as well as modes of trauma, hospital transfer status before receiving care, type of intervention received, follow-up rates, and outcomes including both complication and amputation rates were analyzed.

Results: Between January 2013 and December 2017, a total of 88 patients with traumatic upper extremity vascular injuries were identified. The majority of injuries were due to penetrating trauma (74/88 [84%]), with 41% (10/24) of patients in the lower ADI being victims of gunshot wounds compared with 27% (17/64) of those in the higher ADI ($P = .19$). Patients in the lowest ADI quartile were more likely to be African Americans ($P = .0001$) and more likely to be transferred to our university hospital before receiving care ($P = .007$). Arrival Glasgow Coma Scale score and Injury Severity Score were similar, as was time spent in the emergency department. Length of stay trended longer in the lowest ADI quartile compared with the higher ADI (7.5 vs 11.8; $P = .59$). The rates of long-term follow-up were significantly lower in patients with the lowest ADI scores as opposed to the higher ADI ($P = .0098$); however, there was no statistically significant difference in outcomes between the two groups, including both complication and amputation rates.

Conclusions: The ADI is associated with lower rates of long-term follow-up after upper extremity vascular injuries despite patients' having similar outcomes in regard to complication and amputation rates in both the high and low ADI groups. Further study is warranted to investigate the role of the socioeconomic status in outcomes after traumatic injury.

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Noninvasive and Patient-Specific Assessment of True Severity of Renal Artery Stenosis for New Guidelines for Planning Stent Therapy

Alan P. Sawchuk, MD,[1] Monsurul Khan,[2] Anurag Deb,[2] Raghu L. Motaganahalli, MD,[1] Xin Fang, MD,[3] Fangke Chen, MD,[3] **Huidan (Whitney) Yu, PhD**[1,2]. [1]Indiana University, Indianapolis, Ind; [2]Indiana University-Purdue University Indianapolis, Indianapolis, Ind; [3]Hangzhou First Peoples' Hospital, Hangzhou, China

Objective: Renal artery stenosis (RAS) causes renovascular hypertension, but its severity is difficult to determine. Thus, effective stenting therapy cannot be well planned. This research is to develop and to validate a new, noninvasive, and patient-specific means to assess the true severity of RAS based on clinical computed tomography angiography and Doppler ultrasound.

Methods: As shown in Fig 1, a well-developed in-house computation package, named InVascular, is used to extract the anatomic three-dimensional aortorenal artery together with flow conditions (inlet) and three-element Windkessel model (exits) based on clinical computed tomography angiography and Doppler ultrasound and to quantify the trans-stenotic pressure gradient ($\alpha P = Pa - Pr$; Fig 1, *a*), to parameterize deterioration scenarios of the RAS denoted by the volumetric stenosis degree (S; Fig 1, *b*), and to establish the correlation

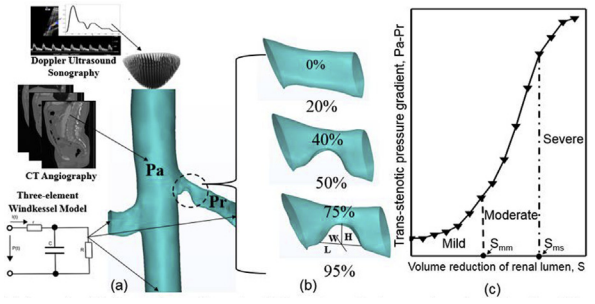

Fig 1. a, Schematic of InVascular used to extract three-dimensional aortorenal artery anatomy based on computed tomography (*CT*) angiography and to quantify the trans-stenotic pressure gradient (Pa-Pr) combining Doppler ultrasound flow condition at the inlet and three-element Windkessel model at the exits. **b,** Parametric deterioration scenarios of stenosis measured from the volume reduction of the renal lumen. **c,** Determination of mild ($S \leq S_{mm}$), moderate ($S_{mm} < S \leq S_{ms}$), or severe ($S > S_{ms}$) stenosis based on the trans-stenotic pressure gradient of the existing stenosis (S).

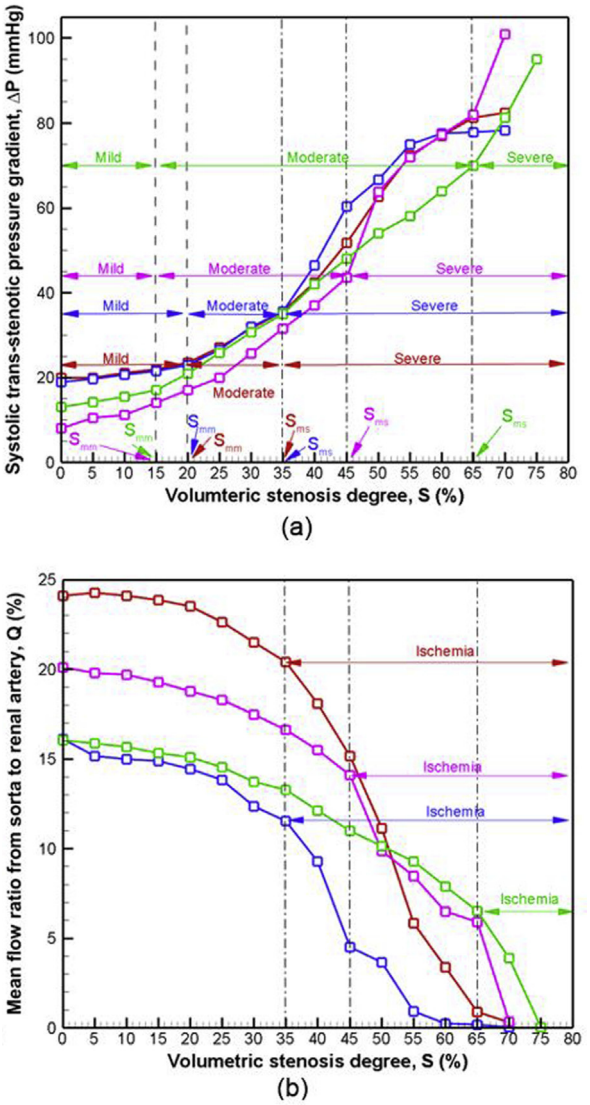

Fig 2. Correlation of **(a)** systolic trans-stenotic pressure gradient ΔP and **(b)** normalized mass flow ratio from aorta to renal artery vs volumetric stenosis degree S of four renal arteries recognized by the four colors. The characteristic stenosis sizes S_{mm} and S_{ms} that indicate mild, moderate, and severe renal artery stenosis (RAS) are shown in **(a),** and ischemia ranges due to the severe RAS are identified in **(b)**.

of αP vs S to identify whether the stenosis is mild, moderate, or severe (Fig 1, *c*). Careful validation has been made for pressure quantification through concurrent invasive measurement and noninvasive computation.

Results: The cases of five patients with 10 renal arteries are studied. For each renal artery, we virtually create a series of progressive stenosis, for each of which the trans-stenotic pressure gradient and flow rate are quantified. The correlations of the systolic trans-stenotic pressure gradient and the flow ratio from aorta to renal artery vs volumetric stenosis degree of four renal arteries are shown in Fig 2. In each renal artery, the two characteristic stenosis sizes, S_{mm} (15% or 20%) and S_{ms} (from 35% to 65%), indicate mild, moderate, and severe RAS.

Conclusions: InVascular provides a unique, noninvasive, and reliable means for patient-specific assessment of RAS severity. Whether a diagnosed RAS is mild (no specific treatment needed), moderate (medical management indicated), or severe (stenting beneficial) is determined by the true flow resistance and relative renal ischemia. We conclude that volume reduction of renal lumen is more accurate to characterize the degree of RAS and that the correlation between trans-stenotic

pressure gradient and volumetric stenosis degree is patient specific and dependent on the specific characteristics of the stenosis and the renal artery. Thus, the same degree of stenosis might be mild for one patient but severe for another patient.

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Innominate Artery Through Ministernotomy With Anatomic Tunneling for Critical Ischemia of the Left Upper Extremity

Alexandra J. Sharp,[1] Adeola T. Odugbesi, MD,[2] Jeanette Man, MD,[2] Anna E. Marjan, MD,[2] Mel J. Sharafuddin, MD[3]. [1]Luther College, Iowa City, Iowa; [2]University of Iowa Carver College of Medicine, Iowa City, Iowa; [3]Surgery, University of Iowa College of Medicine, Iowa City, Iowa

Objective: The patient is a 58-year-old woman with a history of left-sided mastectomy and axillary node dissection for cancer. She developed occlusive disease requiring extensive stenting of the left subclavian-axillary artery and subsequent carotid to proximal brachial artery prosthetic bypass, complicated by stroke. She was referred for critical ischemia of the left upper extremity and computed tomography angiography showing occlusion of the bypass with reconstitution of the proximal brachial artery.

Methods: Conventional extrathoracic inflow options were thought to be unsuitable. We thus opted for more proximal inflow. Limited midline manubriotomy with partial upper median sternotomy was performed, and the innominate artery was mobilized. The most proximal right subclavian artery was chosen for inflow, and the left brachial artery was exposed in the upper arm. A tunnel was bluntly developed from the chest incision behind the clavicle along the anterior margin of the first rib to maintain a course ventral to the anterior scalene muscle. The completed tunnel was digitally inspected during abduction of the left shoulder, confirming ample caliber to accommodate the conduit without compressing the thoracic outlet's contents. A cryopreserved homograft was used for the reconstruction, and a strong pulse was restored to the brachial artery and runoff at completion.

Results: There was resolution of the ischemic pain, with residual "neuropathic" pain managed medically. Duplex ultrasound imaging and computed tomography angiography were available up to 16 months after the procedure, demonstrating patency of the graft, normal digital pressure, and lack of compression at the thoracic outlet.

Conclusions: This case illustrates a new tunneling option in upper extremity revascularization when conventional routes are not feasible. Careful planning based on cross-sectional imaging is mandatory, and inspection of the tunnel during shoulder stress maneuvers is needed to avoid dynamic compression.

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Proximalization of Arterial Inflow for Treatment of Hemodialysis-Induced Arterial Steal Syndrome

Shoaib Shafique, MD, Kate Dell, RN. Franciscan St. Elizabeth Health, Lafayette, Ind

Objective: This was a retrospective analysis of proximalization of arterial inflow for treatment of hemodialysis access-related arterial steal syndrome.

Methods: We performed 12 proximalization procedures during a span of 18 months. The proximalization procedure was performed by creating a bypass from the axillary artery to the arteriovenous (AV) fistula and disconnecting the AV fistula from the brachial artery inflow source. Retrospective review of data was performed to evaluate indications, outcomes, complications, and technical pitfalls.

Retrospective review was conducted of patients who underwent proximalization of arterial inflow from July 2016 to March 2018. We performed this procedure on 12 patients. Indications for the procedure were intractable pain in the hand at all times in seven patients, tissue loss in three patients, and severe pain during dialysis treatment in two patients. All patients were diagnosed with arterial steal syndrome with Doppler ultrasound studies, and subsequent angiography was performed to confirm the diagnosis and to rule out inflow correctable lesions. Selection of patients for proximalization was based on relatively small size of the brachial artery in comparison to the AV fistula and low flow volumes. We used expanded polytetrafluoroethylene (ePTFE) grafts in all patients.

Results: Three patients received four to seven tapered grafts, and the remaining patients received 5-mm or 6-mm ePTFE grafts. Two patients had graft thrombosis within 30 days postoperatively. These appeared to be due to hypotension during dialysis. On further investigation, one of these had venous outflow stenosis, which was corrected by angioplasty of the venous outflow. This patient also required stenting of the anastomosis between the ePTFE graft and the fistula because of stenosis. The other patient had graft revision with a larger conduit. There was no mortality in 30 days. All patients showed improvement in perfusion of the affected hand. One patient had no significant improvement in numbness and was referred for neurologic evaluation. Two patients had partial resolution of pain. The remaining patients had resolution of pain, and all patients with tissue loss healed their ulcers.

Conclusions: Proximalization of arterial inflow can help resolve hemodialysis access-related arterial steal syndrome in the majority of patients in whom the brachial artery is small.

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