specific type of intervention was endovascular stenting (n = 86 [45.3%]), and the most common site was the left renal artery (n = 51 [26.8%]). There were no significant differences in total postoperative complications, intensive care unit length of stay, or in-hospital mortality for patients who had adjunctive branch procedures compared with those who did not (Table II).

Conclusions: Adjunctive peripheral and visceral artery branch interventions at the time of TEVAR for acute TBAD with malperfusion are not uncommon; however, this does not predispose to poorer overall outcomes. Thus, adjunctive arterial branch interventions should be included in the paradigm of treatment of malperfusion associated with TBAD if primary entry tear coverage alone is not successful.

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Computational Methods to Automate the Initial Interpretation of Lower Extremity Arterial Doppler and Duplex Carotid Ultrasound

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Objective: Lower extremity arterial Doppler (LEAD) and duplex carotid ultrasound studies are used for the initial evaluation of peripheral artery disease and carotid stenosis. The initial impression done by the technologist is time-consuming. Interlaboratory variability exists because of different technologists doing an initial impression of these studies and different physicians interpreting them. We examined whether machine learning algorithms could be used to classify these Doppler studies.

Methods: We developed a hierarchical deep learning model to classify aortoiliac, femoropopliteal, and trifurcation disease in LEAD studies and carotid stenosis for duplex carotid ultrasound using physician interpretation as a "gold standard." Waveforms, pressures, flow velocities, and presence of plaque were input into a hierarchical neural network. Artificial intelligence was developed to automate the interpretation of these LEAD and carotid duplex ultrasound studies.

Results: There were 5761 LEAD studies from 2015 to 2017 and 18,650 duplex carotid ultrasound studies from 2016 to 2018 extracted from the IU Health system. The Results show a 97.0% accuracy predicting normal cases, an 88.2% accuracy for aortoiliac disease, a 90.1% accuracy for femoropopliteal disease, and a 90.5% accuracy for trifurcation disease. For internal carotid artery stenosis, the accuracy was 99.2% for predicting 0% to 49% stenosis, 100% for predicting 50% to 69% stenosis, 100% for predicting >70% stenosis, and 100% for predicting occlusion. Table I shows the complete sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for the LEAD study results. For common carotid artery stenosis, the accuracy was 99.9% for predicting 0% to 49% stenosis, 100% for predicting 50% to 99% stenosis, and 100% for predicting occlusion. Table II shows the complete sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for the carotid study results for the random forest model.

Conclusions: Novel machine learning models using LEAD data, including blood pressures and waveforms, and duplex carotid ultrasound data using flow velocities and the presence of plaque show reliable and accurate classification and quantification of normal and diseased arteries.

Table I. Lower extremity arterial Doppler (LEAD) statistics

	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
Normal	98.0	98.0	99.1	95.5	97.0
Aortoiliac	90.0	85.0	89.6	85.4	88.0
Femoropopliteal	94.4	80.2	94.1	89.0	90.1
Trifurcation	79.7	95.4	89.4	90.7	90.5

NPV, Negative predictive value; *PPV*, positive predictive value.

Table II. Carotid artery duplex ultrasound statistics

	Sensitivity, %	Specificity, %	PPV, %	NPV, %	Accuracy, %
CCA (0%-49%)	99.8	100.0	100.0	99.9	99.8
CCA (50%-99%)	100.0	99.9	99.8	100.0	99.9
CCA (occlusion)	99.8	100.0	100.0	99.9	99.9
ICA (0%-49%)	98.2	100.0	100.0	99.4	98.2
ICA (50%-69%)	99.8	99.5	98.4	99.9	99.9
ICA (70%-99%)	98.2	100.0	100.0	99.4	99.6
ICA (occlusion)	98.3	99.9	99.8	99.4	99.6

CCA, Common carotid artery; *ICA*, internal carotid artery; *NPV*, negative predictive value; *PPV*, positive predictive value.

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Fast and Noninvasive Evaluation of In Vivo Pressure in Stenosed Aortoiliac Arteries

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Objective: Whereas fractional flow reserve has been a "gold standard" to determine the severity of coronary stenosis, the trans-stenotic pressure gradient (*TSPG*) might be an alternative to assess the severity of iliac arterial stenoses. Because it is determined by the proximal (P_a) and distal (P_d) pressure to a stenosis, we developed a novel method to evaluate the four-dimensional (space and time) in vivo blood flow (pressure, velocity, and wall shear stress) in stenosed aortoiliac arteries based on computed tomography angiography and Doppler ultrasound. Such a means not only can quantify in vivo blood pressure noninvasively but also enable massive studies to determine whether TSPG can assess the true severity of iliac stenosis.

Methods: We employ a patented in-house computational platform, *InVascular*, to quantify the four-dimensional (space and time) hemodynamics (velocity and pressure) in a stenosed iliac artery. Clinically acquired computed tomography angiography images are used to anatomically extract the three-dimensional flow domain, and the flow information is obtained from the velocity waveforms of Doppler ultrasound. Through the integration of advanced computational modeling and cutting-edge parallel computing technique, *InVascular* can quickly compute the proximal (P_a) and distal (P_d) pressure to a stenosis, schematized in Fig, *a*. Thus, TSPG ($= P_a - P_d$) is obtained.

Results: Three cases with five iliac stenoses are studied, in each of which P_a and P_d are measured during angiography. Fig, *b* compares the cardiac pressure waveforms of P_a (*top*) and P_d (*bottom*) between noninvasive computation (*line*) and invasive measurement (*symbols*), respectively. The good agreements indicate the accuracy of *InVascular*. Statistical analysis for the correlation between computed and measured pressures (systolic, diastolic, and mean arterial values) is shown in the

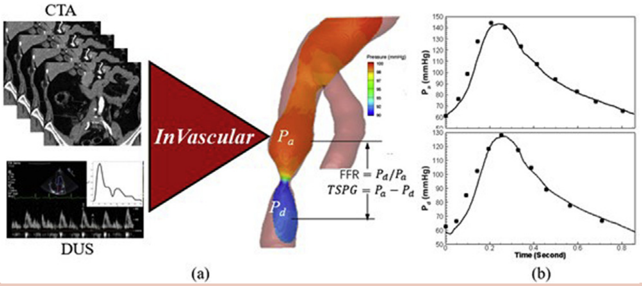

Fig. Calculated and measured pressures. *CTA*, Computed tomography angiography; *DUS*, Doppler ultrasound; *FFR*, fractional flow reserve; *TSPG*, trans-stenotic pressure gradient.

Table. Statistics

Variable	Mean pressure difference measured vs calculated	Standard deviation	*t* value	*P* value	Correlation coefficient	*P* value
Pressure systolic	5.10	7.36	2.19	.06	0.97	3.00E-6
Pressure diastolic	3.90	8.39	1.47	.18	0.66	.04
Mean arterial pressure	4.30	6.48	2.10	.07	0.92	1.75E-4

Table. Both paired sample *t*-test ($P > .05$) and Pearson correlation ($P < .05$) reveal the significant correlation between computed and measured pressures.

Conclusions: *InVascular* is a new and reliable means for noninvasive evaluation of in vivo pressure in stenosed aortoiliac arteries, from which *TSPG* can be obtained. With the outstanding feature of fast computation, *InVascular* will have an impact on the development of a new noninvasive gold standard to determine the true severity of iliac stenosis.

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Frailty Remains Highly Correlated With Mortality After Endovascular Aneurysm Repair In Octogenarians

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Objective: The elective treatment of asymptomatic abdominal aortic aneurysm must be balanced with individual life expectancy. Frailty can help estimate perioperative risk, but scales are heavily weighted by age of the patient. The objective of this study was to assess how frailty affects outcomes of those with advanced age (≥80 years) undergoing endovascular aneurysm repair (EVAR).

Methods: The Vascular Quality Initiative EVAR module was queried for all patients ≥80 years who underwent elective EVAR. A previously validated frailty model, the modified frailty index (mFI), was used to calculate a score for each patient. Scores were calculated both with and without age as a variable. Low-, moderate-, and high-risk groups were created on the basis of the 0 to 25th, 26th to 75th, and 76th to 99th percentile distributions of the score. Logistic and Cox proportional hazard models were built with mFI score as a continuous variable.

Results: Of 9780 patients ≥80 years undergoing elective EVAR, 8462 (87%) had sufficient data for the mFI to be calculated. There was no difference between groups in intraoperative complications or early reoperation. Among the low-, moderate-, and high-frailty groups, the rates of early postoperative complications (7%, 7.1%, and 10%; $P = .003$) and 30-day mortality (0.8%, 1.1%, and 2.7%; $P < .001$) were higher in the highest frailty group. One-year mortality increased from low (4%) to moderate (6.8%) and high (13.6%) across frailty groups ($P < .001$). A Cox proportional hazards model yielded a hazard ratio of 1.09 (95% confidence interval, 1.08-1.1). Kaplan-Meier survival curves are shown in Fig 1. When frailty scores were calculated without age, postoperative complications and mortality were unchanged between groups (Fig 2).

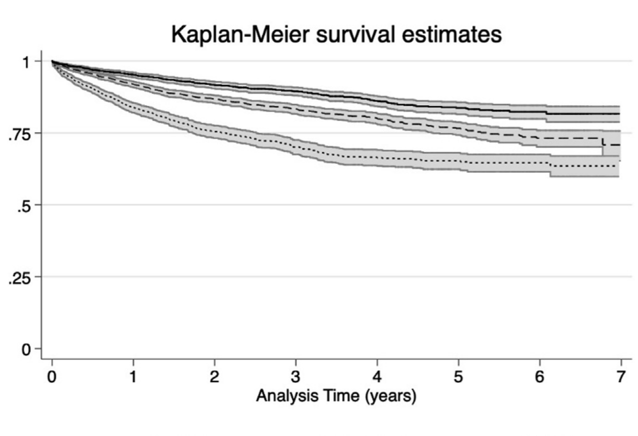

Fig 1. Survival curves with confidence intervals of low-, moderate-, and high-frailty octogenarians after endovascular aneurysm repair (EVAR) in the Vascular Quality Initiative registry.

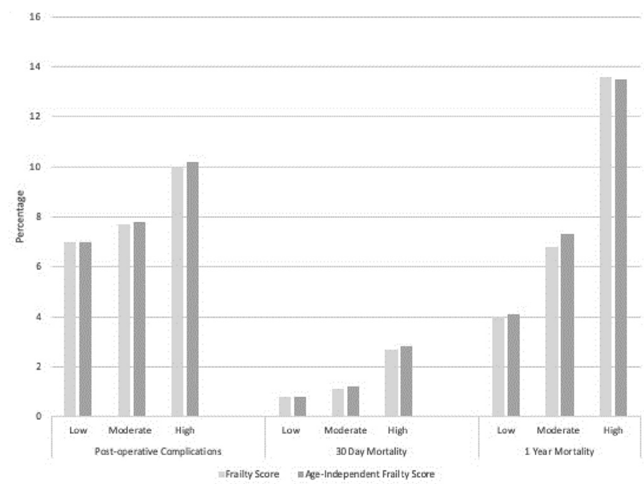

Fig 2. Outcomes after endovascular aneurysm repair (EVAR) by low-, moderate-, and high-frailty groups as calculated with and without age.

Conclusions: A validated, easily calculable frailty index is strongly associated with perioperative and 1-year mortality among patients ≥80 years undergoing EVAR. In low-frailty octogenarians, EVAR has low postoperative morbidity and mortality. Despite being the most heavily weighted component of the mFI, age adds little additional prognostic value past 80 years old.

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Outcomes of Catheter-Directed Thrombolysis of Autogenous Vein Bypass Versus Prosthetic Bypass for Acute Leg Ischemia

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Objective: Thrombolysis, when appropriate, is the first line of therapy for acute limb ischemia in patients with previous lower extremity bypasses. The long-term outcomes of vein vs prosthetic bypass after thrombolysis are not well known.

Methods: This is a retrospective chart review from 2006 to 2016 using *International Classification of Diseases, Ninth Revision* codes at Loyola University. Institutional Review Board approval was obtained. Clinical records and arteriograms of all patients who underwent catheter-directed thrombolytic therapy for occluded vein and prosthetic bypass grafts were examined. We collected demographics, comorbidities, type of graft