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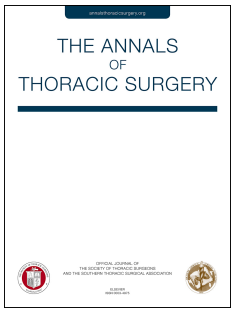

When to Consider Deferral of Surgery in Acute Type A Aortic Dissection: A Review

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PII: S0003-4975(20)31425-9

DOI: https://doi.org/10.1016/j.athoracsur.2020.08.002

Reference: ATS 34200

To appear in: *The Annals of Thoracic Surgery*

Received Date: 2 May 2020

Revised Date: 13 July 2020

Accepted Date: 3 August 2020

Please cite this article as: Sabe AA, Percy E, Kaneko T, Plichta RP, Hughes GC, When to Consider Deferral of Surgery in Acute Type A Aortic Dissection: A Review, *The Annals of Thoracic Surgery* (2020), doi: https://doi.org/10.1016/j.athoracsur.2020.08.002.

When to Consider Deferral of Surgery in Acute Type A Aortic Dissection: A Review

Running Head: Surgical Timing in Type A Dissection

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Word Count: 6810

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Abstract (250/250 words)

Background: Acute type A aortic dissection (ATAAD) is a surgical emergency with an operative mortality of up to 30%, a rate which has not changed meaningfully in over two decades. A growing body of research has highlighted several comorbidities and presenting factors in which delay or permanent deferral of surgery may be considered; however, modern comprehensive summative reviews are lacking. The urgency and timing of this review are underscored by significant challenges in resource utilization posed by the COVID-19 pandemic. This review provides an update on the current understanding of risk assessment, surgical candidacy, and operative timing in patients with ATAAD.

Methods: A literature search was conducted through PubMed and Embase databases to identify relevant studies relating to risk assessment in ATAAD. Articles were selected via group consensus based on quality and relevance.

Results: Several patient factors have been identified which increase risk in ATAAD repair. In particular, frailty, advanced age, prior cardiac surgery, and use of novel anticoagulant medications have been studied. The understanding of malperfusion syndromes has also expanded significantly, including recommendations for surgical delay. Finally, approaches to triage have been significantly influenced by resource limitations related to the ongoing COVID-19 pandemic. While medical management remains a reasonable option in carefully selected patients at prohibitive risk for open surgery, endovascular therapies for treatment of ATAAD are rapidly evolving.

Conclusions: Early surgical repair remains the preferred treatment for most patients with ATAAD, however, improvements in risk stratification should guide appropriate delay or permanent deferral of surgery in select individuals.

Glossary of Abbreviations

ATAAD – Acute Type A Aortic Dissection

CM – Cerebral Malperfusion

DOACs – Direct Oral Anticoagulants

FEIBA – Factor Eight Inhibitor Bypass Activity

IRAD – International Registry of Acute Aortic Dissection

MPS – Malperfusion Syndrome

NOACs – Novel/non-Vitamin K Oral Anticoagulants

PETTICOAT – Provisional Extension to Induce Complete Attachment

STS – Society of Thoracic Surgeons

TEVAR – Thoracic Endovascular Aortic Repair

Acute type A aortic dissection (ATAAD) is a surgical emergency, with a mortality rate of up to 90% in patients who do not receive timely operative intervention.[1–3] Despite significant advances in imaging, perioperative care, and surgical technique, operative mortality rates have remained relatively unchanged between 10% and 30% over the past 2 decades (**Figure 1**).[4–6] Given this relative stagnation in rates of morbidity and mortality associated with ATAAD repair, recent studies have focused on the identification of factors important for risk stratification in this population. Furthermore, new options for endovascular management have emerged and are evolving to become efficacious treatment options for carefully selected individuals with ATAAD.[7] Finally, in the era of the COVID-19 pandemic, traditional algorithms for the treatment of surgical emergencies must be carefully challenged and re-examined with a focus on minimizing infectious spread, and timely and appropriate resource allocation.[8] The aim of this review is to provide a commentary on contemporary approaches to the identification of high-risk features in ATAAD, and when delay, permanent deferral of surgical treatment, or transfer to a specialized center may be considered (**Table 1**).

Methods

Articles discussed in this narrative review were identified through a literature search of English language articles in PubMed (1946-present) and Embase (1974-present), last updated April 25, 2020. The search strategy focused on the identification of articles studying contemporary factors influencing outcomes of ATAAD repair: frailty, age, malperfusion, malperfusion syndrome, prior cardiac surgery, anticoagulant medications, and risk stratification tools. Additionally, current articles regarding the ongoing COVID-19 pandemic were identified through additional search of in-press articles in relevant surgical and cardiothoracic surgical journals. Articles were selected by the authors based on quality and relevance.

Frailty and Advanced Age

Frailty is a multidimensional syndrome involving loss of reserve across multiple systems, leading to increased vulnerability.[9] Although several scoring systems and measurement tools have been developed, assessing frailty in the setting of ATAAD remains a significant challenge given the typically emergent presentation. Consequently, research on the effects of frailty in ATAAD is limited. Nonetheless, frailty assessment in elective proximal aortic surgery has proven useful in the prediction of mortality and discharge disposition.[10,11] In patients presenting with ATAAD who are at risk for frailty, it remains important to evaluate global functional status, activities of daily living, and comorbid conditions. Several comorbidities, including cerebrovascular disease and severe chronic lung disease, have been shown to be independent predictors for 30-day mortality after ATAAD repair and these risks are likely exacerbated in the presence of frailty.[12,13]

In the absence of validated frailty tools in this patient group, advanced age is often considered as a surrogate. Importantly, there is likely to be a significant increase in the number of elderly patients presenting with acute aortic syndromes, in light of the aging population.[14] While many elderly patients do have significant functional limitations, there is not convincing evidence for a "hard" age cut-off with respect to surgery for ATAAD. In fact, several groups have found good short-term outcomes in healthy octogenarians.[15,16] It is important to note, however, that prior work has suggested that long-term survival in elderly patients may not be improved compared to those managed medically (**Figure 2**).[17] In elderly individuals with comorbidities or decreased functional status, medical management is a very reasonable course of action. Open and honest communication of both short- and long-term outcomes, along with discussions of goals of care, are very important in this patient group.

Malperfusion and Malperfusion Syndromes

Malperfusion occurs in 16% to 33% of patients presenting with ATAAD.[1] The presence of clinically apparent malperfusion in any organ system at presentation is an ominous sign, which is associated with increased mortality.[18] For example, Lawton et al. demonstrated that patients with malperfusion and severe acidosis had an operative mortality of 92%.[19]

The distinction between malperfusion and malperfusion syndrome (MPS) is critically important in the optimization of treatment and operative planning. Malperfusion alone has been defined as "*inadequate blood flow to the end organs because of dissection related obstruction of the aorta and its branches",* whereas MPS is defined as *"tissue necrosis and failure of vital organs (such as viscera or lower extremity) secondary to late-stage malperfusion".*[20,21] As such, the diagnosis of MPS requires the presence of both clinical features (e.g.: abdominal pain, tenderness, oliguria or anuria, motor or sensory neurovascular deficits) and laboratory features (e.g.: elevated lactate, serum creatinine, liver or pancreatic enzymes, creatinine kinase) indicative of end-organ ischemia.

The presence of MPS indicates active end-organ ischemia and can itself lead to significant exacerbation of the inflammatory cascade, further complicating management in these individuals. Mesenteric MPS is of particular concern, with a reported mortality rate of 60% or higher in multiple series. Even with early intervention, the mortality rate in these patients is still up to 42%.[22] In light of this, many groups have adopted treatment algorithms which delay operative repair of the proximal aorta in the setting of MPS.

The University of Michigan group was first to describe a novel strategy of operative delay for the treatment of MPS in ATAAD. Their initial landmark study compared the traditional standard of care approach of immediate proximal aortic repair with a cohort managed with initial percutaneous intervention restoring true lumen flow, followed by delayed operative ATAAD repair after resolution of malperfusion injury.[20] The mortality rate in the historic cohort treated with immediate aortic repair was 89% compared to only 25% in the group managed with delayed repair after restoring end-organ perfusion (P=0.003). In the years since this initial

series, their group has consistently shown the benefits of this strategy and have demonstrated a 95% success rate in treating malperfused vascular beds percutaneously.[23] More current techniques, involving the use of thoracic endovascular aortic repair (TEVAR) as the initial step for restoration of flow in MPS, have been successful in comparison to prior fenestration-based strategies.[24,25] Additionally, the PETTICOAT (Provisional Extension To Induce Complete Attachment) technique has also been considered in ATAAD as a means of correcting malperfusion, although this technique requires further study.[26,27] A standardized algorithm has been developed to summarize the approach in those without aortic rupture or tamponade (**Figure 3**).[28]

Importantly, the safety of various time periods for surgical delay in these patients has not been definitely shown. However, important patterns can be inferred from previous research on the timing of surgical repair. In 2013, Booher et al. used the International Registry of Acute Aortic Dissection (IRAD) database to examine a novel classification system for dissection timing.[29] After controlling for delays to initial presentation, they found that longer delays to operative repair were associated with lower follow-up mortality. In this context, their data suggests that patients with MPS who may not initially be surgical candidates but do survive initial MPS management may have favorable surgical outcomes if repair is undertaken in a delayed fashion. In some patients, this may even include delaying repair to the chronic setting in the event that their recovery from MPS is prolonged.

In summary, MPS carries a high risk of morbidity and mortality. Careful workup and patient selection are important in determining optimal procedural approaches to ATAAD repair in these individuals. Operative patients presenting with ATAAD and radiographic concern for malperfusion, but without clear evidence of resultant end-organ dysfunction, are still best treated with the immediate ATAAD repair. In patients with MPS who are otherwise operative candidates, delayed repair of the ATAAD is recommended after reversing clinically apparent mesenteric or limb MPS in centers with adequate and timely access to these techniques.

Otherwise, in patients with MPS and no evidence of tamponade, transfer to an institution with these capabilities may be the best approach.[30]

Cerebral Malperfusion

Patients with cerebral malperfusion (CM) represent a unique subset in which treatment decisions are particularly challenging. CM occurs in 7% to 15% of ATAAD and is associated with short term mortality as high as 50% as well as poor long-term survival.[31–33] A study from the IRAD database found that patients with CM who underwent surgery for ATAAD had a higher incidence of postoperative cerebrovascular accident (17.5% vs. 7.2%, $p < 0.001$) and in-hospital mortality (25.7% vs. 12%, $p < 0.001$) than those without CM undergoing surgery.[34] Hemorrhagic conversion of an ischemic insult during systemic anticoagulation for cardiopulmonary bypass is a significant concern, which complicates decisions regarding immediate or delayed operative management.[35,36]

Despite the morbidity of CM in the setting of ATAAD, several studies have demonstrated that early intervention in these individuals can result in improved mortality and significant neurologic recovery.[37–39] In one study by Di Eusanio et al. utilizing data from IRAD, 84% of patients with stroke and 79% of patients presenting with coma had reversal of brain injury after surgery.[31] Additionally, a recent multicenter study found that 62% of patients with preoperative neurologic deficit had no to moderate postoperative deficits. Notably, patient age (odds ratio 1.041; $P = 0.02$) and history of prior stroke (odds ratio 2.651; $P = 0.03$) were predictive of poor clinical outcome; however, presenting with coma was not. Hemorrhagic conversion occurred in only 7 (5%) patients and no independent predictors of this complication were identified.[40]

Patients with ATAAD and CM who undergo surgery should be carefully selected by an experienced multidisciplinary team based on age, frailty, comorbidities, hemodynamic stability, and extent of other malperfusion syndromes. Preoperative cerebral imaging can aid prognostication, as demonstration of a large infarct or occluded internal carotid artery may

predict a worse neurologic outcome.[40] When experienced clinical evaluation otherwise portends a favorable prognosis, early surgery may be performed with reasonable rates of survival and reversal of cerebral ischemia, including patients presenting with coma. Ultimately, this is an evolving realm and given recent data, including case reports describing advances in percutaneous intervention prior to surgery, decisions should be considered on a case-by-case basis.[40,41]

Prior Cardiac Surgery

Sternal re-entry in patients with prior cardiac surgery poses technical challenges associated with mediastinal adhesions, increased bleeding, as well as the risk of injury to existing bypass grafts if the prior operation included coronary bypass grafting.[42] While there were previous thoughts that fibrotic scarring from prior surgery would provide some protection from tamponade and rupture in ATAAD, this has not consistently proven to be the case in larger database studies.[43]

Several studies have examined the outcomes of patients with prior cardiac surgery undergoing repair of ATAAD. One such study found no significant difference in 30-day morbidity or mortality in 50 patients who had previous cardiac surgery as compared to those from the same era without prior surgery.[44] In contrast, in a recent much larger study utilizing the Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database from 2002-2017, ATAAD repair in patients with prior cardiac surgery was associated with a greater than 2-fold higher risk of mortality compared to those without prior cardiac surgery (odds ratio 2.1; $p< 0.01$).[45] There was a trend towards decreased operative mortality for patients with prior cardiac surgery undergoing ATAAD repair at high-volume centers (25.7% vs. 37.9%, $p = 0.19$). In summary, the currently available evidence suggests that patients with ATAAD and prior cardiac surgery

require careful deliberation, adequate pre-operative planning and potential consideration for transfer to high-volume centers.

Novel/Non-Vitamin K Oral Anticoagulants

The use of novel/non-vitamin K oral anticoagulants (NOACs), also termed direct oral anticoagulants (DOACs), has increased dramatically over the past decade.[46] Given the absence of reliable reversal agents for several of these medications, they can present significant risks to patients requiring emergent cardiovascular surgery. Studies of their use related to ATAAD are limited to small single center experiences or case reports. While adequate reversal of anticoagulation has been achieved in several cases, outcomes in general remain variable and high-quality data is lacking.[47] In 2018, Hamad et al. did report two successful cases of urgent reversal confirmed by thromboelastometry monitoring in patients on rivaroxaban and dabigatran, whose procedures were delayed by 60 hours and 40 hours, respectively.[48]

Antidotes for specific NOACs have been approved in recent years. Specifically, idarucizumab has been approved as a reversal agent for dabigatran, and andexenat alfa is approved as a reversal agent for rivaroxaban and apixaban.[49] Idarucizumab, a monoclonal antibody fragment, has been given prior to heart transplant with useful effect in a small case series.[50] Andexanet alfa acts as a factor Xa decoy, thus significantly reducing (but not eliminating) anticoagulant activity by binding and sequestering apixaban and rivaroxaban. Its use in the setting of emergent cardiac surgery, particularly with cardiopulmonary bypass, has been described in case reports but requires further investigation.[51] It is important to note that andexanet alfa reverses factor Xa inhibitor levels for ~2-3 hours, after which levels return to baseline.[52]

We recommend a multimodal approach in select patients requiring emergent surgery for ATAAD on NOACs. Patient comorbidities and planned extent of operation should be carefully considered, as should other known risk factors for bleeding in proximal aortic repair.[53]

Depending on institutional capability, initial options include delayed surgical repair until half-life clearance of the agent, global coagulation assay, thromboelastometry assays, or preferably direct measurements of anti-factor Xa levels. Post cardiopulmonary bypass options to treat coagulopathy include use of antifibrinolytics, standard blood products such as platelets, fresh frozen plasma, and cryoprecipitate, as well as recombinant factors such as prothrombin complex concentrate, activated factor VIIa, human fibrinogen concentrate, and thoughtful administration of anti-Xa antidotes.[54,55]

Patient-Centered Decisions

Patient-centered decision making is of utmost importance in ATAAD, given the high-risk nature of this condition. Providers must have open and thoughtful discussion of risks and benefits of all available options, including medical management. Discussions around the use of blood products and overall goals of care are paramount in a patient-centered decision-making process.

Patients Who Refuse Blood Products

In rare cases, patients may wish to avoid transfusion of blood products for personal or religious reasons. Favorable outcomes have been demonstrated in studies of Jehovah's Witness patients undergoing elective cardiac surgery with appropriate preoperative planning.[56,57] However, in the setting of ATAAD, which is associated with a high rate of transfusion, the reluctance to receive blood products poses potentially lethal challenges in perioperative management.[33] In select patients, delaying surgery to allow clear counseling on the risks of refusing transfusion may be necessary to obtain informed consent and optimize patient outcomes.

Importantly, one must not assume that any individual will uniformly refuse transfusion of any products until properly counseled on the available choices. Furthermore, treatment with

purified proteins derived from plasma is acceptable to many patients.[58] Options which may be acceptable to patients include treatment with albumin, activated factor VIIa, factor eight inhibitor bypass activity (FEIBA), prothrombin complex concentrate, and human fibrinogen concentrate.[59] Consideration should be given to limiting the scope of the operation with avoidance of prolonged cardiopulmonary bypass times and deep cooling, strict attention to surgical hemostasis, liberal use of recombinant hemostatic factors to facilitate clotting, and vigilant postoperative blood pressure control with early return to the operating room for surgical control of bleeding.[60] Finally, initial medical management for stabilization and correction of the acute inflammatory cascade, followed by delayed surgical repair may be appropriate in some individuals.[61]

Consideration for Goals of Care

Whether operative or non-operative management is planned in patients with ATAAD, the patient and their family should be clearly counseled on "best-case/worst-case" scenarios and clear goals-of-care discussions should be undertaken. In a recent Veteran's Administration study evaluating 95,204 patients who underwent high-risk surgery, only 770 (0.8%) received a palliative care consultation before surgery.[62] Of all the patients who died within 90 days, 29.9% had received a palliative care consultation, with 5.6% having received consultation before surgery. Families of these patients reported an overall significant increase in satisfaction with end-of-life care, communication and support. While challenging in the acute care setting, goals of care should always be carefully considered for those presenting with ATAAD.

Triage Decisions in the Era of COVID-19

In addition to patient-level factors, the ongoing COVID-19 pandemic has highlighted how external forces and hospital resources can influence treatment decisions in patients undergoing complex procedures. As of July 11th, 2020 there were over 12.6 million confirmed cases worldwide, placing an immense strain on healthcare systems around the globe.[63] Additionally,

there has been evidence of significant decreases in the volume of patients presenting with acute dissection. In New York, El-Hamamsy et al. reported a 76.5% decrease in expected volume, raising concerns that patients may not be seeking timely care and the potential for increases in complex delayed presentations.[64]

In the setting of acute pathology such as ATAAD, this pandemic has introduced an additional layer of complexity with regard to operative decision making. In particular, increasingly limited intensive care resources, redeployment of cardiovascular team members, and limitations on inpatient space have reduced the availability of several key elements required to perform resource intensive ATAAD repair. Formal triage committees are being established in some jurisdictions to aid with challenging decisions regarding scarce resource distribution.[65] Recently, the STS COVID-19 Taskforce released a guidance statement which considers four levels of tiered case triage based on the impact of COVID-19 on hospital-wide resources.[66] In the most extreme fourth tier, emergent conditions such as ATAAD are still performed according to resource availability; however, those patients who are considered stable and capable of waiting are deferred until adequate resources can be ensured. In cases of ATAAD in a resource limited setting, transfer of hemodynamically stable individuals to hospitals with greater immediate capacity may be necessary. In an effort to help surgeons estimate and plan for resource allocation, the STS has also launched a “Resource Utilization Tool” (https://www.sts.org/resources/resource-utilization-tool). This application allows surgeons to estimate operative time, ventilator time, length of stay and other factors. These systems will be critically important for decisions regarding allocation of limited hospital resources.

Each health system and hospital will face varying pressures throughout this pandemic and will need to make difficult decisions regarding their ability to allocate resources and perform complex procedures.[67] Currently, at both Brigham and Women’s Hospital and Duke University Medical Center, patients needing urgent surgery, including ATAAD, are screened for symptoms

or exposure to COVID-19, and a rapid (15-45 minute) COVID-19 test is sent upon admission to the hospital. Barring any systemic resource availability concerns, the patient is taken without delay to the operating room and the entire perioperative staff provided with protective personal equipment including N-95 masks and face shields until the test results are available, which typically will result before a skin incision is made. Importantly, there should be no COVID-related delay of transport to the operating room for otherwise operable ATAAD patients.

Operative decision making must remain fluid in response to the constant changes induced by the current pandemic. In patients with ATAAD and complications such as tamponade or coronary ischemia, emergency repair remains the best available option. In patients with more stable presentations, as outlined above, surgeons may consider permanent deferral of surgery or temporary delay until adequate resource planning can be managed. Further, for the ATAAD patient who tests positive for COVID-19, the decision about whether or not to proceed with emergent surgery adds an additional layer of complexity to medical decision making. Reports of ATAAD repair in patients with COVID-19 are scarce, limiting the delineation of any broad conclusions.[68, 69] However, published outcomes of other cardiothoracic procedures in patients with COVID-19 are bleak and highlight the extremely challenging decision-making process around best practice during this unprecedented pandemic.[70]

Current Status of Alternate Strategies

While aortic valve re-suspension with supracoronary ascending aorta and hemiarch replacement with circulatory arrest remains the gold standard approach in the majority of patients with ATAAD, other surgical options exist and may be of use in patients who cannot tolerate lengthy complex procedures. Replacement of the ascending aorta alone, without extension to hemiarch or total arch, has been studied previously. While this procedure is associated with higher 30-day mortality[13], it has been employed in select individuals in whom

there may be advantages to avoiding an open distal repair with circulatory arrest. Furthermore, while total arch replacement has been preferred in some high-volume centers for patients with arch vessel involvement, a more conservative approach may suffice in many scenarios.[71]

In patients who are not surgical candidates, medical management has traditionally been the only alternate strategy available; however, interventional catheter-based options have emerged over the past decade and may be of use in select individuals. Off-label and investigational applications of TEVAR in the ascending aorta have been applied to treat ATAAD. Despite being a higher risk patient population, small studies have demonstrated technical success, early mortality rates below 15%, and relatively low aorta-related mortality rates in the long-term.[72–74] Much more research and technological innovation is required before endovascular repair can be considered for widespread use. However, there is promise for these techniques in patients at prohibitive risk for traditional ATAAD repair.

Finally, medical management remains an option for a significant proportion of patients with ATAAD who are not surgical candidates. Recent data from the IRAD database demonstrates that definitive medical management may be a reasonable option in certain high-risk patients, with 30-day survival rates of nearly 40% with medical management alone.[75] Predictors of success with medical management in ATAAD included prior cardiac surgery, normal admission chest x-ray, presenting hypertension, non-white race and most proximal dissection extent limited to the ascending aorta without root involvement (**Figure 4**).[75]

Risk Stratification Tools

Considering the complex and high-risk presentations associated with ATAAD, risk-stratification tools have been developed. The most well validated of these tools is the “Penn Classification”, which stratifies patients according to ischemic malperfusion pattern.[76] Specifically, this system stratifies risk according to the presence or absence of branch-vessel malperfusion, circulatory collapse, or both. While the Penn Classification has performed well in

validation studies, its clinical application remains challenging due to the broad range of presentations in patients with ATAAD. Another clinically-based tool, developed from the IRAD database, incorporates pre- and intra-operative variables to yield a simple risk model with very good utility in predicting death in ATAAD.[77]

These scoring systems have utility in their ability to offer rapid estimates of operative mortality, however, they should be used with caution and careful clinical correlation. Specifically, none of the current tools take into account frailty, the presence of other comorbidities, or the complexity of the required repair. A detailed assessment of all factors by an experienced clinical team, along with open and direct conversation with patients and their families still provides the strongest foundation for decision making in this complex condition.

One important component which is recognized by both scoring systems is the concept of hemodynamic instability or circulatory collapse in the pre-operative period. Several studies have found pre-operative shock or hemodynamic instability to be associated with significantly higher operative mortality.[78-79] In the IRAD tool, the presence of hypotension (systolic pressure <100 mm Hg) or shock with or without tamponade (systolic pressure <80 mmHg) was independently predictive of operative mortality (odds ratio 3.23).[77] Furthermore, those with cardiac arrest prior to surgery are at particularly high risk. In a recent study of patients with ATAAD undergoing cardiopulmonary resuscitation, Uehara et al. showed that duration of resuscitation greater than 15 minutes was an extremely strong independent predictor for operative mortality following surgical repair (hazard ratio 8.27).[80] In the context of these scoring systems, the presence of hemodynamic instability or collapse should be viewed as an ominous sign, with longer durations potentially serving as a relative contraindication to operative repair.

Conclusion

ATAAD remains a life-threatening condition, with or without surgery. Though our understanding of risk assessment has improved in recent years, clinical decisions remain

complex and require a considered, multidisciplinary approach. Optimizing surgical outcomes mandates thoughtful patient selection informed by predicted survival postoperatively, as well as patient-centered discussions of goals of care. Timing of surgery requires a nuanced characterization of the severity and extent of dissection, and potential reversibility of malperfusion syndromes. Further study in the area of endovascular techniques may improve outcomes in this complex group. In the modern era, with the challenges of resource allocation highlighted by COVID-19, we must hasten our collective understanding and investigation into determining when patients may benefit from surgical delay or permanent deferral of surgery altogether, and when transfer to specialized centers may be warranted.

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Table 1: Considerations for Potential Deferral of Emergent Surgery or Alternate Therapy in Acute Type A Aortic Dissection

Risk Factors for Consideration
Frailty and Advanced Age
Visceral and Extremity Malperfusion and Malperfusion syndromes
Cerebral Malperfusion and Major Brain Injury
Prior Cardiac Surgery and Redo Sternotomy
Pre-operative use of Novel Oral Anticoagulants
Patient Directed Goals of Care
Refusal of Blood Products
External Issues Related to Resource Availability
Availability of Alternate Strategies
Applications of Current Risk Prediction Tools

Figure Legends

Figure 1. Thirty-day mortality following ATAAD repair in North America over the era spanning 2004-2016 from the Society of Thoracic Surgeons database. Reproduced from Helder and colleagues[13] with permission from The Society of Thoracic Surgeons.

Figure 2. Long-term outcomes of surgical repair versus medical management in octogenarians with ATAAD. Reproduced from Dumfarth and colleagues[17] with permission from the European Association for Cardio-Thoracic Surgery.

Figure 3. Algorithm for managing malperfusion syndromes in those presenting with acute type A aortic dissection. Reproduced from Yang and colleagues [28] with permission from Wolters Kluwer Health, Inc.

Figure 4. Factors influencing in-hospital survival in medically managed patients with ATAAD. Reproduced from Wang and colleagues[75] with permission from Elsevier.