Preoperative Risk Assessment for Optimal TEVAR Outcomes

Evaluating which imaging, risk stratification, and system-specific options to consider before thoracic endovascular aortic repair.

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Thoracic endovascular aortic repair (TEVAR) is intended to reduce the operative morbidity and mortality associated with both thoracic aneurysm disease and dissection as compared with open procedures (Figure 1).[1] This minimally invasive approach also means that an increased number of patients are now suitable for treatment. Although randomized data comparing TEVAR to open repair are not currently available, the rapid expansion of available devices and experience has led to reasonable treatment outcomes, with some pioneering centers providing data out to 12 years of follow-up.[2]

Improved patient selection, thoracic stent graft innovation, and perioperative management have improved rates of spinal cord ischemia, stroke, myocardial infarction, and death.[3] However, preoperative assessment and investigation remain crucial components in improving the outcomes of endovascular thoracic aortic disease treatment.

Preoperative assessment before TEVAR is of particular interest. The rapid expansion of devices and associated technology means that the operating surgeon has options to treat different pathologies that can only be assessed with precise imaging and planning. Without this treatment, failure and long-term reintervention (15% within 2.75 years[4]) may pose further significant risk.

An increasing number of elderly patients with significant comorbidities and thoracic aneurysms are undergoing treatment, perhaps due to more frequent cross-sectional imaging and an understanding that there is now a treatment option for the "less fit" group. However, treatment of thoracic aortic pathologies in the elderly can be controversial, especially in octogenarians, who need careful assessment.[5,6] Despite positive 30-day mortality of 6.5% in this patient population, long-term survival is poor, with a median survival of 4.3 to 5.8 years posttreatment.[7-9] In contrast, patients who undergo acute treatments for aortic trauma or acute aortic syndrome, which are associated with worse initial outcomes, seem to fare better in the long term than compared with octogenarians, perhaps due to fewer comorbidities and their younger age.[7,8]

This article outlines preoperative assessment strategies necessary to help clinicians decide the correct strategy for repair, stratify risk to make decisions on when and

Figure 1. Thoracic endovascular aortic stent deployed in the aortic arch.

whom to treat, and preoperative optimization to ensure best outcomes.

IMAGING

Preoperative planning for stent sizing and deployment position requires high-resolution CTA at 1-mm slices or less from the supra-aortic vessels to the common femoral arteries. Careful planning using multiplanar and three-dimensional reconstruction is a minimum requirement for accurate assessment of treatment options depending on pathology and stent graft landing zones. Use of dedicated software, such as Aquarius Intuition (TeraRecon), EndoSize (Therenva), or 3mensio (Pie Medical Imaging), allows straight and curved centerline reconstruction, with precise measurements of length and angulation.

Accurate and contemporaneous imaging allows for careful planning. Aneurysm size and/or indication for treatment, proximal and distal landing zone angulation, length, and quality, as well as access vessel stenoses and tortuosity, all require formal assessment. The clinician must then assess whether endovascular or open repair is the correct treatment and whether the risk of treatment now outweighs the risks of continued surveillance and ensure that the correct device is selected. The operating surgeon must also be mindful of the operative risk to the patient and the long-term durability of any graft.

GENERALIZED PREOPERATIVE RISK STRATIFICATION

Cardiopulmonary Exercise Testing

Cardiopulmonary exercise testing (CPET) is an effective method for overall risk assessment. In the United Kingdom, 82% of health care centers formally measure patients' preoperative fitness before elective infrarenal abdominal aortic aneurysm repair, most often with CPET.[10] CPET has been extensively investigated for many surgical specialties, including infrarenal aortic aneurysm treatment, because it offers the most appropriate evaluation of actual cardiopulmonary function.[11] Barakat et al found a 5.5% rate of pulmonary complications and a 5.5% rate of cardiac complications after EVAR (compared with 28% and 20%; $P = .001$ and $P = .018$, respectively, after open repair).[11] The study found two significant variables affecting cardiac complications: open repair (odds ratio [OR], 6.99; $P = .011$) and anaerobic threshold (OR, 0.55; $P = .005$). They also found two significant variables for pulmonary complications: open repair (OR, 14.29; $P < .001$) and ventilator equivalent for carbon dioxide (OR, 1.18; $P = .005$). This study suggests that anaerobic threshold and ventilator equivalent for carbon dioxide may be useful in risk stratifying patients before treatment and confirms previous research, which suggests that complications can be predicted by an anaerobic threshold of 10.1 mL/min/kg.[12] Pulmonary, renal, gastrointestinal, infective, cardiovascular, hematologic, and pain complications were significantly greater with a lower anaerobic threshold.

This information is advantageous in the postoperative setting, primarily as it allows for perioperative and discharge planning. It also allows for detailed discussions with patients so that they are adequately made aware of possible complications and can provide informed consent.

Frailty

With the advancing age of the population and the pathology-delaying effects of smoking cessation and statin therapy, frailty is becoming a vital component of assessing patients for vascular surgery. Many different frailty index scores are available; however, none have been examined in the context of TEVAR. A retrospective study of 107 patients undergoing lower limb bypass showed that the Barthel index (a frailty measure designed for stroke patients) and body mass index can risk stratify patients in terms of mortality. Research on aortic valve replacement found that frailty scores can predict mortality and length of hospital stay.[13]

It is reasonable to assume that CPET testing and frailty assessment are useful in stratifying the risk for patients undergoing TEVAR. There is an advantage to understanding the risk/benefit ratio for prophylactic aneurysm repair and as a screening test for those who require more extensive investigation. In addition, there may be some advantage in selecting those who may be best served with a prehabilitation program, such as those undergoing vascular surgery.[14] However, for many patients, a more specific preoperative risk assessment is necessary to reduce operative complications and ensure long-term survival.

SYSTEM-SPECIFIC INVESTIGATION

Investigation of specific systems may further refine the operative risk and has the advantage of defining treatments that may optimize the results of TEVAR and improve long-term morbidity and mortality.

Cardiac Investigation

The American College of Cardiology/American Heart Association guidelines[15] suggest that anyone with an exercise tolerance of four metabolic equivalents (METs) or more needs no further investigation for noncardiac surgery, based on data from McFalls et al.[16] Four METs equates to leisure cycling at < 10 mph, moderate-effort gardening, or slow stair climbing.[17] Ascertaining that patients are able to achieve four METs is dependent on patients giving accurate histories and limited exercise capabilities of this cohort of

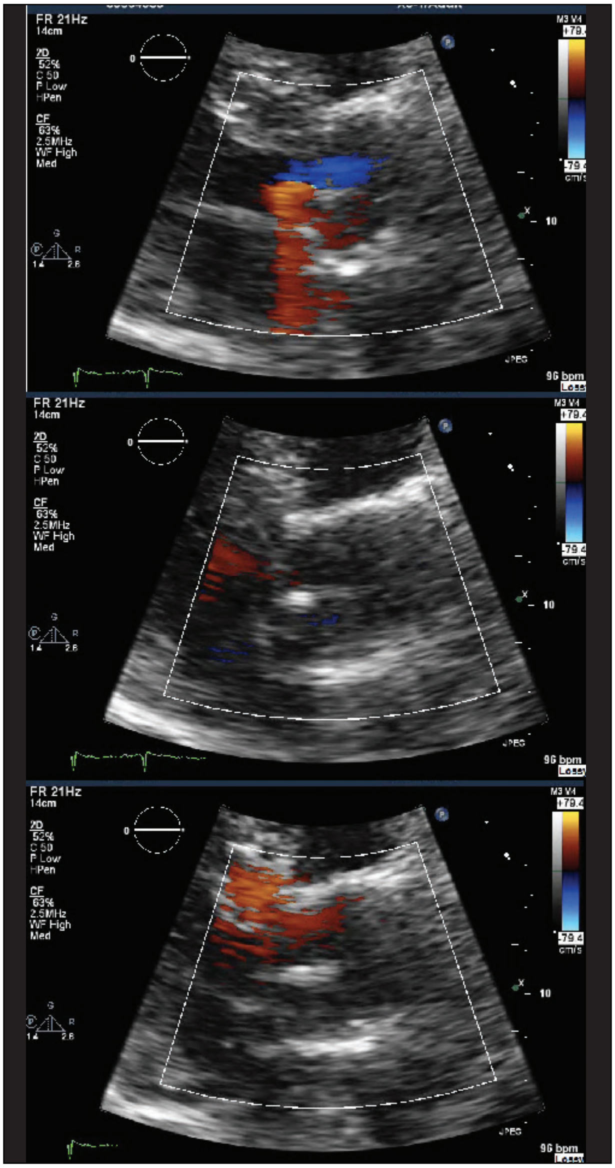
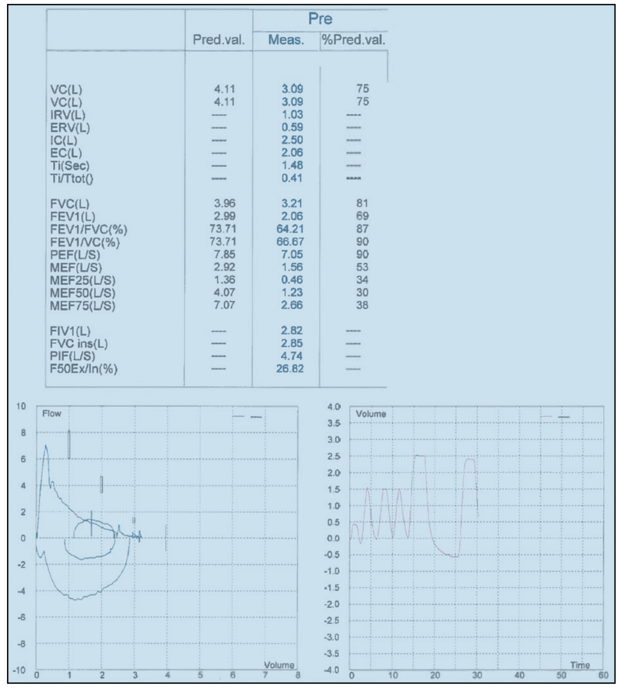


Figure 2. Representative images of a dobutamine stress echocardiogram.



		Pre	
	Pred.val.	Meas.	%Pred.val.
VC(L)	4.11	3.09	75
VC(L)	4.11	3.09	75
IRV(L)	----	1.03	----
ERV(L)	----	0.59	----
IC(L)	----	2.50	----
EC(L)	----	2.06	----
Ti(Sec)	----	1.48	----
Ti/Ttot()	----	0.41	----
FVC(L)	3.96	3.21	81
FEV1(L)	2.99	2.06	69
FEV1/FVC(%)	73.71	64.21	87
FEV1/VC(%)	73.71	66.67	90
PEF(L/S)	7.85	7.05	90
MEF(L/S)	2.92	1.56	53
MEF25(L/S)	1.36	0.46	34
MEF50(L/S)	4.07	1.23	30
MEF75(L/S)	7.07	2.66	38
FIV1(L)	----	2.82	----
FVC ins(L)	----	2.85	----
PIF(L/S)	----	4.74	----
F50Ex/In(%)	----	26.82	----

Figure 3. Example output of pulmonary function tests.

patients with vascular disease. Therefore, many centers, including our own, investigate more intensely with specific assessment.

A recent study by Ganapathi et al suggests that electrocardiography and transthoracic echocardiography are sufficient for TEVAR workup. Although this study reported an overall cardiac event rate of 2.4% and cardiac death rate of 0.8%, none occurred in the high-risk groups undergoing more intensive cardiac investigation.[18] All of the cardiac events occurred in those with normal resting electrocardiograms and transthoracic echocardiograms. All of the deaths (all-cause mortality at 30 days, 5.5%) occurred in these patients, suggesting the study criteria for investigation may have missed those warranting further testing. A dobutamine stress echocardiogram will identify areas of inducible ischemia in addition to valvular dysfunction and ejection fractions (Figure 2).

In our practice, those with two or more segments of inducible ischemia or those deemed higher risk undergo formal coronary angiography and treatment of high-risk lesions. Although the risk during TEVAR may be significantly reduced, Bub et al described a study of 345 patients undergoing complex aortic repair with a cardiac event rate of 17%, overall mortality of 6.3%, and cardiac death rate of 2%.[19] Forty-seven percent of those who had a cardiac event showed normal cardiac stress testing results.

Pulmonary Function Tests

Respiratory complications after open aortic surgery are well known, with rates of up to 25% after abdominal aortic surgery reported.[20] Chronic obstructive pulmonary disease is an understandable and accepted risk factor in the development of such complications.[20] The benefit of spirometry and pulmonary function testing (Figure 3) is clear in cardiothoracic surgery and open abdominal aortic surgery. Abdominal surgery, such as aneurysm repair, confers a higher risk of pulmonary complications, and spirometry before surgery can allow for risk stratification, with a forced expiratory volume in 1 second being most significant. However, the evidence for TEVAR is less clear.

During planning, it is crucial to select between open and endovascular options to determine which population may not benefit from TEVAR and for the choice of anesthesia.

The logistics of the TEVAR approach can be detrimental to respiratory function, particularly in patients whose respiratory pathology leaves them toeing a tight line. Lying flat for a prolonged period, which may be several hours in complex cases, worsens basal atelectasis and increases already existing ventilation-perfusion mismatch. In those undergoing TEVAR, good chest physiotherapy and breathing exercises have been shown to improve postoperative pneumonia rates and should be used as a standard bundle of care.[21]

General anesthetic is a known contributory factor to postoperative pulmonary complications, possibly due to a decreased functional residual capacity and the risk of ventilation trauma in these patients. However, the benefit of neuroaxial blockade has not been clearly shown.[21] Indeed, it could be argued that good ventilation strategies with positive end expiratory pressure may reduce basal alveolar collapses and thereby potentially negate the need for noninvasive respiratory therapy in the postoperative period.

There is also a growing body of evidence of the use of Optiflow nasal high-flow cannula oxygenation (Fisher & Paykel Healthcare) in patients with concomitant respiratory disease. It has been used in a variety of ways both in the preoperative preinduction oxygenation optimization and in the postoperative period in critical care to reduce the incidence of reintubation.[22] The evidence mostly comes from usage in neonatal and pediatric care. It is well established that high-flow, adequately heated, humidified oxygen flow reduces anatomical dead space, provides some positive end expiratory pressure (although lower than in closed circuit devices such as noninvasive ventilation), and seems to be adequate to increase lung volume or recruit collapsed alveoli. It also seems to provide a much more consistent oxygen F_{IO_2} than other low-flow delivery aids and is well tolerated with little discomfort and preservation of mucociliary function. However, there is the concern that the indications, timing, and escalation of its use still need to be clarified.[23]

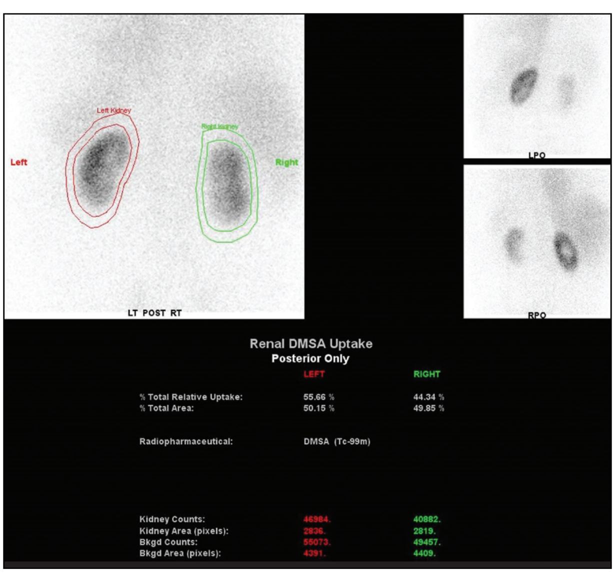


Figure 4. Example split renal function assessment using dimercaptosuccinic acid nuclear imaging study.

In our practice, those with significant respiratory disease are assessed by a respiratory specialist, with subsequent optimization of inhaled or nebulized medications, consideration of pre- and postoperative use of continuous positive airway pressure, preoperative training (prehabilitation), and provisions made for postoperative intensive respiratory management.

Renal Function

Routine preoperative blood tests of renal function assessment with calculation of the glomerular filtration rate allow general assessment of function. On its own, there is a vital preoperative marker of risk in open surgery[22]; however, in TEVAR the relationship has not been shown. Furthermore, renal assessment is necessary if complex pathology may lead to the sacrifice of a part of or a whole kidney, in which case split function assessment with dimercaptosuccinic acid or mercaptoacetyltriglycine nuclear medicine imaging is indicated (Figure 4).

Poor results may significantly reduce the complexity of the planned repair and again inform patients of their potential risks of future renal failure. Stent options for treatment of aortic disease, particularly in complex configurations, come with the additional consideration of the need for intraoperative use of iodinated contrast, which is known to be highly nephrotoxic. Patients with chronic kidney disease may therefore develop acute-on-chronic renal failure in the postoperative period and may require a period of hemofiltration in a level 3 facility. Knowledge of this potential outcome can lead to lower contrast use techniques or decisions to perform open surgery instead.

Risk Scores

Two risk scores have been developed from the American College of Surgeons National Surgical Quality Improvement Program database. The Assessment of Thoracic Endografting Operative Mortality risk score assigns a score of 0 to 30 based on 10 variables, with low risk (< 5), moderate risk (5–9), and high risk (> 10); the risk group 30-day mortality was 1.3%, 6.6%, and 24%, respectively.[24] The risk score developed by Hu et al assigns a score of 0 to 6 based on the number of risk factors present, which offers a simpler proposition for clinicians.[25] Scores of 0 to 6 produced expected 30-day mortality rates of 1.33% to 38.49%. Although academically robust, these risk scores are not widely used clinically because they do not fully consider crucial factors such as the complexity of repair, likely long-term benefit to the patient, and patient preference.

CONCLUSION

TEVAR offers a treatment option for thoracic artery disease with low morbidity and mortality, but with an increasing number of available options and an increase in patients who were previously not fit for open repair undergoing surgery, there is a need for accurate preoperative assessment to guide surgical decisions, stratify operative risk, and attempt to ensure longer-term survival. Imaging, overall risk, and specific measures of risk and scoring systems all have their role in determining the best treatment option and defining strategies for improved short- and long-term results for TEVAR.

In our practice, careful patient selection is undertaken using a combination of high-resolution CT imaging and specific preoperative investigation. Patients who are young and fit on preoperative investigation with or without a proven connective tissue disease may be offered open repair. In those with significant comorbidity, TEVAR may be offered, but the complexity of an endovascular repair must be taken into consideration, and continued surveillance may be appropriate if the risk with TEVAR is high. For those considered for TEVAR, general risk assessment allows formal consent and may prompt presurgical training (prehabilitation). System-specific preassessment allows optimization of cardiac and respiratory disease to reduce the risks of surgery and may reduce long-term mortality from associated disease after TEVAR. A structured preassessment service is necessary to achieve these goals in a timely and cost-effective fashion. ■

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