Coexistence of Arterial Compression in Patients With Neurogenic Thoracic Outlet Syndrome

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**IMPORTANCE** Patients with neurogenic thoracic outlet syndrome (NTOS) may have signs and symptoms of arterial compromise without thrombosis or aneurysm.

**OBJECTIVE** To evaluate these patients’ presentation, duration of signs and symptoms, and outcomes of immediate surgical operation.

**DESIGN, SETTING, AND PARTICIPANTS** Demographic and clinical data for patients with NTOS and signs and symptoms of arterial compromise without arterial thrombosis or aneurysm were extracted from a prospectively maintained, institutional review board–approved database and patient medical records between May 22, 2003, and October 16, 2012, in the Johns Hopkins Medical Institutions’ Department of Vascular and Endovascular Surgery.

**INTERVENTIONS** All patients received immediate first rib resection and scalenectomy (FRRS) (n = 15), cervical rib resection and FRRS (n = 6), or FRRS and second rib resection due to fusion (n = 1). Further physical therapy or anterior scalene block was not considered owing to arterial compression.

**MAIN OUTCOMES AND MEASURES** Surgical intervention relieved arterial and neurogenic symptoms, and abnormal duplex velocities returned to normal in adduction.

**RESULTS** Twenty-two patients (13 women and 9 men; mean age, 25 years [range, 12-41 years]) presented with the following signs and symptoms a mean of 37 months (range, 1-144 months) after developing symptoms of NTOS: arm discoloration (n = 15), infraclavicular bruit with arm abduction (n = 9), more than 50% change in subclavian artery velocity in abduction by duplex scan (n = 12), cervical rib (n = 6), abnormal first rib (n = 3), and/or history of embolization (n = 2). In addition, 2 patients had venous thrombosis. The mean follow-up time was 11 months (range, 1-34 months), and all patient outcomes improved in the postoperative period.

**CONCLUSIONS AND RELEVANCE** Arterial compression can coexist with NTOS and can be elucidated in most patients by medical record review and physical examination, along with confirmation by a duplex scan. Those with evidence of arterial compression and for whom physical therapy has failed should receive surgery to alleviate their symptoms. Prompt surgical intervention affords good outcomes in these patients. Outcomes for patients with NTOS and arterial compression following immediate surgical intervention were previously unknown.
Arterial Compression in Patients With NTOS

In 2009, Chang and colleagues evaluated the long-term quality-of-life outcomes in patients after surgical intervention for thoracic outlet syndrome (TOS). In this study, patients with neurogenic thoracic outlet syndrome (NTOS) and venous thoracic outlet syndrome were assessed after transaxillary first rib resection and scalenectomy (FRRS). Chang et al found that patients with TOS demonstrated significant improvement both physically and mentally after FRRS.

It was observed that a subset of patients with NTOS do not have improved symptoms after physical therapy. In fact, TOS-related symptoms were found to worsen with physical therapy in a small subset of patients as noted on physical examination. These patients generally reported color changes in the affected upper extremity that appeared ischemic during an elevated arm stress test. Many of these patients also demonstrated a positive Adson maneuver, an infraclavicular bruit, and/or a rib abnormality on chest radiography, indicating a component of arterial compression in addition to their primary NTOS diagnosis. Several of these patients were found to have arterial compression on a duplex scan, often with a significant change in blood flow velocities in the subclavian artery with arm abduction.

The purpose of this study was to evaluate and examine the demographic and clinical characteristics of 22 patients with NTOS who also had signs and symptoms of arterial compression without thrombosis or aneurysm and who underwent FRRS to decompress the thoracic outlet and relieve arterial symptoms.

Methods

A retrospective review of a prospectively acquired database from the Johns Hopkins Medical Institutions was performed. Data from patients who presented to the clinic between May 22, 2003, and April 20, 2011, were reviewed. The database includes demographic information, patient medical history, clinical etiology, symptoms, interventions, outcomes, and follow-up information regarding all patients who have received surgical intervention for TOS at the Johns Hopkins Medical Institutions. This database is maintained by the Johns Hopkins Medical Institutions’ Department of Vascular and Endovascular Surgery (Baltimore, Maryland) and has approval from the institutional review board to follow the clinical outcomes of these patients. Patient consent was not obtained; any additional information was found in the electronic patient medical records.

A total of 423 patients received surgical intervention for TOS between August 4, 2003, and June 16, 2011. Patients were evaluated for TOS preoperatively at the Johns Hopkins Medical Institutions. Patients whose symptoms worsened after TOS-specific physical therapy were evaluated in the clinic for signs of arterial compression. A detailed medical record review and physical examination were performed in addition to imaging studies. Patients with symptoms indicative of vascular compression received duplex scanning to assess patency. Evidence of previous thrombosis can be seen as chronic changes in the vein wall, and compression of the subclavian artery can be seen in abduction of the arm with a significant change in blood flow velocities. In our vascular laboratory, significant compression of the subclavian artery is defined as an increase of more than 50% or a decrease of more than 50% in subclavian artery flow velocities on arm abduction. Chest radiographs were obtained to detect rib abnormalities as a potential cause of arterial compression. A subset of 22 patients was classified as having arterial compression without thrombosis or aneurysm. Patients were included in this study if they had signs and symptoms of arterial compression in addition to NTOS, received FRRS, and returned for follow-up postoperatively.

Follow-up testing included subsequent postoperative duplex scans to assess arterial flow velocities in abduction. Patients were classified as having a successful surgical outcome if the patient’s TOS-related symptoms were relieved after operative intervention and if patients demonstrated good blood flow through the subclavian artery and revealed adequate blood flow velocities in abduction, indicating minimal arterial compression after surgery. The follow-up time was defined as the length of time (in months) between surgical intervention and the patient’s latest clinic visit.

Results

Of the patients diagnosed with TOS between May 22, 2003, and April 20, 2011, a total of 22 had NTOS with signs and symptoms of arterial compromise without thrombosis or aneurysm. These patients (13 women and 9 men; mean age, 25 years [range, 12-41 years]) presented to the clinic a mean of 37 months (range, 1-144 months) after developing symptoms of TOS.

Through a detailed medical record review and routine physical examination, all patients were determined to have neurogenic symptoms, such as pain, numbness, tingling, weakness, and/or atrophy, along with signs and symptoms of arterial compression. Many precipitating factors were identified in this patient subset: 15 patients (68%) experienced regular arm discoloration, including paleness and rubor on exertion; 9 (41%) were identified as having an infraclavicular bruit with arm abduction; and 2 (9%) had a history of embolization. Also, as seen via chest radiography, 6 patients (27%) had a cervical rib and 3 (14%) had an abnormal first rib. In addition, 2 patients (9%) had venous thrombosis in addition to arterial symptoms. Three patients (14%) experienced symptoms of TOS bilaterally.

Preoperative upper extremity duplex scanning was useful in diagnosing patients with arterial compression. In our subset, 12 patients were identified as having significant compression of the subclavian artery on arm abduction as seen by duplex scan. Of these, 6 had an increase of more than 50% in subclavian artery flow velocity with arm abduction. Figure 1 shows the duplex scan results of a patient’s arm in adduction (Figure 1A) and abduction (Figure 1B), with a significant increase in subclavian artery flow velocity (from 163 to 335 cm/s on abduction). The other 6 had an increase of more than 50% in subclavian artery flow velocity on arm abduction. Figure 2 shows the duplex scan results of a patient’s arm in adduction (Figure 2A) and abduction (Figure 2B). Note the complete ces-
sation of blood flow in the subclavian artery with arm abduction in this patient (from 167 to 0 cm/s on abduction). The other 10 patients either did not have a duplex scan or did not show a significant change in subclavian artery flow velocities on arm abduction.

Between June 30, 2006, and December 21, 2012, all 22 patients immediately received FRRS (n = 15), cervical rib resection and FRRS (n = 6), or FRRS and second rib resection due to fusion (n = 1) at Johns Hopkins Medical Institutions. Preoperative physical therapy or anterior scalene blocks were not considered for this patient subset owing to evidence of arterial compression. Of these patients, 7 (32%) had an intraoperative pneumothorax that was treated overnight with a chest tube, which did not prolong their length of stay. There were no intraoperative complications, such as injury to the vein, artery, or nerve root.

Surgical intervention relieved arterial and neurogenic symptoms in all 22 patients (100%), and abnormal blood flow velocities on duplex scan returned to normal in abduction after surgery. Patients were followed up for a mean of 11 months (range, 1-34 months). All patients had improved symptoms in the postoperative period and had no further complications.

Discussion

Compression of the brachial plexus nerves or subclavian vessels as they pass through the thoracic outlet can cause irritation or injury to the neurovascular structures, resulting in many neurological and/or vascular signs and symptoms. Compression of the subclavian artery is rare, and most patients with NTOS only have compression of the brachial plexus nerves. However, there is a small subset of patients with a preliminary diagnosis of NTOS who are found, on further examination, to have an arterial component to their condition.

Neurogenic TOS often develops in adults in their 20s to 40s, with greater prevalence among women. The patients in our series with an arterial component were younger than those with NTOS alone, with men and women found in comparable proportions. In our study, patients had a mean age of 25 years (range, 12-41 years) and 13 patients (59%) were female. In a series we described of 421 patients diagnosed with NTOS at our institution, patients had a mean age of 40 years (range, 10-82 years) and 304 patients (72%) were female. In addition, patients with an arterial component to their NTOS had a shorter...
length of symptoms. They presented to the clinic a mean of 37 months (range, 1-144 months) after developing symptoms compared with a mean of 56 months (range, 1-516 months) in the neurogenic subset.

In our study, patients’ symptoms did not improve with physical therapy because of the arterial component. When patients with NTOS are found to have compression of the subclavian artery, they should be treated surgically sooner than patients who solely have neurogenic symptoms. Conservative measures should not be implemented in this patient subset because arterial compression does not allow patients' symptoms to improve with physical therapy. Chronic compression causes repetitive injury to the subclavian artery wall, which can potentially result in stenosis or thrombosis. Progressive damage to the arterial wall can lead to aneurysm formation, ultimately resulting in local occlusion or distal embolization.

Anatomical compression can be due to a history of traumatic injuries or chronic and repetitive motion activities. Another common source of compression in arterial TO is the presence of rib abnormalities, such as cervical ribs and atypical first or second ribs. Chang and colleagues recently reviewed their operative experience in patients with TO resulting from cervical ribs causing clinical symptoms. Our patient population is distinct in that the patients with a cervical rib were not found to have a subclavian artery aneurysm or arterial embolization, as shown by a detailed medical record review and physiocal examination and/or duplex scanning. In our study, only 6 patients with arterial compression (27%) had a cervical rib, meaning that the first rib compresses the artery in most of these patients. The first rib had to be surgically removed to alleviate compression of the subclavian artery in our patient subset.

Surgical intervention affords excellent outcomes in patients with NTOS and arterial compression. This group of patients with an arterial component appears to have better outcomes than patients with NTOS alone. In our series following up 141 patients with NTOS, 128 (91%) had improved symptoms after FRRS. Other studies report a 90% or greater success rate after surgical intervention for arterial TOS and neurogenic-arterial TOS.

Conclusions
Arterial compression can coexist with NTOS and can be elucidated by medical record review and physical examination, along with confirmation by duplex scan. Conservative measures, such as physical therapy and anterior scalene blocks, should not be used because only surgery will alleviate the arterial compression. We have determined that prompt surgical intervention results in even better outcomes in this patient subset.