoL, health, and wellbeing is a requirement of modern medicine that also demonstrates the effectiveness

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of revascularization in patients with no significant complications [30]. The evaluation of the intergroup differences in the general index of QoL (Table 3) in the field of functional status of patients may contribute to a better understanding of the patient, and the impact of multiple morbidities on the effectiveness of CEA and CAS.

The present study had several limitations. This study was cross-sectional and non-randomized and was a small study conducted in a single center. Although the study controlled several major variables (Table 1), not all HR-QoL determinants were controlled for, other than ischemic stroke, MI, and mortality, and it is possible that conditions such as atrial fibrillation (AF) [77], arthritis [36,81], lung disease other than COPD [82], and chronic kidney disease [78,79] may have affected the results regarding the impact of CEA compared with CAS on HR-QoL as reported by the patients (Table 2). We were not able to assess the impact of exercise [83,84], lifestyle [38], social support [85], or living in rural areas compared with urban areas [86]. Also, the size of both study groups was not sufficient to assess the potential relationship between the development of post-revascularization QoL [52] and the evolution of HR-QoL levels. Finally, with respect to HR-QoL after asymptomatic revascularization using the CAS procedure, only to conventional or first-generation stents were used. The emergence and increasing use of new technologies of stenting in clinical practice, including double-mesh stents, can result in the reduction of perioperative complications to 1% [48,52,56] and minimize the risk associated with the symptomatic state and other risk factors [55], and may affect clinical outcome following CEA and CAS when evaluated using a standardized objective QoL assessment method [30].

In conclusion, previous studies have not sufficiently highlighted the problem of the influence of comorbidities on the effectiveness of asymptomatic critical ICA stenosis revascularization, making it difficult to determine the effectiveness of CEA compared with CAS in short-term and long-term observational studies. In this study, we confirmed the impact of several important comorbidities on the effectiveness of revascularization for asymptomatic critical ICA stenosis for all patients who underwent CEA or CAS, as well as comparing patients who underwent CEA with those who underwent CAS, using the SF-36 in short-term and long-term follow-up. In future studies, it would be important to investigate the influence of comorbidities on the effectiveness of revascularization of asymptomatic critical ICA stenosis in the CEA and CAS to determine the effectiveness of these two methods and to improve the QoL for patients.

Conclusions

This study aimed to evaluate the relationship between existing comorbidities and the effectiveness of revascularization of asymptomatic critical internal carotid artery (ICA) stenosis treated with carotid endarterectomy (CEA) or carotid artery stenting (CAS) and short-term and long-term outcome in terms of health-related quality of life (HRQoL). The comorbidities of atherosclerotic vascular disease, coronary artery disease (CAD), and previous myocardial infarction (MI) had a significant influence of the effectiveness of revascularization and postoperative HRQoL in all patients studied who were treated with CEA and CAS. When the two groups were compared, CAD and previous MI were significant comorbidities in the CEA group, and COPD was a significant comorbidity in the CAS group.

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