Treatment of Symptomatic Carotid Webs

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Background: The present study aims to describe the clinical characteristics and treatment outcomes of patients with symptomatic carotid web treated at a single institution in South America.
Methods: Retrospective study of a single-center experience of patients with carotid webs surgically treated from September 2019 to September 2023.
Results: Ten patients had carotid webs, 6 (60%) were females. Median age was 54.5 years (range: 35−77 years). All patients were symptomatic. Diagnosis was made in 90% ($n = 9$) of the patients with either computed tomography angiography or magnetic resonance alone. One (10%) patient underwent angiography for definite diagnosis. The median interval from the first neurological event to intervention was 90 months (range: 3 days−108 months). Four (40%) patients underwent surgical treatment within 1 month from symptom onset and carotid web diagnosis, with a median of 3.5 days (range: 3−9 days). Six (60%) patients underwent delayed surgical treatment since the cause of the neurological event was uncertain, with a median of 54 months (range: 6−108 months). These 6 patients had recurrent neurological events. Three (30%) patients underwent carotid endarterectomies with polyurethane patch and 3 (30%) by eversion technique. Three (30%) patients underwent segmental resection and reanastomosis of the internal carotid artery. One underwent internal carotid artery plasty with saphenous vein. At a median follow-up of 30 months (range: 6−46 months), 1 patient persists with mild aphasia, another patient has severe aphasia and right hemiparesis, both as sequelae of their initial strokes, and another patient has suffered 3 nonischemic episodes of brief transient right hemiparesis attributed to epileptic seizures. The other 7 patients remain without new neurological events.
Conclusions: Neurological events of carotid distribution deserve accurate imaging work up, keeping in mind the diagnosis of carotid web. Surgical treatment for carotid web seems effective for preventing recurrences; nevertheless, further studies are warranted to define the best management for these patients.

INTRODUCTION

A carotid web is defined as a noncircumferential focal type of fibromuscular dysplasia (FMD) occurring at the origin of the carotid bulb.[1] The carotid web was first described in 1968 by Rainer et al.[2] as fibromuscular hyperplasia at the carotid artery causing recurrent neurological events, and it is assumed to have a different stroke mechanism

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than carotid stenosis. On the former, the web is believed to produce turbulence due to the disruption of laminar flow, that leads to a proaggregatory platelet response and local thrombosis due to stasis that may cause distal emboli and stroke. On the latter, there are 3 main hypotheses for the cause of neurological events. The first one is similar to the web: distal embolization of thrombus that may form around the atherosclerotic plaque. The second is believed to be a reduced distal perfusion from a severe stenosis. The third is plaque rupture with luminal compromise or plaque distal embolization.[1,3] Moreover, there is a contrast in the pattern of flow hemodynamics between a carotid web and a carotid plaque due to atherosclerosis. The first is focal, characterized by a membrane-like short lesion protruding into the artery lumen. In contrast, the second usually involves a more extended, concentric, and irregular segment within the vessel wall.[1,3]

Different studies have reported that medical treatment for carotid web is insufficient, with recurrent stroke rates up to 56%; furthermore, these studies have recommended carotid intervention as a secure and effective option for preventing recurrent strokes in these patients.[4,5]

There are very few case series of patients with carotid web, with at most 300 patients in the literature. The present study aims to describe the clinical characteristics and treatment outcomes of patients with symptomatic carotid web treated at a single institution.

MATERIALS AND METHODS

This study was performed with approval of the institution review board of the Pontifical Catholic University of Chile and abides by the norms established in the Helsinki Conference of 1964 and its revision in 2012. Informed consent has been obtained from the patients for publication of medical images.

A retrospective review of all patients from a single academic hospital with diagnosis of symptomatic carotid web treated between September 2019 and September 2023 was performed. Data were gathered from hospital, outpatient clinic records, and follow-up contact directly with patients. Variables included gender, age, diabetes mellitus, systemic arterial hypertension, dyslipidemia, present or prior smoking history, obesity, hypothyroidism, migraine, type of neurological symptoms, image studies such as carotid duplex, computed tomography angiography (CTA), magnetic resonance imaging (MRI) and angiography, surgical treatment, operative time, postoperative outcomes, and follow-up.

A carotid web was defined as a shelf-like, focal, smooth-filling defect in the carotid bulb. The carotid web was diagnosed with image studies in consensus between radiologists, vascular surgeons, and neurologists. In each case, other cardioembolic etiologies of transient ischemic attack or stroke were excluded by stroke neurologists with other paraclinical studies including echocardiogram and 24-hour electrocardiographic Holter. Patients were started with antiplatelets (aspirin 100 mg daily and/or clopidogrel 75 mg daily) and statins upon diagnosis, at the discretion of the vascular surgeon or neurologist.

All procedures were performed under general anesthesia with neurophysiologic monitoring with bispectral index. Surgical technique was left at the discretion of the surgeon; these included carotid endarterectomy (CEA) with polyester-urethane patch (Vascular-patch, B. Braun Medical AG, Tuttlingen, Germany) with or without shunt, CEA with eversion technique or resection of carotid web segment with internal carotid artery reimplantation, or with vein plasty. Internal carotid artery stump pressure was measured in 6 cases and used to determine the use of shunt or not (stump pressure $>$40 mm Hg). In one case, surgical specimen were sent for surgical pathology examination for research purposes. Patients were admitted to the cardiovascular intensive care unit for postoperative care and discharged from the hospital at the discretion of the surgeon. Patients were maintained with aspirin 100 mg and atorvastatin 40 mg daily after discharge. Regular surveillance was done with a carotid duplex at 6 months, 12 months and yearly thereafter.

Data were analyzed using SPSS v25 (IBM, Boston, USA). Normality was tested using the Kolmogorov-Smirnov test. Quantitative measures were reported as medians and ranges, and the frequency of events was described as frequency and percentages.

RESULTS

Ten patients with carotid webs were treated surgically at our institution during the study period: 4 (40%) males and 6 (60%) females. Median age was 54.5 years (range: 35—77 years). Five (50%) patients had diabetes mellitus, 5 (50%) patients had systemic arterial hypertension, 2 (20%) patients had obesity, and 3 (30%) patients had dyslipidemia. Two (20%) patients were active smokers and 3 (30%) had hypothyroidism. Two (20%) patients

Table I. Clinical characteristics and surgical treatment

N°	Gender	Age	Neurological event	Main symptoms	Interval from first symptom to surgery	Surgical treatment
1	F	61	Left insular stroke	Dysarthria, right facial paresis, left hemiparesis	9 days	CEA with polyester-urethane patch
2	M	76	Left parietal lobe stroke	Dysarthria, right hemiparesis	4 days	CEA with polyester-urethane patch
3	F	47	Left parietal and insular lobe stroke	Paraphasia, right crural paresis, right hemianopsia	3 days	CEA with polyester-urethane patch
4	M	35	Left periventricular stroke	Right transient hemiparesis, and aphemia	9 months	ICA plasty with vein
5	M	42	Malignant left medial cerebral artery stroke	Aphasia, right hemiparesis, and spasticity	6 months	ICA resection + primary reimplantation
6	F	53	Left medial cerebral artery stroke	Transcortical aphasia	9 years	ICA resection + primary reimplantation
7	F	56	Left medial cerebral artery stroke	Vertigo	7 years	CEA by eversion
8	F	42	TIA	Right brachial hemiparesis	5 years	ICA resection + primary reimplantation
9	F	77	TIA	Recurrent episodes of amaurosis fugax	4 years	CEA by eversion
10	M	75	TIA	Right brachial hemiparesis	3 days	CEA by eversion

TIA, transient ischemic attack; ICA, internal carotid artery.

had a history of migraine and were regular users of ergotamine.

Three (30%) patients presented transitory ischemic attacks, 1 presented recurrent episodes of amaurosis fugax, and 2 had transient right brachial hemiparesis. Seven (70%) patients presented ipsilateral hemispheric stroke, with a variety of symptoms, including aphasia, dysarthria, hemianopsia, vertigo, and different degrees of motor and sensory deficits. Table I summarizes clinical characteristics and treatments.

In 3 (30%) patients, a carotid duplex was performed without a definitive diagnosis. Diagnosis was made in 90% ($n = 9$) of the patients with head and neck CTA and MRI. Figures 1 and 2 One (10%) patient underwent angiography for definite diagnosis. Nine (90%) patients had carotid webs in the left carotid artery and 1 (10%) in the right carotid artery. None had bilateral lesions. Neither echocardiogram nor 24-hour electrocardiographic Holter revealed a possible cardiac embolic stroke in any of the patients.

Four (40%) patients underwent surgical treatment within a month of carotid web diagnosis, with a median of 4.5 days (range: 3−9 days). Six (60%) patients underwent a delayed surgical treatment since the cause of the neurological event couldn't be reached initially, with a median of 54 months (range: 6 months−108 months). These 6 patients had recurrent neurological events. A complete workup was repeated upon recurrence, finally reaching the carotid web diagnosis. One patient presented a cerebral infarction of the left middle cerebral artery treated with decompressive craniotomy, with global aphasia as sequelae 6 months before definitive diagnosis. Another patient, whose initial neurological event occurred 9 months before definitive diagnosis, required angiography since the carotid web diagnosis couldn't be reached with duplex, MRI, or CTA. The angiography clearly demonstrated a shelf-like filling defect in the posterior carotid bulb and stasis of contrasted flow in the area. Figure 3.

Definitive surgical treatment included: 3 (30%) carotid endarterectomies with polyurethane patch, 2 with use of shunt and 1 without. Three (30%) patients underwent carotid endarterectomies by eversion technique. Three (30%) patients underwent segmental resection of the compromised segment of the internal carotid artery, with primary internal

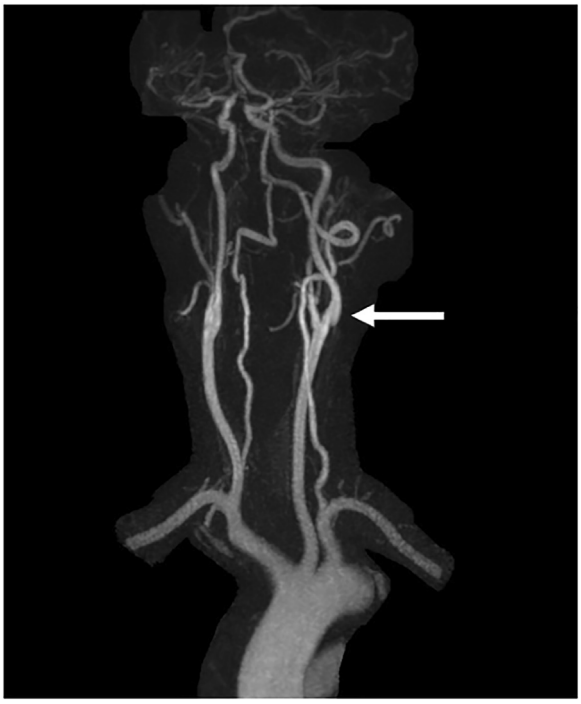

Fig. 1. Magnetic resonance imagining of a 77-year-old female patient. White *arrow* points to a film-like structure in the posterior bulb protruding into the vessel lumen, corresponding to a carotid web.

carotid artery reimplantation. One patient underwent segmental resection of the carotid web with saphenous vein plasty. Figures 4 and 5 show intraoperative images of the carotid web. Median operative time was 130 min (range: 60 min−190 min). Operative complication rate was 0%. No patient presented immediate postoperative stroke or cranial nerve lesion. The median time of hospital stay in the intensive care unit was 1 day (range: 1−2 days), and the median overall length of hospital stay was 3 days (range: 2−4 days). Histopathological analysis can be seen in Figure 6.

At a median follow-up of 30 months (range: 6−46 months), one patient persists with mild aphasia, another patient has severe aphasia, right hemianopsia and right hemiparesis, both as sequelae of their initial strokes, and another patient has suffered 3 nonischemic episodes of brief transient right hemiparesis attributed to possible epileptic seizures. The other 7 patients are well, with full neurological recovery and no recurrent symptoms.

DISCUSSION

In the present study, we describe 10 patients with carotid web that were successfully treated at our academic institution over 4 years. Due to its low incidence, there are scarce studies in the literature reporting patients with carotid webs, resulting in an unknown topic for many clinicians, including vascular surgeons, neurologists, and radiologists, with a high rate of misdiagnosis.[6] With the advances reached by different imaging modalities in recent years, the misdiagnosis has diminished, and carotid web has become more acknowledged, especially when considering differential diagnosis when scrutinizing a stroke of an unknown source.[7] Of notice, in the present series, 6 patients' diagnoses couldn't be reached at first and were cataloged as cryptogenic strokes. At that moment, they were studied and treated in other institutions, confirming that the carotid web is still unrecognized by many. After their neurological event recurrence, they were seen at our institution, where a carotid web diagnosis was finally made.

In the present series, there was a 90% prevalence of carotid webs on the left side. Similarly, Wang et al.[8] reported a 66.6% prevalence of carotid web on the left side. Notwithstanding, the largest studies on the topic didn't report on carotid web laterality.[4,5,7] Hypothesizing a reason for the present study left dominancy is somewhat unreasonable due to the lack of data.

Since its first description more than half a century ago, the carotid web has been called different terms such as carotid diaphragm, carotid septum, carotid shelf, focal carotid FMD, carotid pseudovalvular fold, carotid megabulb, carotid spur, among others.[4] It is crucial to leave these terms behind and unify them by using only ''carotid web'' for more accessible data gathering on this condition, and a much better comprehension of the disease.

Carotid webs have been more commonly detected in young adult female patients, particularly in African-American women.[9,10] Of notice, 60% of the patients in the present study were females with a median age of 50 years. A systemic review on carotid webs found a female prevalence of 61.7%, hypothesizing it might be related to the higher prevalence of collagen vascular disorders found in women related to hormone levels and X-chromosome genetic disorders.[4] Likewise, in a study by Joux et al.[10] and Sajedi et al.,[9] carotid web rates in patients under 55 years of age with stroke of unknown origin were 37% and 21%, respectively. If a recurrent stroke is seen in a patient without a clear etiology, with no vascular risk factors, and with negative diagnostic workup, a carotid web must be ruled out with imaging.[3]

Imaging studies include CTA, MRI, carotid duplex, and angiography. CTA permits multiplane

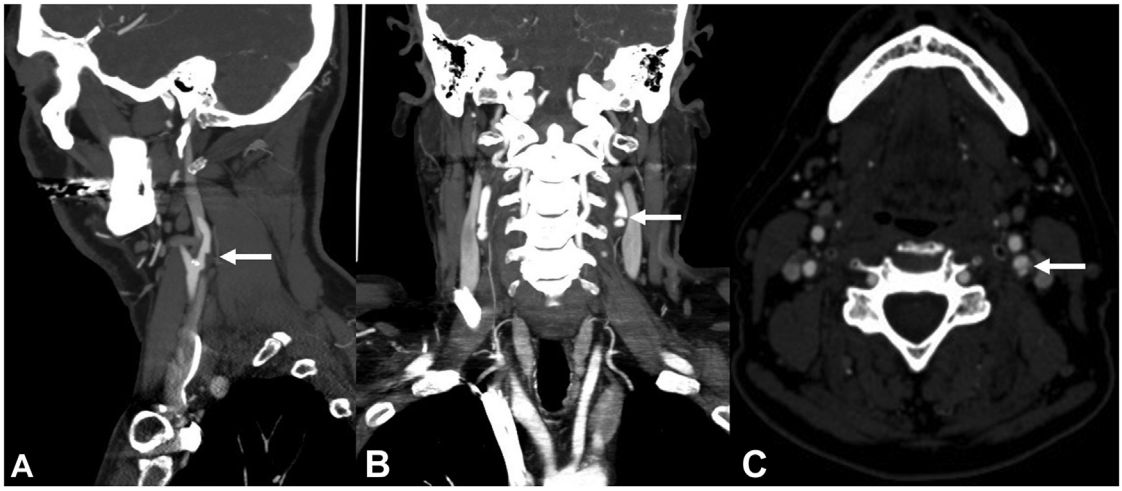

Fig. 2. Computed tomography reconstructions of a 75-year-old male patient. White *arrow* shows a low-density shadow with a thin line and a focal membrane-filling defect, compatible with a carotid web. **(A)** Sagittal view. **(B)** Coronal view. **(C)** Axial view.

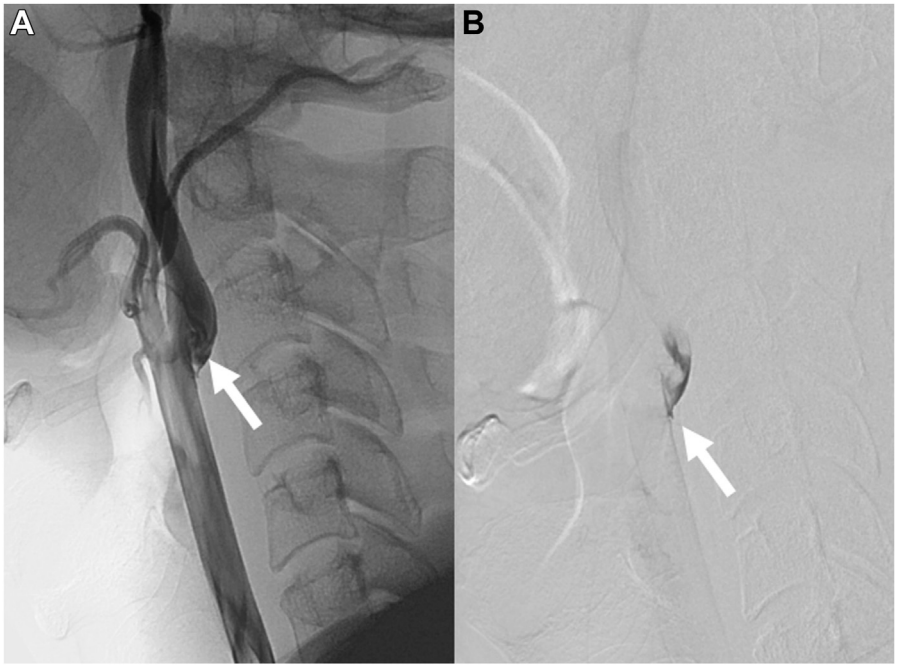

Fig. 3. Angiography with a lateral view of a 35-year-old male patient. **(A)** White *arrow* showing a shelf-like filling defect in the posterior carotid bulb proximal to the internal carotid artery. **(B)** White arrow showing stasis of contrast in the web due to the turbulent flow.

reconstructions, allowing the identification of thrombus and atherosclerotic changes.[11] Usually, a low-density shadow with a thin line can be seen in an axial view, and a focal membrane-filling defect might be seen in a sagittal view.[12] MRI might provide similar morphologic features as CTA. A film-like structure can be seen in the posterior bulb protruding into the vessel lumen, and a prism morphology wall within the carotid web might be seen with an increased signal enhancement. Additionally, hemodynamics within the vessel can be evaluated.[13] Ultrasound can also be a helpful

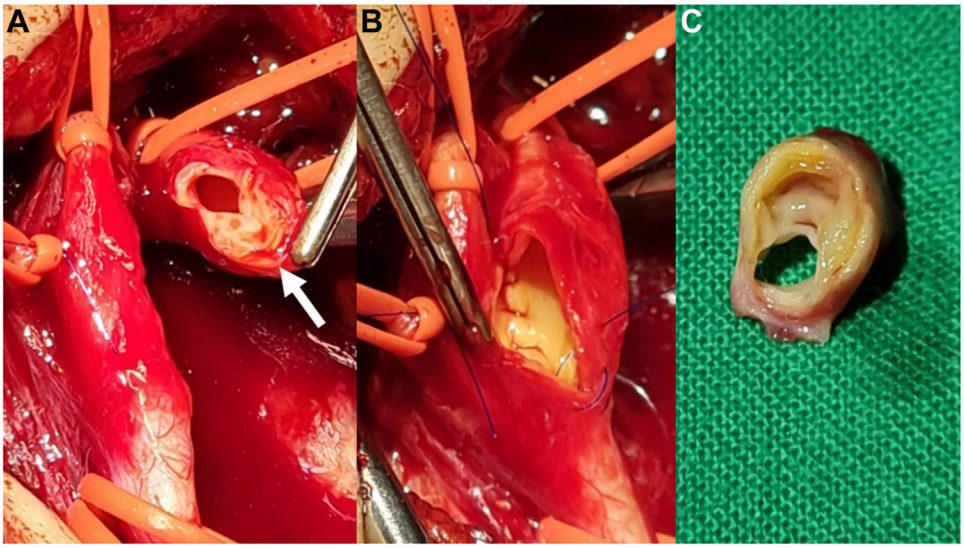

Fig. 4. Surgical image of carotid web resection. **(A)** Transection of the internal carotid artery at the carotid bulb, observing the focal web lesion on the posterior wall of the proximal internal carotid artery (*white arrow*). **(B)** Reimplantation of the internal carotid artery to the carotid bulb after segmental resection including the carotid web. **(C)** Macroscopic image of the carotid web.

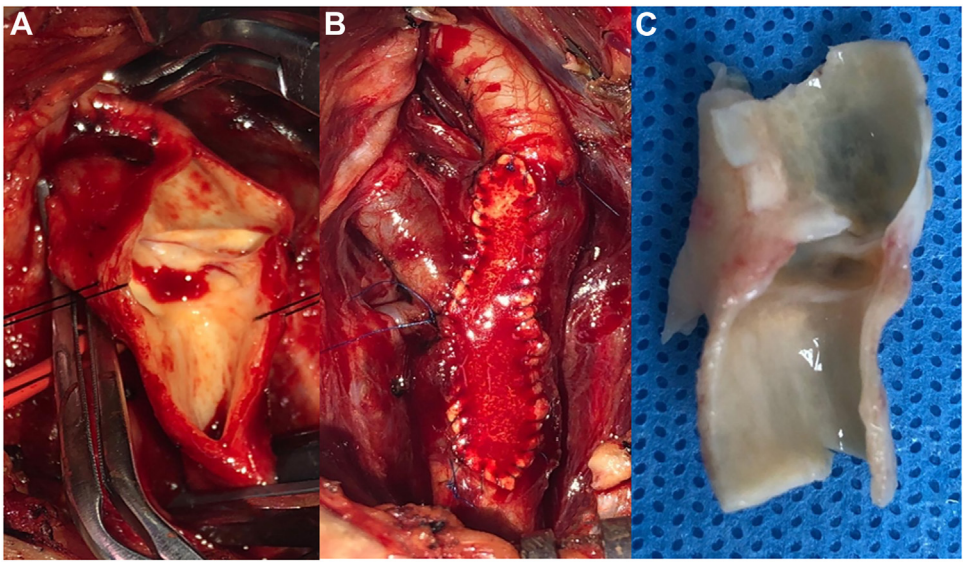

Fig. 5. Surgical image of carotid web resection of a 76-year-old male patient. **(A)** Arteriotomy of the carotid bulb observing the web. **(B)** Closure with polyester-urethane patch (Vascular-patch, B. Braun Medical AG, Tuttlingen, Germany) after carotid web resection. **(C)** Macroscopic image of the carotid web.

resource for diagnosing carotid webs, where a ''cliff-like'' arterial stenosis in a longitudinal view might be observed. Color Doppler can show an eddy in the angle between the web and the vessel wall.[14] Of note, an initial carotid duplex was performed in 3 patients of the present series without any conclusive diagnosis. Similarly, Brinster et al.[7] couldn't confirm the diagnosis with carotid duplex on any of their 52 patients; hence, reaching a definitive diagnosis with computed tomography scans. Radiology reports of our patients also described a ''nonsignificant stenosis at the carotid bulb'' since

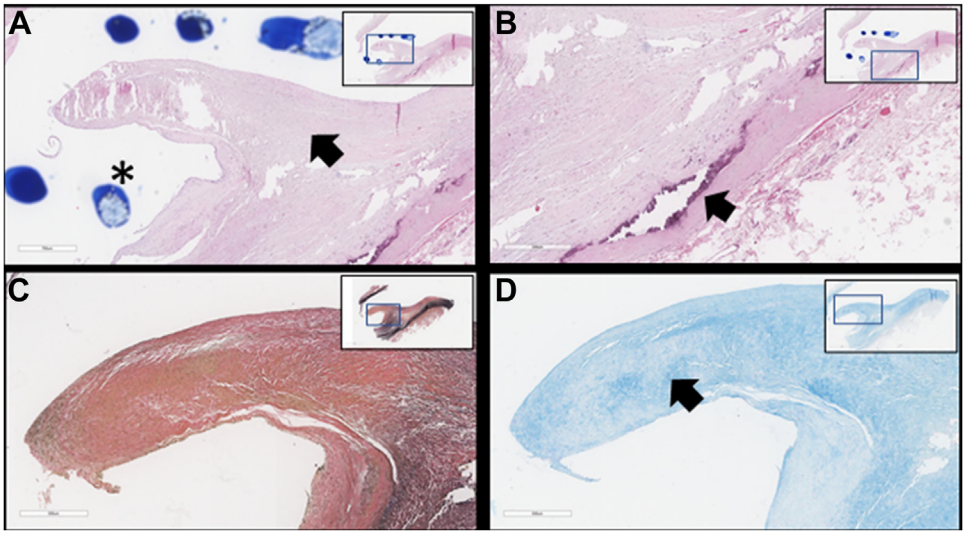

Fig. 6. Histopathology of carotid web. **(A)** Medium magnification revealed an intimal proliferation (*black arrow*) and the asterisk show the web pocket. **(B)** The arterial wall shows medial calcific sclerosis (*black arrow*). **(C)** Elastic stain revealed absence of elastic fibers in the intraluminal proliferation and hyperplasia within the vascular wall. **(D)** Alcian blue highlights the fibromixoid degeneration (*arrow*).

many of these webs involved less than 50% stenosis. This also correlates with no significant increase in velocity in Doppler ultrasound studies that likely explains the lack of diagnosis using this method. This may confound treating physicians that do not recognize the possibility of a carotid web and may lead to medical management of these patients.

In the present series, the diagnosis was confirmed in 90% of the patients with computed tomography scan and MRI, with cross-sectional imaging using different projections. If after CTA or MRI diagnosis is not reached; we recommend performing an angiography since the web might be small and hidden, a shelf-like filling defect might be seen in the posterior bulb, as occurred in one of our patients. Brinster et al.[7] proposed the isolated stagnation and delayed contrast washout in the posterior carotid bulb to be considered pathognomonic of the carotid web until proven otherwise. Furthermore, it is worth mentioning that most webs appear in the posterolateral wall, so a lateral projection during angiographic evaluation is needed, and misdiagnosis may result if only front and side projections are obtained.[15]

Treatment for the carotid web includes medical therapy or intervention. In the largest systematic review comprising 289 patients, half were treated medically, and half were intervened. Among the 151 patients who underwent intervention, the recurrent stroke rate was 0%, and the complication rate was 0.006% ($n = 1$). On the contrary, patients treated medically had a recurrent stroke rate of 33.3%.[4] Likewise, in the largest single-center experience reporting 52 patients with carotid web, 10 patients were treated with dual antiplatelet and statin at first, with a recurrence stroke rate of 100% during a mean interval follow-up of 43 months. Moreover, half of these patients had permanent neurological deficits following their recurrent strokes.[7] Other studies have reported recurrent stroke rates of 20–75% after medical therapy.[1,4,5,11] Since we did not follow patients treated medically after the diagnosis of the carotid web, we are not able to describe our recurrence rate, but it is alarming that we found 6 carotid webs after recurrent strokes in patients that previously did not have a clear cause of their first stroke.

CEA and carotid stent (CAS) have been proven effective and safe for treating carotid webs. Haussen et al.[16] reported 24 symptomatic patients with carotid web treated with CAS, with no periprocedural events, and with a recurrence stroke rate of 0%. Likewise, Turpinant et al.[17] reported 14 patients with carotid webs who underwent angioplasty and CAS, with a periprocedural and postoperative stroke rate of 0%. On the contrary, Multon et al.[18] and Mathew et al.[19] treated 18% and 90% of their patients with stents, respectively. In the former study, 1 patient had an external iliac rupture treated by a covered stent, and in the latter, 1 patient remained hypotensive for a week, hypothesizing this was

due to stimulation of the carotid baroreceptor. In both studies, stroke and restenosis rates were 0%, at a mean follow-up of 12 months and 5 months, respectively. In the present series, none of the patients underwent endovascular stenting since, in our institution, the primary conduct for carotid stenosis requiring intervention has been and currently is surgical treatment, leaving CAS for specific circumstances such as restenosis, very high or low lesions, history of radiotherapy or high infection risk.

Various surgical techniques have been used to treat carotid web, such as CEA with and without patch, primary resection, and anastomosis. Multon et al.[18] resected the proximal internal carotid artery with direct anastomosis in 84.6% of their surgical treated patients. Likewise, Borghese et al.[20] did a carotid end-to-end anastomosis in 3 patients with carotid web. Brinster et al.[7] used the classic endarterectomy technique in all ($n = 27$) of their surgically treated patients; nevertheless, the closure technique wasn't specified. Similarly, Haynes et al.[21] performed CEA with primary closure in 7 patients, affirming primary closure to be safe since no significant stenosis was encountered at the level of the carotid bifurcation. Comparably, in the present study, the CEA technique with patch and proximal internal carotid artery resection with primary anastomosis were used without eventualities and without postoperative complications. Primary resection and anastomosis was performed in 30% of the patients. One case was due to vessel wall inflammation encountered in surgery and the other 2 were because of the favorable anatomy with a tortuous internal carotid artery. All of these cases had a prism morphology and broad type of web. Furthermore, contrary to the aforementioned studies, we have also performed CEA using the eversion technique at the proximal carotid internal artery. Due to the small case series, a comparison between techniques is unfeasible; nonetheless, we are prospectively gathering more patients, and hopefully, we will be able to compare long term outcomes between techniques.

On the present series, 1 carotid web specimen was sent to histopathology diagnosis for research purposes. Intimal hyperplasia within the vascular wall with fibromyxoid degeneration was found, which might explain the macroscopic valve-like lesion in carotid webs. Equally, Rodriguez-Castro et al.[22] described the histologic analysis in one of their patients with carotid web, describing a fibromuscular hyperplasia protruding into the lumen forming a valve-like lesion. Wang et al.[8] reported the histological features of 9 patients with carotid webs, finding features of intimal hyperplasia with vascular smooth muscle cells in an extracellular matrix in all of them. The authors described that the changes seen in the media layer, such as loss of smooth muscle cells and elastic fibers fragmentation substituted by mucoid extracellular tissue, to be different from the histology of FMD. Likewise, the international consensus on FMD classified the carotid web as a separated histological condition.[23]

Limitations of the present study include the retrospective nature of the study. Furthermore, more patients presenting with carotid web might have been treated medically by the neurology department before the study period without a registry. Also, the small sample size affects the possibility of performing statistical analyses. Finally, asymptomatic patients with carotid webs weren't assessed, and the best treatment for these patients remained undefined.

CONCLUSION

The present study reported an initial single-center experience successfully treating patients with carotid web. Remarkably, all patients who got delayed in surgical treatment after their first neurological event experienced a recurrence of the event. Upon encountering a neurological event of an unknown cause in any patient, we recommend an in-depth examination and extensive imaging studies of the carotid bifurcation. Surgical treatment for carotid web seems effective for preventing recurrences; nevertheless, further studies are warranted to define the best management for these patients.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Mauricio Gonzalez-Urquijo: Writing — review & editing, Writing — original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jose Francisco Vargas:** Writing — review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Michelle Marchesini:** Writing — review & editing, Writing — original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Leopoldo Marine:** Visualization, Validation, Supervision, Resources, Project administration, Methodology. **Renato Mertens:** Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis. **Francisco Valdes:** Visualization, Validation, Supervision, Resources, Project

administration. **Jaime Godoy-Santín:** Visualization, Validation, Supervision, Resources, Methodology, Formal analysis. **Patricio Mellado:** Visualization, Validation, Supervision, Project administration, Formal analysis, Data curation, Conceptualization. **Hector Miranda:** Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **José Pablo Zoroquiaín:** Supervision, Project administration, Investigation, Data curation, Conceptualization. **Patricio Sandoval:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Formal analysis.

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