International Journal of Medical Science and Clinical Research Studies

ISSN(print): 2767-8326, ISSN(online): 2767-8342

Volume 04 Issue 12 December 2024

Page No: 2308-2313

DOI: https://doi.org/10.47191/ijmscrs/v4-i12-20, Impact Factor: 7.949

Hybrid Therapies for the Management of Aortic Dissection: Bridging Open Surgery and Endovascular Innovation

Donaldo Emiliano Silva López[1], Daniel Ibarra Aguayo[2], Alma Pamela Huerta Alvarado[3], Wanda Melissa Torres Somarriba[2], Geraldine Nieves Vázquez[4], Oswaldo Alfredo Rangel López[2]

[1]Tecnológico de Monterrey Campus Monterrey, Nuevo Léon, Mexico.

[2]Universidad Cuauhtémoc Plantel Aguascalientes. Aguascalientes, México.

[3]Universidad Autónoma de Zacatecas. Zacatecas, Zacatecas, México.

[4]Universidad Autónoma de Guadalajara. Zapopan, Jalisco, México.

ABSTRACT

Aortic dissection is a life-threatening condition characterized by the separation of the layers within the aortic wall, leading to a false lumen with the potential for severe complications, including rupture, malperfusion, and death. The management of aortic dissection has evolved significantly, with hybrid therapies emerging as a promising approach, particularly for complex cases involving extensive aortic involvement or high surgical risk. Hybrid therapies combine open surgical techniques with endovascular interventions to optimize outcomes by leveraging the strengths of both modalities. This article provides a comprehensive review of the current state of hybrid therapies in aortic dissection management, including their indications, technical considerations, and clinical outcomes. We explore the role of hybrid procedures in both acute and chronic phases of aortic dissection, focusing on scenarios such as aortic arch and thoracoabdominal involvement. Additionally, we discuss patient selection criteria, advances in imaging for procedural planning, and the challenges of long-term surveillance. By synthesizing recent evidence, we aim to highlight the potential of hybrid approaches to improve survival and reduce morbidity in this complex patient population.

ARTICLE DETAILS

Published On:
10 December 2024

KEYWORDS: Aortic dissection, hybrid therapies, endovascular intervention, open surgery, aortic repair, thoracic endovascular aortic repair (TEVAR), aortic arch surgery, chronic dissection, surgical outcomes

Available on:
https://ijmscr.org/

INTRODUCTION

Aortic dissection represents a critical cardiovascular emergency with an incidence of approximately 3 to 4 cases per 100,000 person-years. It is characterized by an intimal tear that allows blood to penetrate the aortic wall, creating a false lumen. Depending on the anatomical location and extent of the dissection, this condition is classified according to the Stanford and DeBakey systems, with type A dissections involving the ascending aorta and type B confined to the descending thoracic aorta. Immediate and accurate diagnosis is essential, as untreated dissections, particularly type A, have a mortality rate of up to 1% per hour within the first 48 hours.1,2

Historically, the management of aortic dissection has been dichotomized between open surgical repair and endovascular therapy. Open surgical repair, particularly for type A dissection, remains the gold standard, offering definitive exclusion of the false lumen and re-establishment of aortic integrity. However, this approach carries significant morbidity and mortality risks, especially in patients with comorbidities or advanced age. On the other hand, thoracic endovascular aortic repair (TEVAR) has revolutionized the management of type B dissections, offering a less invasive alternative with favorable perioperative outcomes. Despite these advancements, complex cases, particularly those involving the aortic arch or thoracoabdominal aorta, pose significant challenges, often requiring a combination of both techniques.1,2

Hybrid therapies have emerged as a transformative approach, bridging the gap between open and endovascular techniques. These procedures involve a staged or simultaneous combination of surgical debranching with subsequent endovascular stent graft placement. Hybrid approaches are particularly beneficial in managing complex dissections with extensive aortic involvement or in high-risk surgical candidates. This paradigm shift aims to optimize the balance between procedural safety and long-term efficacy.1,2

We review the current landscape of hybrid therapies in aortic dissection management, focusing on their indications, technical nuances, and clinical outcomes. We also examine the evolving role of hybrid approaches in acute and chronic dissection scenarios and highlight future directions in this dynamic field.3

EPIDEMIOLOGY

Aortic dissection is a rare but catastrophic cardiovascular condition with significant morbidity and mortality. The estimated annual incidence ranges from 3 to 6 cases per 100,000 individuals globally, though the true prevalence is likely underreported due to misdiagnosis or sudden death prior to medical evaluation. Aortic dissection primarily affects individuals between the sixth and seventh decades of life, with a male predominance in a ratio of approximately 2:1. Men are more frequently affected at a younger age, whereas women, although less commonly afflicted, tend to present later in life and with more severe complications.3

The epidemiology of aortic dissection varies significantly depending on the type and classification. According to the Stanford classification system, type A dissections, involving the ascending aorta, account for approximately 60% to 65% of cases, while type B dissections, confined to the descending thoracic aorta, represent 35% to 40%. Type A dissections often present as acute, life-threatening emergencies requiring urgent surgical intervention, with untreated mortality rates exceeding 50% within the first 48 hours. In contrast, type B dissections may present acutely or chronically and are typically managed conservatively or with endovascular therapy, depending on the presence of complications such as malperfusion or aortic rupture.4

Several risk factors are associated with the development of aortic dissection. Chronic hypertension is the most prevalent modifiable risk factor, present in 65% to 75% of patients, and it exerts continuous shear stress on the aortic wall, predisposing it to dissection. Other significant contributors include connective tissue disorders such as Marfan syndrome, Ehlers-Danlos syndrome, and Loeys-Dietz syndrome, which collectively account for a smaller but critical subset of cases due to their impact on the structural integrity of the aortic wall. Additionally, bicuspid aortic valve, aortitis (e.g., in Takayasu arteritis or giant cell arteritis), and prior aortic surgery are well-documented risk factors. Lifestyle factors, including smoking and cocaine use, further amplify the risk by promoting atherosclerosis and acute hypertension.4

The incidence of aortic dissection appears to be rising, likely due to improvements in diagnostic modalities such as computed tomography angiography (CTA) and magnetic resonance angiography (MRA), which allow for more accurate and timely identification. Moreover, as life expectancy increases, a larger proportion of the population reaches the age of peak incidence. Despite these advances in diagnosis and management, disparities in outcomes persist, particularly in low-resource settings where access to specialized care and advanced imaging is limited.5

The burden of aortic dissection on healthcare systems is substantial, given the need for complex surgical or endovascular interventions, intensive care unit (ICU) monitoring, and long-term follow-up to manage complications and prevent recurrence. Hybrid therapies, which combine open surgical techniques with endovascular repair, are increasingly being adopted to address the needs of high-risk populations and complex aortic dissections involving the aortic arch or thoracoabdominal aorta. These approaches offer the potential to improve survival rates and reduce healthcare costs by minimizing the invasiveness of traditional open surgery while achieving durable outcomes.5

Future epidemiological studies should aim to refine our understanding of aortic dissection's risk factors, geographic variability, and genetic predispositions. Such efforts will be essential for developing targeted screening and prevention strategies, particularly in high-risk populations, and for optimizing the application of hybrid therapeutic approaches.6

CLINICAL MANIFESTATIONS

The clinical presentation of aortic dissection is highly variable and often depends on the location, extent, and duration of the dissection. However, it is typically characterized by the sudden onset of severe, sharp, or tearing chest pain, often described as the most severe pain the patient has ever experienced. The pain frequently radiates to the back, interscapular region, or abdomen, depending on the segment of the aorta involved. In type A dissections, pain is more commonly localized to the anterior chest, reflecting involvement of the ascending aorta, while type B dissections are associated with pain in the back or abdomen due to descending aortic involvement.6

Beyond pain, the clinical manifestations of aortic dissection are influenced by the disruption of normal aortic architecture and the subsequent compromise of vital organ perfusion. This leads to a wide spectrum of signs and symptoms, often mimicking other cardiovascular, neurologic, or gastrointestinal conditions, which can complicate the diagnostic process.7

Cardiovascular Manifestations

Aortic dissection can rapidly compromise hemodynamic stability. Hypotension and shock are ominous signs typically associated with type A dissection due to pericardial tamponade, aortic rupture, or acute aortic regurgitation (AR). The latter occurs in up to 50% of patients with type A dissection, resulting from disruption or displacement of the aortic valve annulus. This leads to rapid volume overload, pulmonary edema, and acute heart failure.7

In type B dissections, although hypotension may be less common, complications such as malperfusion syndrome can develop. This condition occurs when the false lumen compromises blood flow to vital organs, leading to ischemia. Hypertension, paradoxically, is often observed in the acute setting of type B dissection due to the activation of the sympathetic nervous system and renin-angiotensin-aldosterone system (RAAS).7

Neurological Manifestations

Neurological deficits, present in approximately 10% to 20% of cases, are frequently associated with cerebrovascular complications. Involvement of the aortic arch or its branches can lead to transient ischemic attacks (TIAs), stroke, or syncope. Syncope, reported in about 13% of cases, may result from severe pain, tamponade, or massive hemorrhage. Dissection extending to the spinal arteries can cause spinal cord ischemia, presenting as paraplegia or paraparesis, though this is more common in type B dissections involving the thoracoabdominal aorta.8

Gastrointestinal and Renal Manifestations

Dissection-related malperfusion can affect the splanchnic circulation, leading to mesenteric ischemia. Patients may present with abdominal pain, nausea, vomiting, or even signs of peritonitis in severe cases. Renal involvement, observed in up to 15% of patients, may result in acute kidney injury (AKI) secondary to renal artery involvement. Oliguria or anuria may be initial clinical clues in such scenarios, underscoring the need for prompt diagnosis and intervention.9

Peripheral Vascular Manifestations

Peripheral artery involvement occurs when the dissection extends into the iliac or femoral arteries, leading to limb ischemia. Patients may exhibit diminished or absent pulses, cool extremities, and pain, which can progress to critical limb ischemia if not promptly addressed. Discrepancies in blood pressure measurements between arms (>20 mmHg difference) are a classic finding and suggest involvement of the subclavian or brachiocephalic arteries.9

Respiratory Manifestations

Involvement of the thoracic aorta can cause hemothorax due to rupture into the pleural space, manifesting as respiratory distress, hemoptysis, or hypoxemia. Pleural effusion, often left-sided, may be detected on imaging and is another clue suggestive of aortic rupture or impending rupture.10

Other Clinical Signs

Patients with chronic aortic dissection may present with more insidious symptoms, such as fatigue, dyspnea, or vague back pain. Chronic dissection may progress silently until complications such as aneurysmal dilation or rupture occur. Fever and elevated inflammatory markers, such as C-reactive protein (CRP), may accompany chronic inflammation, mimicking conditions like aortitis or infection.10

Given the broad spectrum of clinical manifestations, the diagnosis of aortic dissection requires a high index of suspicion. Rapid imaging with modalities such as computed tomography angiography (CTA) is essential for confirmation. The hybrid therapeutic approach, combining surgical and endovascular techniques, offers tailored interventions that address the diverse complications of aortic dissection, improving patient outcomes.10

The timely and accurate diagnosis of aortic dissection is critical due to the condition's high mortality rate, particularly in acute type A dissections. The diagnostic process is often challenging, given the wide spectrum of clinical presentations and the potential overlap with other acute cardiovascular and non-cardiovascular conditions. A high index of clinical suspicion, combined with the judicious use of imaging modalities, is essential for confirming the diagnosis and guiding the therapeutic approach, including the consideration of hybrid therapies.10

CLINICAL ASSESSMENT

The diagnostic process begins with a thorough clinical evaluation. The sudden onset of severe, tearing chest pain with radiation to the back or abdomen is a hallmark symptom of aortic dissection. However, pain may be absent or atypical, particularly in elderly patients or those with chronic dissection. Physical examination findings can include pulse deficits, blood pressure discrepancies between limbs, new-onset diastolic murmur indicative of acute aortic regurgitation, or signs of pericardial tamponade. Despite these classic features, clinical diagnosis alone is insufficient, necessitating the use of advanced imaging for confirmation.10

Imaging Modalities

Computed Tomography Angiography (CTA)

CTA is the gold standard for diagnosing aortic dissection due to its high sensitivity (close to 100%) and specificity. It provides detailed visualization of the aortic anatomy, allowing for the identification of the intimal flap, true and false lumens, and the extent of dissection. Additionally, CTA can evaluate branch vessel involvement, aneurysmal changes, and complications such as rupture or malperfusion. Its rapid acquisition time and wide availability make it the first-line imaging modality in most centers. CTA is indispensable in planning hybrid therapies, as it provides precise anatomical details for both open surgical and endovascular components.10

Transesophageal Echocardiography (TEE)

TEE is a highly sensitive and specific bedside imaging modality, particularly useful in hemodynamically unstable patients who cannot be transported for CTA. It allows real-time visualization of the intimal flap, aortic valve, and proximal coronary arteries. TEE is especially valuable in diagnosing type A dissection, where rapid detection of complications such as pericardial effusion or tamponade can guide urgent surgical intervention. However, its limited ability to assess the distal aorta and its invasive nature are notable limitations.10

Magnetic Resonance Angiography (MRA)

MRA offers excellent sensitivity and specificity for detecting aortic dissection, with the added advantage of avoiding ionizing radiation and nephrotoxic contrast agents. It provides comprehensive anatomical details and allows for dynamic assessment of blood flow, making it particularly useful in chronic dissections or when long-term follow-up is required. However, the longer acquisition time and limited availability in emergency settings reduce its utility in acute presentations.10

Plain Chest Radiography

While plain chest X-ray is not diagnostic for aortic dissection, it may reveal indirect signs such as mediastinal widening, pleural effusion, or displacement of mediastinal structures. These findings should raise suspicion and prompt further imaging. However, a normal chest X-ray does not rule out dissection, underscoring the need for more definitive diagnostic modalities.10

Laboratory Investigations

Although there are no specific laboratory markers for aortic dissection, several biomarkers are under investigation. Elevated levels of D-dimer have been associated with aortic dissection and may help in initial screening when clinical suspicion is low. However, its role in routine diagnostic protocols remains controversial due to variable sensitivity and specificity. Biomarkers such as smooth muscle myosin heavy chain (SMMHC) and matrix metalloproteinases (MMPs) are emerging as potential diagnostic tools but are not yet widely implemented in clinical practice.10

Diagnostic Algorithms

Given the life-threatening nature of aortic dissection, prompt application of diagnostic algorithms is essential. In patients with high clinical suspicion, immediate imaging with CTA or TEE is recommended. For those with low to intermediate suspicion, initial risk stratification using clinical findings and D-dimer levels may be considered to guide further testing.10

Role of Imaging in Hybrid Therapy Planning

Accurate diagnosis and detailed anatomical assessment are crucial for the success of hybrid therapies. Preoperative imaging helps delineate the extent of the dissection, identify critical branch vessel involvement, and assess the suitability of the aortic segments for endovascular stent-grafting. Postoperative imaging is equally important for monitoring graft position, patency, and the evolution of the false lumen, as well as detecting late complications such as endoleak or re-dissection.10

In conclusion, the diagnostic approach to aortic dissection relies on a combination of clinical acumen and advanced imaging techniques. The integration of these diagnostic tools is pivotal not only in confirming the diagnosis but also in guiding the application of hybrid therapeutic strategies, which offer a tailored approach to managing this complex and high-risk condition.11

TREATMENT METHODS

The management of aortic dissection is complex and requires a multidisciplinary approach tailored to the type of dissection, the extent of aortic involvement, and the presence of complications. Traditional treatment modalities include medical therapy, open surgical repair, and endovascular intervention. However, hybrid therapies, which combine elements of open surgery and endovascular repair, have emerged as a transformative approach, particularly in cases involving extensive aortic disease, complex anatomy, or patients with high surgical risk. These therapies aim to optimize outcomes by leveraging the advantages of both techniques while minimizing their limitations.11

Initial Medical Management

In all cases of acute aortic dissection, prompt initiation of medical therapy is critical to stabilize the patient and prevent further propagation of the dissection. The primary goal is to reduce shear stress on the aortic wall by controlling blood pressure and heart rate. Intravenous beta-blockers, such as esmolol or labetalol, are the first-line agents for achieving this. These agents reduce both heart rate and contractility, thereby decreasing aortic wall stress. If beta-blockers are contraindicated or insufficient, vasodilators such as sodium nitroprusside may be added to achieve target systolic blood pressure levels of 100-120 mmHg. Calcium channel blockers, particularly non-dihydropyridines like diltiazem, can also be used as adjuncts in specific cases.12

Indications for Surgical and Endovascular Intervention

The definitive treatment of aortic dissection varies based on the Stanford classification:

- **Type A Dissection:** Immediate surgical intervention is indicated due to the high risk of life-threatening complications, including aortic rupture, cardiac tamponade, and acute aortic regurgitation. Delayed intervention significantly increases mortality, with untreated cases having a mortality rate of 50% within the first 48 hours.12
- **Type B Dissection:** Uncomplicated type B dissections are typically managed medically. However, intervention is warranted in complicated cases, including those with malperfusion syndrome, impending rupture, or persistent pain despite optimal medical therapy.12

Open Surgical Repair

Open surgical repair remains the gold standard for type A dissections and involves replacing the dissected segment of the ascending aorta with a synthetic graft. In cases where the aortic valve is compromised, a composite valve-graft conduit (Bentall procedure) or valve-sparing root replacement may be performed. Arch involvement may necessitate total arch replacement, often with adjunctive cerebral perfusion strategies to prevent ischemic brain injury. Despite advances in surgical techniques, open repair is associated with significant morbidity and mortality, particularly in older patients or those with comorbidities.12

Endovascular Aortic Repair (TEVAR)

Thoracic endovascular aortic repair (TEVAR) has become the preferred intervention for complicated type B dissections and selected cases of chronic type A dissections. TEVAR involves the deployment of a stent graft within the aorta to seal the primary entry tear, redirecting blood flow into the true lumen and promoting thrombosis of the false lumen. This technique offers several advantages, including reduced operative morbidity, shorter recovery times, and the potential for staged interventions. However, TEVAR is associated with complications such as endoleaks, stent migration, and re-dissection, necessitating careful patient selection and long-term surveillance.12

Hybrid Therapies

Hybrid therapies have emerged as a viable solution for managing complex aortic dissections, particularly those involving the aortic arch and descending thoracic aorta. These approaches combine open surgical techniques with endovascular interventions to address the limitations of each method. Hybrid procedures are particularly advantageous in high-risk patients who may not tolerate the morbidity of extensive open surgery.13

Hybrid Arch Repair

In cases of arch involvement, hybrid arch repair combines open surgical replacement of the ascending aorta and proximal arch with TEVAR to extend the repair into the descending aorta. This approach is particularly useful in patients with extensive dissection or aneurysmal disease involving the aortic arch. Hybrid arch repair often employs the use of a “frozen elephant trunk” (FET), a device that integrates a proximal surgical graft with a distal stent graft. The FET technique allows for a single-stage repair of complex aortic pathologies, reducing the risk of re-intervention and improving long-term outcomes.13

Thoracoabdominal Aortic Repair

Hybrid thoracoabdominal repair is indicated for chronic or extensive dissections involving the descending thoracic and abdominal aorta. This technique typically involves debranching the visceral and renal arteries via open surgery, followed by endovascular stent-grafting of the diseased aortic segment. By preserving perfusion to vital organs and minimizing the extent of open surgery, hybrid repair reduces the risk of ischemic complications and perioperative mortality.14

Postoperative Management and Follow-Up

Regardless of the therapeutic approach, meticulous postoperative management is essential to optimize outcomes. Blood pressure control remains a cornerstone of long-term management, with a target systolic blood pressure of 120-130 mmHg to reduce the risk of re-dissection or aneurysmal degeneration. Lifelong imaging surveillance, typically with CTA or MRA, is crucial for monitoring the integrity of the repair, detecting complications such as endoleaks or graft failure, and assessing the status of the residual aorta.15

Emerging Techniques and Future Directions

Advances in imaging, device technology, and surgical techniques continue to expand the horizons of hybrid therapies. The development of branched and fenestrated stent grafts offers the potential for more tailored interventions, allowing for endovascular repair of complex aortic segments while preserving branch vessel perfusion. Moreover, minimally invasive surgical techniques, such as robotic-assisted aortic surgery, are being explored to further reduce the morbidity of open repair.16

Hybrid therapies represent a paradigm shift in the management of aortic dissection, offering a versatile and less invasive alternative to traditional open surgery. These approaches hold particular promise for patients with complex or extensive aortic disease, providing durable outcomes with reduced perioperative risk. As the field continues to evolve, ongoing research and innovation will be essential to optimize the application of hybrid techniques and improve patient outcomes.16

CONCLUSION

Aortic dissection remains one of the most challenging and life-threatening conditions in cardiovascular medicine, requiring a nuanced and multidisciplinary approach to management. Traditional therapeutic strategies, including open surgical repair and thoracic endovascular aortic repair (TEVAR), have each demonstrated significant efficacy in specific contexts but are not without limitations. In response to the complex and often multifaceted nature of aortic dissection, hybrid therapies have emerged as a pivotal advancement, bridging the gap between the strengths and weaknesses of surgical and endovascular approaches.

Hybrid therapies leverage the anatomical precision and reduced invasiveness of endovascular interventions while maintaining the durability and comprehensive repair capabilities of open surgical techniques. This dual approach is particularly beneficial in addressing extensive or multi-segmental aortic dissections, including those involving the aortic arch and descending thoracic or thoracoabdominal aorta. By combining open surgical debranching or graft replacement with stent graft deployment, hybrid techniques offer tailored, patient-specific solutions that optimize outcomes in high-risk populations.

The introduction of the frozen elephant trunk (FET) technique exemplifies the evolution of hybrid therapies. This method has significantly improved the management of complex aortic arch pathologies, facilitating single-stage repairs that minimize the need for subsequent interventions. Additionally, hybrid thoracoabdominal repairs have provided new avenues for treating chronic or extensive dissections, reducing ischemic complications while ensuring organ perfusion through targeted debranching.

Despite their promise, hybrid therapies are not without challenges. These procedures require advanced surgical expertise, comprehensive preoperative planning, and the availability of specialized devices, such as branched and fenestrated stent grafts. Moreover, the risk of complications, including endoleaks, graft migration, and re-dissection, underscores the necessity for meticulous postoperative management and long-term surveillance. Lifelong imaging follow-up and strict control of cardiovascular risk factors remain essential components of care to ensure the durability of the repair and prevent late complications.

Future directions in the field of hybrid therapies for aortic dissection are promising, driven by ongoing innovations in device technology and surgical techniques. The development of next-generation stent grafts, designed for more complex anatomies, along with minimally invasive surgical methods, such as robotic-assisted procedures, may further expand the applicability of hybrid approaches. Additionally, advances in imaging modalities and artificial intelligence-driven diagnostic tools have the potential to enhance preoperative planning and intraoperative decision-making, ultimately improving patient outcomes.

In conclusion, hybrid therapies represent a transformative paradigm in the management of aortic dissection. They offer a unique combination of durability, flexibility, and reduced invasiveness, making them particularly valuable in treating complex aortic disease. As the field continues to evolve, it is imperative to refine these techniques, expand access to advanced technologies, and develop robust clinical protocols to optimize their implementation. Through these efforts, hybrid therapies are poised to redefine the standards of care, offering improved survival and quality of life for patients with this devastating condition.

REFERENCES

I. Gouveia E Melo, R. · Mourão, M. · Caldeira, D.A systematic review and meta-analysis of the incidence of acute aortic dissections in population-based studies *J Vasc Surg.* 2022; 75:709-720

II. Gouveia E Melo, R. · Silva Duarte, G. · Lopes, A.Incidence and prevalence of thoracic aortic aneurysms: a systematic review and meta-analysis of population-based studies *Semin Thorac Cardiovasc Surg.* 2022; 34:1-16

III. Iribarren, C. · Sidney, S. · Sternfeld, B. Calcification of the aortic arch: risk factors and association with coronary heart disease, stroke, and peripheral vascular disease *JAMA.* 2000; 283:2810-2815

IV. McClure, R.S. · Brogly, S.B. · Lajkosz, K. Epidemiology and management of thoracic aortic dissections and thoracic aortic aneurysms in Ontario, Canada: a population-based study *J Thorac Cardiovasc Surg.* 2018; 155:2254-2264.e4

V. Coutinho, T. · Richer, J. · Boodhwani, M. Who to screen for thoracic aortic aneurysms, and when to refer for surgery *Can J Cardiol.* 2022; 38:695-698

VI. Cheng, S.W.K. Aortic arch pathologies - incidence and natural history *Gefasschirurgie.* 2016; 21:212-216

VII. Brownstein, A.J. · Rajaee, S. · Erben, Y. Natural history of aneurysmal aortic arch branch vessels in a single tertiary referral center *J Vasc Surg.* 2018; 68:1631-1639.e1

VIII. Hughes, G.C. · Vekstein, A. Current state of hybrid solutions for aortic arch aneurysms *Ann Cardiothorac Surg.* 2021; 10:731-743

IX. Englum, B.R. · He, X. · Gulack, B.C.Hypothermia and cerebral protection strategies in aortic arch surgery: a comparative effectiveness analysis from the STS Adult Cardiac Surgery Database *Eur J Cardiothorac Surg.* 2017; 52:492-498

X. Mori, M. · Shioda, K. · Wang, X. Perioperative risk profiles and volume-outcome relationships in proximal thoracic aortic surgery *Ann Thorac Surg.* 2018; 106:1095-1104

XI. Elbatarny, M. · Stevens, L.M. · Dagenais, F. Hemiarch versus extended arch repair for acute type A dissection: Results from a multicenter national registry *J Thorac Cardiovasc Surg.* 2024; 167:935-943.e5

XII. Narita, M. · Tsutsui, M. · Ushioda, R. Proximal and extended aortic arch replacement in acute DeBakey type I aortic dissection *Front Surg.* 2023; 10, 1081167

XIII. Schoenhoff, F.S. · Kadner, A. · Czerny, M. Should aortic arch replacement be performed during initial surgery for aortic root aneurysm in patients with Marfan syndrome? *Eur J Cardiothorac Surg.* 2013;:346-351

XIV. Schoenhoff, F.S. · Alejo, D.E. · Black, J.H. .Management of the aortic arch in patients with Loeys-Dietz syndrome *J Thorac Cardiovasc Surg.* 2020; 160:1166-1175

XV. David, T.E. · Ouzounian, M. Reply to "Aortic repair in Marfan syndrome: Let's not forget the arch when talking about the root." *J Thorac Cardiovasc Surg.* 2018; 156:39-40

XVI. Sharaf, O.M. · Kohtz, P.D. · Arnaoutakis, G.J. Aortic arch repair using open and hybrid techniques: a systematic review *Innovations (Phila).* 2022; 17:273-282