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## Evaluation and treatment of thoracic outlet syndrome during the global pandemic due to SARS-CoV-2 and COVID-19



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### ABSTRACT

The global SARS-CoV-2/COVID-19 pandemic has required a reduction in nonemergency treatment for a variety of disorders. This report summarizes conclusions of an international multidisciplinary consensus group assembled to address evaluation and treatment of patients with thoracic outlet syndrome (TOS), a group of conditions characterized by extrinsic compression of the neurovascular structures serving the upper extremity. The following recommendations were developed in relation to the three defined types of TOS (neurogenic, venous, and arterial) and three phases of pandemic response (preparatory, urgent with limited resources, and emergency with complete diversion of resources).

- In-person evaluation and treatment for neurogenic TOS (interventional or surgical) are generally postponed during all pandemic phases, with telephone/telemedicine visits and at-home physical therapy exercises recommended when feasible.
- Venous TOS presenting with acute upper extremity deep venous thrombosis (Paget-Schroetter syndrome) is managed primarily with anticoagulation, with percutaneous interventions for venous TOS (thrombolysis) considered in early phases (I and II) and surgical treatment delayed until pandemic conditions resolve. Catheter-based interventions may also be considered for selected patients with central subclavian vein obstruction and threatened hemodialysis access in all pandemic phases, with definitive surgical treatment postponed.
- Evaluation and surgical treatment for arterial TOS should be reserved for limb-threatening situations, such as acute upper extremity ischemia or acute digital embolization, in all phases of pandemic response. In late pandemic phases, surgery should be restricted to thrombolysis or brachial artery thromboembolectomy, with more definitive treatment delayed until pandemic conditions resolve. (*J Vasc Surg* 2020;72:790-8.)

**Keywords:** Coronavirus; Hospital resources; Upper extremity; Neurogenic; Brachial plexus; Subclavian vein; Deep venous thrombosis; Axillary artery; Subclavian artery; Thromboembolism; Triage; Endovascular treatment; Surgical treatment; Telemedicine; Teleconference; Consensus

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Thoracic outlet syndrome (TOS) refers to a group of conditions in which the neurovascular structures that serve the upper extremity are subject to extrinsic compression as they pass through the base of the neck, underneath the clavicle, and over the first rib, extending to the subcoracoid space.<sup>1,2</sup> Three types of TOS are defined according to the specific structures affected and the resulting clinical syndromes: *neurogenic TOS*, caused by compression of the brachial plexus nerves, which can lead to pain, paresthesia, and functional disability; *venous TOS*, caused by compression and pathologic stenosis of the subclavian vein, which can lead to axillary-subclavian vein “effort” thrombosis (Paget-Schroetter syndrome), positional compression of the axillary vein without thrombosis (McCleery syndrome), or central venous stenosis causing compromised hemodialysis access; and *arterial TOS*, caused by compression and pathologic changes of the subclavian artery in association with a bone abnormality of the first or cervical ribs, most typically with stenosis, aneurysm formation, and upper extremity thromboembolism. These distinctions are clinically relevant, given the different diagnostic and treatment approaches for each of the three types of TOS as described in the 2016 reporting standards of the Society for Vascular Surgery (SVS).<sup>2</sup>

In December 2019, clustered cases of a severe atypical pneumonia were first observed in Wuhan, China, that were subsequently attributed to a novel coronavirus designated SARS-CoV-2.<sup>3-5</sup> By March 2020, rapid worldwide spread of SARS-CoV-2 infection led the World Health Organization to declare a public health emergency of international concern and a global pandemic.<sup>6</sup> The first case of COVID-19 in the United States was reported on January 20, 2020, followed by evidence for person-to-person transmission and community spread.<sup>7,8</sup> Travel restrictions were implemented in the United States in February 2020, and public health containment and mitigation measures quickly followed. In early March 2020, the Centers for Disease Control and Prevention recommended that hospitals and medical practitioners prepare for a surge in COVID-19 cases that threatened to overwhelm medical resources. Tiered frameworks to guide nonemergency surgery were independently developed by the Centers for Medicare & Medicaid Services, the American College of Surgeons (ACS), the SVS, and the Vascular and Endovascular Surgery Society.<sup>9-16</sup> On March 13, 2020, the ACS advised members against performing elective scheduled procedures to minimize the use of essential personal protective equipment (PPE), intensive care unit (ICU) beds, and ventilators.<sup>11-14</sup> With regard to the management of TOS, the ACS and SVS guidelines designated surgical treatment for neurogenic TOS in tier 1 (postpone); other venous TOS in tier 2a (consider postponing); and symptomatic venous TOS with acute occlusion and marked

swelling, arterial TOS with thrombosis, and thrombolysis (arterial and venous) in tier 2b (postpone if possible).<sup>14,15</sup> Although these recommendations relate to nonemergency operations, they do not address the overall evaluation and treatment for TOS, suggesting that more comprehensive guidelines would be of use.

Many physicians are uncertain about the most appropriate approaches to be taken in evaluating patients for suspected TOS. There are also variations and nuances in the approaches taken to clinical evaluation and management of TOS and marked differences in the care provided for these conditions in different clinical settings. These concerns have all been magnified as a result of restricted access to specialists and uncertainty about the most appropriate patient care during the SARS-CoV-2/COVID-19 pandemic. Because much of the care for patients with TOS is considered elective, in most areas physicians have postponed or cancelled in-person office evaluations and follow-up visits, physical therapy, pain management, imaging and other testing, and the conduct of surgical and interventional procedures. Nonetheless, there remain situations in which patient care must be provided, expertise obtained, and (in some cases) interventions and surgical treatment conducted, depending on the specific clinical situation and the local phase of pandemic response at a given time. The purpose of this report is to describe the approaches that a group of TOS specialists has taken for the evaluation and treatment of TOS during the global SARS-CoV-2/COVID-19 pandemic in an effort to offer more detailed guidelines and recommendations for other physicians and specialists.

## METHODS

This report represents a summary of an ad hoc multidisciplinary consensus teleconference and intervening e-mail communications held between March 31 and May 8, 2020, conducted by a group of specialists with acknowledged expertise in the evaluation and treatment of TOS from across the United States, United Kingdom, and The Netherlands.

Throughout this document, the three types of TOS are defined and considered as described in the 2016 reporting standards of the SVS.<sup>2</sup> Consideration is also given to the ACS classification system used to describe three different phases of local and institutional conditions in response to the SARS-CoV-2/COVID-19 pandemic, as illustrated in the Fig:

*Phase I, semiurgent setting (preparation phase).*

There are few COVID-19 patients, hospital resources are not exhausted, the institution still has ICU and ventilator capacity, the COVID-19 trajectory is not in rapid escalation phase, and surgery is restricted to patients who are likely to experience compromised survival if it is not performed within the next 3 months.

*Phase II, urgent setting.* There are many COVID-19

patients, ICU and ventilator capacity is limited, operating room supplies are limited, and surgery is restricted to patients whose survival is threatened if it is not performed within the next few days.

*Phase III, emergency setting.* All hospital resources are routed to COVID-19 patients, there is no ICU or ventilator capacity, operating room supplies are exhausted, and surgery is restricted to patients who may not survive if it is not performed within a few hours.<sup>10-14,17</sup>

Transitions between phases are dependent on local-regional COVID-19 case numbers and hospital resources, and decisions to transition from phase III toward a gradual easing of social distancing and travel restrictions are made at the hospital, community, and statewide levels. These transitions involve several considerations: sufficient preoperative testing capacity for SARS-CoV-2/COVID-19; deferral of surgery for patients testing positive for SARS-CoV-2/COVID-19; adequate PPE for potential aerosol-generating procedures (ie, intubation and extubation); and availability of sufficient PPE for routine clinic and hospital care. Local conditions and government regulations will also influence the incidence and prevalence of the disease along with potential fluctuations in resources. It is also foreseeable that conditions may arise during any easing of restrictions that will require transitions back to higher level phases of pandemic response. As restrictions are eased and hospitals transition back from phase III toward phase II and phase I conditions, interventional and surgical treatment for patients with TOS may emerge with a relatively high priority based on published scoring systems.<sup>18</sup> This is based on the recognition that patients with these conditions are often substantially disabled but generally young, active, and otherwise healthy and that the procedures involved are generally associated with minimal morbidity, no intensive care use, and short hospital stays.

## RESULTS

Recommendations regarding the evaluation and treatment of patients with suspected or established TOS were developed and described in relation to the three types of TOS (neurogenic, venous, and arterial) and for each phase of local institutional response to the pandemic. The recommendations that follow are based on the assumption that patients are asymptomatic with respect to COVID-19 and negative for SARS-CoV-2 by molecular testing. Approaches to other patient cohorts (asymptomatic with close contact to a known-positive individual or recent travel history from an area of widespread community transmission, symptomatic but untested or under investigation, or symptomatic and test-positive) may differ with regard to isolation measures used in the local

medical practice environment but are not expected to diverge significantly from the recommendations outlined herein.

### General principles.

- Evaluation and treatment for TOS should aim to defer treatment in the absence of imminent life- or limb-threatening complications, with increased thresholds for intervention and surgery; incorporate telemedicine to prevent diversion of patients toward office visits and emergency department care and to avoid hospitalization and use of critical care resources; reduce unnecessary exposure of patients and medical personnel; maintain potentially scarce resources and protect existing capacity; and define/document the circumstances surrounding perceived deviations from optimal care to help support later clinical decision-making.
- In-person evaluation and treatment of neurogenic TOS (interventional or surgical) are generally deferred during all pandemic conditions, with telephone/telemedicine visits and at-home physical therapy exercises recommended for established patients when feasible. During pandemic phase I, treatment may be considered in exceptional cases of neurogenic TOS with severe unrelenting pain, neurologic dysfunction, and pronounced disability (such as those with Disabilities of the Arm, Shoulder, and Hand scores >90).<sup>2</sup> During pandemic phases II and III, interventional and surgical management for neurogenic TOS is delayed until pandemic conditions resolve.
- Venous TOS presenting with acute upper extremity deep venous thrombosis characteristic of Paget-Schroetter syndrome (sudden spontaneous arm swelling, cyanosis, pain and heaviness, non-hemodynamically significant pulmonary embolism) or positional axillary-subclavian vein compression without thrombosis should be managed primarily with anticoagulation until pandemic conditions resolve. Evaluation and percutaneous interventions for venous TOS (upper extremity venography, catheter-directed thrombolysis, and balloon angioplasty) may be considered for arm swelling symptoms in pandemic phases I and II but should be reserved for rare limb-threatening situations presenting with massive arm swelling and severe pain (phlegmasia cerulea dolens) in phase III, with surgical treatment delayed until pandemic conditions resolve. Catheter-based interventions may be considered for selected patients with central subclavian vein obstruction and threatened hemodialysis access in all pandemic phases, with definitive surgical treatment delayed until pandemic conditions resolve.
- Evaluation and treatment of arterial TOS should be reserved for limb-threatening situations, such as acute upper extremity ischemia or acute digital embolization, in all pandemic phases and in phases II and III should be restricted to a brachial artery approach to re-establish perfusion. Definitive rib resection and arterial aneurysm repair should be deferred until phase I conditions return.

**Neurogenic TOS.** As the diagnosis of neurogenic TOS involves comprehensive review of medical records, evaluation of previous studies and treatments, and targeted physical examination in accord with established criteria, it is recommended that patients with suspected neurogenic TOS be referred to a specialist with expertise in management of this condition.<sup>1,2</sup> Whereas prompt diagnosis, physical therapy management, and surgical treatment for patients who have not improved with conservative approaches are otherwise considered optimal, this condition is not limb or life threatening. Treatment of neurogenic TOS is directed toward improving symptoms and achieving optimal upper extremity function and is thereby considered elective under pandemic conditions.

In-person office evaluations for new patients with suspected neurogenic TOS are not conducted but are deferred until the resolution of pandemic conditions (at least 3 months). Initial patient-physician interaction may be offered by telephone/telemedicine at the discretion of the TOS specialist to offer education, to provide reassurance, and to help alleviate patient anxiety (particularly for competitive athletes, performance musicians, military personnel, and other high-performance populations), with the recognition that definitive clinical diagnosis of neurogenic TOS requires in-person physical examination.<sup>2,19</sup> For patients with a reasonable suspicion of neurogenic TOS based on review of secondary medical records and communication with the primary care provider or referring physician but where evaluation is acknowledged to be incomplete, an at-home physical therapy exercise program can be recommended. Such exercises may be provided through printed forms by the TOS specialist or an affiliated physical therapist or with telemedicine if available, but in-person physical therapy visits are not conducted and are deferred until the resolution of pandemic conditions. In patients with a reasonable suspicion of neurogenic TOS and an adequate specialist evaluation through telemedicine, anti-inflammatory agents, muscle relaxants, or neuropathic medications may be recommended or prescribed directly by the TOS specialist.

All diagnostic imaging studies (eg, chest radiographs; cervical spine, brachial plexus, or chest computed tomography [CT] or magnetic resonance [MR] imaging), electrodiagnostic testing (eg, nerve conduction velocity and electromyography), vascular laboratory studies (eg, segmental arterial pressure waveforms with provocative maneuvers or arterial/venous duplex ultrasound evaluations), and other evaluations that might otherwise be appropriate in the assessment of neurogenic TOS are deferred until the resolution of pandemic conditions.

All interventions potentially relevant to diagnosis and treatment of neurogenic TOS, including scalene muscle injections with local anesthetic or botulinum toxin, muscle trigger point injections, and cervical sympathetic

nerve blocks, are deferred until the resolution of pandemic conditions to allow conservation and mobilization of PPE toward the pandemic response.

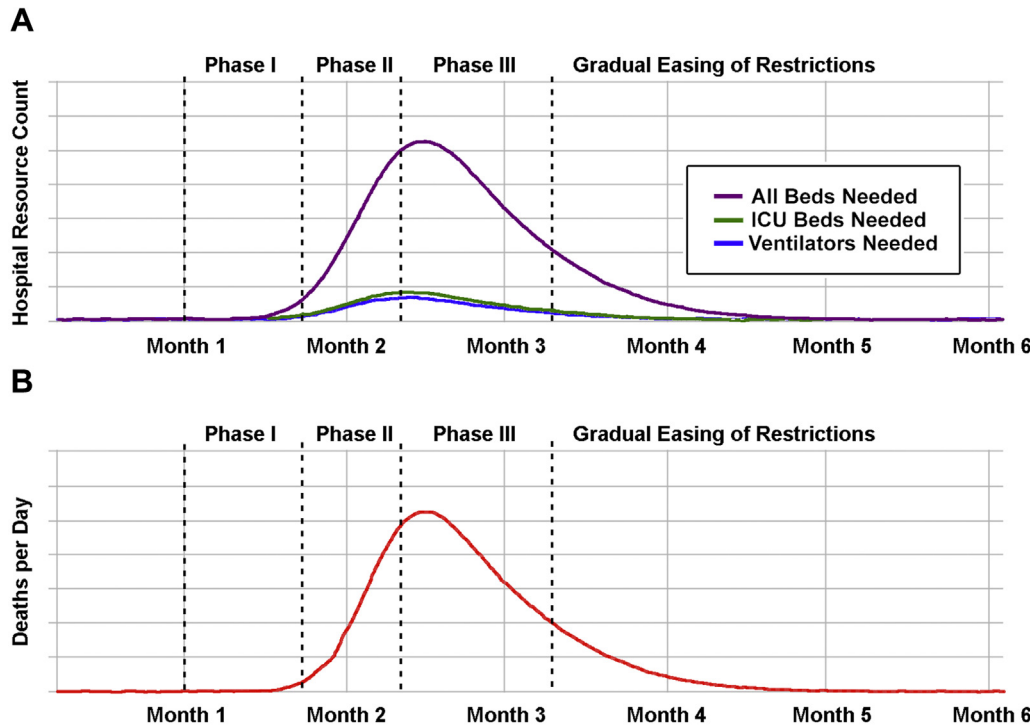
All surgical procedures related to neurogenic TOS should generally be postponed until the resolution of pandemic conditions. During pandemic phase I, treatment may be considered in exceptional cases of neurogenic TOS with severe unrelenting pain, neurologic dysfunction, and pronounced functional disability, such as those with Disabilities of the Arm, Shoulder, and Hand scores  $>90$ .<sup>2</sup> It is still recommended that surgery be postponed even for patients with more chronic pain and neurologic symptoms in the presence of a cervical rib and thenar/hypothenar muscle atrophy (Gilliat-Sumner hand), which is unlikely to change outcomes in the span of several months, given the chronic nature of the clinical presentation.

Nonemergency in-person follow-up office evaluations for patients with established neurogenic TOS are not conducted, including for those who have previously undergone surgical treatment, but are deferred until the resolution of pandemic conditions. Patient assessment may be offered by telephone/telemedicine at the discretion of the TOS specialist, with the recognition that definitive clinical evaluation requires in-person physical examination.<sup>2,19</sup> Prescription renewals for ongoing medications are considered and written by the TOS specialist physician, including planned tapering of postoperative opioid pain medications. At-home physical therapy exercises may be recommended and provided through printed forms by the TOS specialist or an affiliated physical therapist, but in-person physical therapy visits are not conducted and are deferred until the resolution of pandemic conditions. Physical restrictions, disability, and timing of return to work are determined by the TOS specialist physician.

In-person urgent or emergency office evaluation may be considered for patients who have undergone previous surgical treatment for neurogenic TOS if initial telephone/telemedicine consultation suggests unexpectedly severe symptoms, postoperative wound or other complications, acute arterial insufficiency, or acute venous thromboembolism.

**Venous TOS.** As the diagnosis of venous TOS involves comprehensive evaluation in accord with established criteria, it is recommended that patients with suspected venous TOS be referred to a specialist with expertise in management of this condition.<sup>1,2</sup> Whereas optimal management for acute axillary-subclavian vein "effort" thrombosis (Paget-Schroetter syndrome) is otherwise prompt clinical diagnosis, intervention (catheter-directed thrombolysis), and surgical treatment, this condition is not usually limb or life threatening. Treatment of venous TOS is directed toward improving arm swelling symptoms and achieving





**Fig.** Graphical depiction of theoretical forecasting models for the SARS-CoV-2/COVID-19 pandemic in the United States, illustrating projected hospital resource use (**A**) and deaths per day (**B**). The three phases of pandemic response are highlighted by the vertical dashed lines, as well as the eventual transition from phase III toward easing of restrictions and recovery. ICU, Intensive care unit.

optimal upper extremity function and is thereby considered nonurgent under pandemic conditions. Exceptions are those with progressive worsening of arm swelling despite therapeutic anticoagulation and the rare patient presenting with massive acute limb-threatening arm swelling and severe pain (phlegmasia cerulea dolens), in whom interventional treatment may be considered urgent.

In-person office evaluations for new patients with suspected venous TOS are not conducted but are deferred until the resolution of pandemic conditions. Initial patient-physician interaction may be offered by telephone/telemedicine at the discretion of the TOS specialist to offer education and to help alleviate patient anxiety, with the recognition that definitive clinical diagnosis of venous TOS requires in-person physical examination and appropriate vascular imaging studies (eg, venous duplex ultrasound with provocative maneuvers or catheter-based venography).<sup>2,19</sup> Prescriptions for outpatient oral anticoagulation treatment (with a novel oral anticoagulant or injectable heparin to avoid the need for laboratory blood testing with warfarin) may be recommended or written by the TOS specialist based on an adequate telemedicine consultation and a presumptive clinical or radiographic diagnosis of axillary-subclavian vein thrombosis. It is also generally

recommended that patients with a presumptive diagnosis of venous TOS have restrictions placed on elevated arm activity with the affected upper extremity and potential use of an elastic compression sleeve garment for management of arm swelling.

Upper extremity duplex ultrasound may confirm (but cannot exclude) the clinical diagnosis of acute axillary-subclavian vein effort thrombosis, whereas CT angiography, MR angiography, and catheter-based venography can confirm or exclude the diagnosis.<sup>20</sup> Pulmonary embolism secondary to upper extremity venous thrombosis and venous TOS is not uncommon (approximately 20% of patients) but only rarely results in hemodynamic compromise. In phase I or phase II pandemic conditions, upper extremity venous duplex ultrasound with provocative maneuvers or CT/MR angiography may be reasonable as performed on a selective basis in an outpatient setting, determined by the local expertise and availability of hospital staff, resources, and number of patients with COVID-19. In phase III pandemic conditions, all diagnostic imaging studies and interventions (eg, venous duplex ultrasound, CT angiography, MR angiography, and catheter-based venography) that may otherwise be appropriate to the assessment of venous TOS are deferred until the resolution of pandemic conditions.

In phase I or phase II pandemic conditions, catheter-based evaluation and interventions potentially relevant to the initial treatment of venous TOS (including thrombolysis, pharmacomechanical thrombectomy, and venous balloon angioplasty) are performed on a selective basis, determined by the local expertise and availability of hospital staff, resources, and number of patients with COVID-19. During phase III pandemic conditions, catheter-based evaluation and interventions (including thrombolysis, pharmacomechanical thrombectomy, and venous balloon angioplasty) for venous TOS are deferred until the resolution of pandemic conditions. During all pandemic phases, interventional treatment may be considered for the exceptionally rare patient presenting with massive acute limb-threatening arm swelling and severe pain (phlegmasia cerulea dolens).

Catheter-based interventions for salvage of hemodialysis access threatened by central subclavian vein stenosis are individualized and performed on a selective basis during phase I and phase II pandemic conditions based on local expertise and the availability of hospital staff, resources, and number of patients with COVID-19. Any such intervention should be acknowledged to have diminished long-term patency over more definitive alternatives, and placement of stents in the subclavian vein should be avoided. Catheter-based interventions of the subclavian vein for salvage of hemodialysis access that require in-patient hospitalization are discouraged in phase III pandemic conditions and should be deferred or postponed until the resolution of pandemic conditions. If local expertise exists for outpatient thrombectomy, initial attempts at this approach can be considered in phase III before placement of a tunneled catheter.

All surgical procedures related to venous TOS, including those for acute axillary-subclavian vein thrombosis (Paget-Schroetter syndrome), positional axillary-subclavian vein compression without thrombosis (McCleery syndrome), and threatened hemodialysis access due to central subclavian vein obstruction, are postponed until the resolution of pandemic conditions.

Nonemergency follow-up office evaluations for patients with established venous TOS are not conducted, including for those who have previously undergone surgical treatment, but are deferred until the resolution of pandemic conditions. Patient interaction may be offered by telephone/telemedicine at the discretion of the TOS specialist, with the recognition that definitive clinical evaluation requires in-person physical examination.<sup>2,19</sup> Prescription renewals for ongoing medications are considered by the TOS specialist physician, including anticoagulation and planned tapering of postoperative opioid pain medications. At-home physical therapy exercises may be recommended to patients who have

previously undergone surgery for venous TOS, with exercises provided by the TOS specialist or an affiliated physical therapist, but in-person physical therapy visits are not conducted and are deferred until the resolution of pandemic conditions. Physical restrictions, disability, and timing of return to work are determined by the TOS specialist physician.

In-person urgent or emergency follow-up office evaluation may be considered for patients who have undergone previous surgical treatment for venous TOS if initial telephone/telemedicine consultation suggests unexpectedly severe symptoms, postoperative wound or other complications, acute arterial insufficiency, or acute venous thromboembolism.

**Arterial TOS.** As the diagnosis of arterial TOS involves comprehensive evaluation in accord with established criteria, it is recommended that patients with suspected arterial TOS be referred to a specialist with expertise in management of this condition.<sup>1,2</sup> Arterial TOS involves subclavian artery disease in the presence of a bone abnormality, such as a cervical rib or anomalous first rib, with subclavian artery stenosis and aneurysm formation that may lead to acute thromboembolism and limb-threatening ischemia. It is important to emphasize that positional absence or dampening of the upper extremity arterial pulses during arm elevation, in the presence of normal arterial pulses with the arm at rest and in the absence of thromboembolism or subclavian artery disease (thrombosis or aneurysm), does not represent arterial TOS. In addition, recognition of a cervical rib (by plain film radiography of the chest or cervical spine) should prompt further axial imaging to evaluate the potential for a subclavian artery aneurysm. Prompt diagnosis, intervention, and surgical treatment for acute upper extremity ischemia related to arterial TOS is considered necessary, given the potential for limb-threatening complications. In such situations, treatment of arterial TOS is directed toward limb salvage and achieving optimal upper extremity function and is thereby considered urgent or emergent even under pandemic conditions. Arterial TOS in the absence of acute upper extremity ischemia, such as with digital embolization and subclavian artery aneurysm, has the potential to progress to more severe limb-threatening ischemia that may lead to the need for urgent or emergency treatment. Such situations thereby warrant urgent evaluation and appropriate treatment considerations to prevent progression, even if not providing definitive management.

In-person routine office evaluations for new patients with suspected arterial TOS without evidence of distal embolic disease are not conducted but are deferred until the resolution of pandemic conditions; however,



it is recommended that initial patient-physician interaction be offered by telephone/telemedicine at the discretion of the TOS specialist to offer education and to help alleviate patient anxiety, with the recognition that definitive clinical diagnosis of arterial TOS requires in-person physical examination and appropriate vascular imaging studies (eg, duplex ultrasound, CT angiography, MR angiography, or catheter-based arteriography).<sup>2,19</sup> Prescriptions for outpatient oral antiplatelet or anticoagulation treatment (with a novel oral anticoagulant or injectable heparin to avoid the need for laboratory blood testing with warfarin) may be recommended or written by the TOS specialist based on an adequate telemedicine consultation and a presumptive clinical or radiographic diagnosis of subclavian artery aneurysm. It is also recommended that patients with a presumptive diagnosis of arterial TOS have restrictions placed on elevated arm activity with the affected upper extremity.

Urgent in-person clinical examination in the office or emergency department setting is necessary for evaluation of possible acute upper extremity ischemia or arterial thromboembolism. Upper extremity segmental pulse pressures and waveforms can provide sound evidence in diagnosis of acute upper extremity ischemia due to thromboembolism, and upper extremity duplex ultrasound with provocative maneuvers may confirm (but cannot exclude) a clinical suspicion of subclavian artery aneurysm while other sources of arterial embolism are evaluated and excluded. CT angiography, MR angiography, and catheter-based arteriography can confirm or exclude the diagnosis of arterial TOS, and such studies can be recommended on an emergency basis in the presence of acute ischemia and on an urgent basis in the presence of digital thromboembolism. In the absence of acute upper extremity ischemia or digital thromboembolism, all diagnostic imaging studies (eg, ultrasound, CT angiography, MR angiography, or catheter-based arteriography) that may otherwise be appropriate in the assessment of possible arterial TOS are deferred until the resolution of pandemic conditions.

Endovascular interventions potentially applicable to the initial treatment of arterial TOS, including catheter-directed thrombolysis of the axillary or subclavian arteries, are considered appropriate in the setting of limb-threatening ischemia or arterial thromboembolism in all phases of response to pandemic conditions. For patients with subacute or chronic symptoms attributable to arterial TOS and for those with asymptomatic (incidentally identified) axillary or subclavian artery aneurysms, such interventions are generally deferred while the patient is treated with

antiplatelet or anticoagulation medications until the resolution of pandemic conditions.

Surgical treatment for acute upper extremity ischemia due to brachial artery thromboembolism is recommended on an emergency basis in all phases of response to pandemic conditions. This is optimally performed through a brachial artery approach with open thromboembolectomy to restore arterial flow for limb salvage. Balloon catheter thrombectomy, intraoperative administration of thrombolytic agents, and vasodilators are potentially useful adjuncts. Forearm fasciotomy is considered when there is a prolonged period of ischemia and suspected compartment syndrome on revascularization. Intraoperative arteriography may be included in the same procedure, both to ensure satisfactory restoration of arterial flow and to further assess the potential axillary and subclavian artery source of thromboembolism. In phase I pandemic conditions, more definitive surgical treatment may also be considered to include cervical and first rib resection and direct subclavian artery reconstruction with interposition bypass grafting or endovascular placement of a covered subclavian artery stent. In phase II or phase III pandemic conditions, definitive thoracic outlet decompression should generally be postponed if satisfactory revascularization can be accomplished through a brachial artery approach alone, with the patient treated with antiplatelet or anticoagulation medications until the resolution of pandemic conditions. For patients with subacute or chronic symptoms attributable to arterial TOS and for those with asymptomatic (incidentally identified) axillary or subclavian artery aneurysms, surgical treatment is postponed while the patient is treated with antiplatelet or anticoagulation medications until the resolution of pandemic conditions.

Nonemergency in-person follow-up office evaluations for patients with established arterial TOS are not conducted, including for those who have previously undergone surgical treatment, but are deferred until the resolution of pandemic conditions. Patient interaction may be offered by telephone/telemedicine at the discretion of the TOS specialist, with the recognition that definitive clinical evaluation requires in-person physical examination.<sup>2,19</sup> Prescription renewals for ongoing medications are considered by the TOS specialist physician, including antiplatelet agents, anticoagulation, and planned tapering of postoperative opioid pain medications. At-home physical therapy exercises may be recommended to patients who have previously undergone surgery for arterial TOS, with exercises provided by the TOS specialist or an affiliated physical therapist. In-person physical therapy visits are not conducted but are deferred until the resolution of pandemic conditions.

Physical restrictions, disability, and timing of return to work are determined by the TOS specialist physician.

In-person urgent or emergency follow-up office evaluation may be considered for patients who have undergone previous surgical treatment for arterial TOS if initial telephone/telemedicine consultation suggests unexpectedly severe symptoms, postoperative wound or other complications, acute arterial insufficiency, or acute venous thromboembolism.

## CONCLUSIONS

The SARS-CoV-2/COVID-19 pandemic has placed enormous and unprecedented strain on medical care systems across the globe. With emergency department, hospital, and intensive care utilization rapidly outstripping the available resources, one of the primary goals of physicians and surgeons during this time is to preserve and expand hospital resources ("staff, space, and stuff").<sup>21-23</sup> The management of TOS varies according to the particular type, but surgical therapy of neurogenic and venous TOS should generally not be offered because of the risks of SARS-CoV-2 infection and transmission as well as the need to limit exposure of medical personnel and the consumption of hospital resources. Surgical treatment for arterial TOS should also be limited as much as possible and, when necessary for limb salvage, should be largely confined to brachial-based interventions. In most cases, more definitive surgical treatment for all forms of TOS is deferred or postponed until the easing of restrictions and resolution of pandemic conditions. Regrettably, it is foreseeable that future infectious disease pandemics will arise that may once again threaten to overwhelm regional and national health care infrastructures, for which we hope these guidelines will be of value as a framework for evaluation and management of patients with TOS.

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## REFERENCES

1. Illig KA, Thompson RW, Freischlag JA, Donahue DM, Jordan SE, Edgelow PI, editors. Thoracic outlet syndrome. London: Springer; 2013.
2. Illig KA, Donahue D, Duncan A, Freischlag J, Gelabert H, Johansen K, et al. Reporting standards of the Society for Vascular Surgery for thoracic outlet syndrome. *J Vasc Surg* 2016;64:e23-35.
3. Zhou P, Yang XL, Wang XG, Hu B, Zhang W, Si HR, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature* 2020;579:270-3.
4. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020;395:497-506.
5. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med* 2020;382:1199-207.
6. World Health Organization. WHO characterizes COVID-19 as a pandemic. Available at: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen>. Accessed April 3, 2020.
7. Holshue ML, DeBolt C, Lindquist S, Lofy KH, Wiesman J, Bruce H, et al. Washington State 2019-nCoV Case Investigation Team. First case of 2019 novel coronavirus in the United States. *N Engl J Med* 2020;382:929-36.
8. Ghinai I, McPherson TD, Hunter JC, Kirking HL, Christiansen D, Joshi K, et al. Illinois COVID-19 Investigation Team. First known person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the USA. *Lancet* 2020;395:1137-44.
9. Centers for Medicare & Medicaid Services. CMS releases recommendations on adult elective surgeries, non-essential medical, surgical and dental procedures during COVID19 response. Available at: <https://www.cms.gov/newsroom/press-releases/cms-releases-recommendations-adult-elective-surgeries-non-essential-medical-surgical-and-dental>. Accessed April 3, 2020.
10. American College of Surgeons. Clinical issues and guidance. Available at: <https://www.facs.org/covid-19/clinical-guidance>. Accessed April 3, 2020.
11. American College of Surgeons. Recommendations for management of elective surgical procedures. Available at: <https://www.facs.org/covid-19/clinical-guidance/elective-surgery>. Accessed April 3, 2020.
12. American College of Surgeons. Guidance for triage of non-emergent surgical procedures. Available at: <https://www.facs.org/covid-19/clinical-guidance/triage>. Accessed April 3, 2020.
13. American College of Surgeons. COVID-19 guidelines for triage of thoracic patients. Available at: <https://www.facs.org/covid-19/clinical-guidance/elective-case/thoracic-cancer>. Accessed April 3, 2020.
14. American College of Surgeons. COVID-19 guidelines for triage of vascular surgery patients. Available at: <https://www.facs.org/covid-19/clinical-guidance/elective-case/vascular-surgery>. Accessed April 3, 2020.
15. Society for Vascular Surgery. Vascular surgery triage by tier class. Available at: <https://vascular.org/sites/default/files/Vascular%20surgery%20triage%20by%20Tier%20Class%203.24.20.pdf>. Accessed April 3, 2020.
16. Vascular and Endovascular Surgery Society. VESS COVID-19 statement. Available at: <https://vesurgery.org/site/wp-content/uploads/2020/03/VESS-COVID-19-Statement.pdf>. Accessed April 3, 2020.
17. Murray CJ; Institute for Health Metrics and Evaluation COVID-19 Health Service Utilization Forecasting Team, University of Washington. Forecasting COVID-19 impact on hospital bed-days, ICU-days, ventilator-days and deaths by US state in the next 4 months. Available at: <http://covid19.healthdata.org>. Accessed April 3, 2020.
18. Prachand VN, Milner R, Angelos P, Posner MC, Fung JJ, Agrawal N, et al. Medically necessary, time-sensitive procedures: scoring system to ethically and efficiently manage resource scarcity and provider risk during the COVID-19 pandemic. *J Am Coll Surg* 2020;231:281-8.
19. Humphries MD; Vascular and Endovascular Surgery Society. VESS telemedicine statement. Available at: <https://vesurgery.org/site/wp-content/uploads/2020/03/VESS-Telemedicine-Statement-2020.pdf>. Accessed April 3, 2020.
20. Brownie ER, Abuirqeba AA, Ohman JW, Rubin BC, Thompson RW. False-negative upper extremity ultrasound in the initial evaluation of patients with suspected

- subclavian vein thrombosis due to thoracic outlet syndrome (Paget-Schroetter syndrome). *J Vasc Surg Venous Lymphat Disord* 2020;8:118-26.
21. Starnes BW, Sing N. Letter from Seattle: amid COVID-19 pandemic, time to act is long past due. Available at: <https://vascularspecialistonline.com/letter-from-seattle-amid-covid-19-pandemic-time-to-act-is-long-past-due/>. Accessed April 3, 2020.
22. Moghadas SM, Shoukat A, Fitzpatrick MC, Wells CR, Sah P, Pandey A, et al. Projecting hospital utilization during the COVID-19 outbreaks in the United States. *Proc Natl Acad Sci U S A* 2020;117:9122-6.
23. Forrester JD, Nassar AK, Maggio PM, Hawn MT. Precautions for operating room team members during the COVID-19 pandemic. *J Am Coll Surg* 2020;230:1098-101.

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