Abstract

The occurrence of aortic dissection involving a right-sided aortic arch (RAA) is extremely rare. Majority of the symptomatic cases have been managed with open surgical treatment. However, middle-aged and elderly patients with coexistent comorbidities have higher postoperative risks if managed by surgery. The purpose of this case study is to review the literature for occurrence and treatment modalities for RAA with dissection, to review the various literature studies which have helped establish a consensus and guidelines in the management of aortic dissections, to review previous reported cases of successful endovascular management of RAA dissections, and to report our experience of treating a case of Stanford Type B right-sided aortic dissection managed by complete endovascular approach, the first of its kind in India. Our search in the databases revealed around 32 cases of RAA with aortic dissection published in the literature, most of which have been treated with open surgical approach; however, very few cases are managed with endovascular approach only like in our case.

Key Words: Endovascular management of right aortic arch dissections, right aortic arch with dissection, right-sided aortic arch

Introduction

The occurrence of right-sided aortic arch (RAA) is very rare among general population, with approximately 0.1% incidence. RAA is usually asymptomatic unless complications such as aneurysmal dilatation or dissection occur. The incidence of aortic dissection among the persons with RAA is extremely rare. Our search in the databases revealed around 32 cases of RAA with aortic dissection published in the English literature.

Majority of the symptomatic cases have been managed with open surgical management. Risk of rupture of aortic aneurysms is more in older patients, but advanced age is linked to higher operative risks, especially with open surgical repair. The associated complications of open surgery include lower extremity paralysis, stroke, and mortality. With the advent of newer modalities in the interventional radiology, use of an alternative management using endovascular aortic stenting is increasing as studies have shown reduced complications, especially in middle-aged and elderly patients with comorbidities.2,3

The objective of this case study is to review the literature for occurrence and treatment modalities for RAA with dissection, to review the various literature studies which have helped establish a consensus and guidelines in the management of aortic dissections, to review previous reported cases of successful endovascular management of RAA dissections, and to report our experience of treating a case of Stanford Type B right-sided aortic dissection managed by complete endovascular approach.

Design of study

This case study was performed by gathering data from literature about the various reported cases of RAA with dissection. There were 32 cases of RAA with dissection reported in literature. The data were analyzed for age and gender preponderance, type of the RAA, type of dissection, presentation of patient, and treatment modality.

Results

Literature review [Tables 1 and 2] has revealed that Type II pattern of RAA was most commonly seen, i.e., in

Access this article online

Website: www.indjvascsurg.org
DOI: 10.4103/0972-0820.191490

How to cite this article: Prabhu SD, Rai S, Keerthiraj B, Acharya P, Prabhu D, Gudi H. Endovascular Stenting - Novel Technique in the Management of Acute Stanford Type B Aortic Dissection Involving Right-sided Aortic Arch: Is This the Way Forward? Systematic Literature Review with Case Study. Indian J Vasc Endovasc Surg 2016;3:114-24.

Received: July, 2016. Accepted: August, 2016.

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com
Table 1: Literature review of RAA with dissection of cases reported in 20th century. Data was collected with regards to incidence, age/gender distribution, type of RAA, type of dissection and modality of treatment

| Study/Year     | Size | Age/sex   | Presentation | Type of RAA                                      | Type of Stanford dissection | Treatment                                                                 |
|----------------|------|-----------|--------------|-------------------------------------------------|----------------------------|---------------------------------------------------------------------------|
| Roan et al., 1979[4] | 1    | 48/Female | Dissection   | Type II, LSA arising from aortic diverticulum   | N.A                        | Surgery. Partial cardiopulmonary bypass                                   |
| Bodine et al., 1982[5] | 1    | 61/Female | Dissection   | RAA-Type N.A                                    | N.A                        | NA                                                                        |
| Floten et al., 1984[6] | 1    | 64/Male   | Dissection   | Type II with aberrant LSA arising from Kommerell's diverticulum | Type B                     | Surgery- Bilateral thoracotomy approach. No extracorporeal circulation   |
| Ohteki et al., 1987[7] | 1    | 62/Male   | Dissection   | Type II with aberrant LSA arising from Kommerell's diverticulum | Type B                     | Surgery- Left thoracotomy and median sternotomy approach                 |
| Roan et al., 1979[8] | 1    | 64/Male   | Dissection   | Type II, LSA - Shuford type-3                   | Type B, entry located proximal to aberrant LSA DeBackey Type IIIB (Stanford Type B) | Surgery- Right thoracotomy approach, brachio-femoral Bypass               |
| Bodine et al., 1982[9] | 1    | 49/Male   | Dissection   | RAA with aberrant LSA                           | Type B                     | Surgery- Right thoracotomy approach, partial cardiopulmonary bypass      |
| Floten et al., 1984[10] | 2    | 53/Male, 47/Male | Dissection | Both were Type II aberrant LSA arising from Kommerell's diverticulum | Both Were Debackey IIIB (Type B) | 53/M-Medical treatment                                                   |
| Ohteki et al., 1987[11] | 1    | 64/Male   | Dissection   | Type II, aberrant LSA                           | DeBackey IIIIB (Type B)    | 47/M-surgery with femoro-femoral bypass                                   |
| Kanoh et al., 1995[12] | 1    | 69/Female | Dissection   | Type II aberrant LSA - arising from retroesophageal aortic diverticulum | Type B                     | Surgery- Median sternotomy and left thoracotomy approach                 |
| Osako et al., 1996[13] | 1    | 70/Female | Dissection   | Type II with aberrant LSA arising from Kommerell's diverticulum | Debackey Type IIIB (Type B) | Surgery- Right thoracotomy approach                                       |
| Masiello et al., 1996[14] | 1    | 48/Male   | Dissection   | N.A                                              | Type B                     | Surgery- right-postero-lateral thoracotomy approach. Circulatory arrest in profound hypothermia and cerebral retroperfusion |
| Ko et al., 1996[15] | 1    | NA        | NA           | Type II LSA arising from aortic diverticulum     | Type B                     | NA                                                                        |
| Senthil and Treasure, 1996[16] | 1    | 72/Male   | Dissection   | Type I mirror image branching                   | Type B                     | Surgery - Right thoracotomy approach, full cardiopulmonary bypass and deep hypothermic circulatory arrest |
| Nomoto et al., 1997[17] | 1    | 45/Male   | Dissection   | Type II LSA arising from aortic diverticulum     | Type A                     | Surgery- midline sternotomy approach, cardio-pulmonary bypass, hypothermia |
| Moizumi et al., 1999[18] | 1    | 39/Male   | Dissection   | Type II with vascular ring                      | Type A                     | Surgery- Right thoracotomy approach, hypothermia, cardiopulmonary bypass |
| Minato et al., 1999[19] | 1    | 50/Male   | Dissection   | Type II with aberrant LSA                       | DebackeyIIIA (TypeB)       | Surgery - right thoracotomy approach, partial cardiopulmonary bypass     |
| Kuki et al., 2000[20] | 1    | 75/Female | Dissection   | Type II LSA arising from Kommerell's diverticulum | Type B                     | Surgery- Thoraco-abdominal - standard thoracotomy approach, retroperitoneal approach. Cardiopulmonary bypass, separate arterial perfusion SMA |
| Yamazaki et al., 2000[21] | 1    | 56/Male   | Dissection   | Type II with aberrant LSA arising from Kommerell's diverticulum | Type B                     | Endovascular treatment via right external iliac artery through retroperitoneal approach, stent grafting |

RAA: Right aortic arch, N.A: Details not available
### Table 2: Literature review of RAA with dissection of cases reported in 21st century

| Study/Year                  | Size | Age/sex | Presentation                                      | Type of RAA                       | Type of Stanford dissection | Treatment                                                                 |
|----------------------------|------|---------|--------------------------------------------------|-----------------------------------|-----------------------------|---------------------------------------------------------------------------|
| Tsunemi et al., 2001[20]    | 1    | 51/Male | Dissection                                       | Type II with aberrant LSA         | Type B                      | Surgery- Right thoracotomy approach                                       |
| Kaneda et al., 2001[21]     | 1    | 58/Male | Dissection                                       | Type I RAA with mirror-image branching | Type B                      | Surgery-right posterolateral thoracotomy approach                           |
| Born et al., 2003[22]       | 1    | 55/Male | Upper GI bleeding due to ruptured RAA dissection  | Type I mirror image but separate origin of right CCA and right SA | Type B                      | Died before treatment                                                      |
| Paziouros et al., 2005[23]  | 1    | 64/Male | Dissection                                       | N.A                               | Type A                      | Surgery- median sternotomy approach                                       |
| Hori et al., 2009[24]       | 1    | 78/Male | Dissection                                       | Type II aberrant LSA arising from Kommerrell’s diverticulum | Type A                      | Surgery- median sternotomy approach, hypothermia, cardiopulmonary bypass |
| Kim et al., 2010[25]        | 1    | 47/Male | Dissection                                       | Type II LSA arising from Kommerrell’s diverticulum | Type B from RAA to renal artery | Surgery- Right posterolateral thoracotomy approach, cardio-pulmonary bypass, hypothermia |
| Obitsu et al., 2010[26]     | 1    | 57/Male | Dissection                                       | Type II, LCCA and LSA arising from Kommerrell’s diverticulum | DeBackey IIIa (Type B)      | Surgery- Median sternotomy & right posterolateral5thintercostals thoracotomy approach, cardiopulmonary bypass, hypothermia, selective cerebral perfusion. Staged hybrid repair: surgery- Total arch replacement (median sternotomy approach, cardio-pulmonary bypass, hypothermia, selective cerebral perfusion) later followed by endovascular repair after 3 months. |
| Sato et al., 2011[27]       | 1    | 67/Male | Dissection                                       | Type II with aberrant LSA from Kommerrell’s diverticulum | Type A                      | Endovascular treatment, stent grafting                                     |
| Kim et al., 2012[28]        | 1    | 32/Male | Dissection                                       | Type II LSA arising from Kommerrell’s diverticulum | Type B                      | Emergency total arch replacement through a median sternotomy approach      |
| Croccia et al., 2012[29]    | 1    | 62/Male | Dissection                                       | Type I RAA with mirror image branching | Type B                      | Endovascular treatment, right femoral approach, stent grafting             |
| Ebner et al., 2013[30]      | 1    | 62/Female | Dissection with hemopericardium                   | Type II with aberrant LSA from Kommerrell’s diverticulum | Type A                      | Surgery with graft replacement                                              |
| Zhou, 2013[31]              | 1    | 65/Male | Dissection                                       | Type II LSA arising from Kommerrell’s diverticulum | Type B                      | Endovascular treatment, right femoral approach, DSA, stent grafting         |
| He et al., 2015[32]         | 1    | 69/Male | Aortic Dissection                                 | Type II RAA with aberrant LSA arising from Kommerrell’s diverticulum | Type B                      | Endovascular treatment, stent grafting                                     |
| Hsu et al., 2015[33]        | 1    | 47/Male | Aortic Dissection                                 | Type II RAA with aberrant LSA arising from Kommerrell’s diverticulum | Type B                      | Total Endovascular repair                                                  |

RAA: Right aortic arch, N.A: Details not available

23 cases, in which the left subclavian artery (LSCA) had aberrant origin with 5 cases showing origin directly from aortic arch or in 19 cases arising from Kommerrell’s aortic diverticulum. RAA with mirror image branching was seen in four cases. Type B aortic dissection in which ascending aorta was spared was the most common presentation as seen in 24 cases reported in the literature. Type A dissection involving ascending aorta was seen in six cases. Most patients had presented with symptomatic RAA dissection in 60–69 year age group (12 cases), followed by seven cases each in 40–49 and 50–59 year age group. Four cases were reported in 70–79 year age group, with only two cases in 30–39 year age group. It was seen that males were more commonly affected as seen in 25 cases in the
literature compared to six cases in female patients. Almost all patients had presented with symptoms related to acute dissection while rupture was seen in three patients and hemopericardium in one patient.

Out of the 32 cases, 26 cases were managed with open surgical approach and they required a cardiopulmonary bypass, either partial or complete, and hypothermia. Only four cases were managed by endovascular approach, while in one case, a hybrid procedure is followed comprising two-stage open surgery and endovascular treatment. There is increasing number of successful endovascular treatments reported in literature in the recent decades in keeping pace with the changing trends and recommendations in the medical fraternity.

We also report a case of complete endovascular management of acute Type B dissection in a 45-year-old male who had Type II RAA branching pattern with aberrant LSCA. This case report is probably the first of this kind from India demonstrating complete endovascular management of Type B dissecting aortic aneurysm involving aortic arch, descending thoracic aorta, and abdominal aorta up to the level of renal arteries by deploying endovascular stent graft.

A 41-year-old male patient came to our emergency room with chief complaints of worsening upper back pain and retrosternal chest pain of 3 days duration. The patient was a known hypertensive on regular medication. The subsequent clinical examination revealed normal vitals with blood pressure of 160/90 and nonspecific electrocardiography changes. Chest radiograph revealed widened superior mediastinum with a convex contour toward the right side [Figure 1a]. RAA was suspected and chest computed tomography (CT) was suggested. However, the patient did not comply and sought discharge against medical advice on with antihypertensive and analgesics prescription. Two days later, he came to emergency department with unresolved chest pain and hypertension (blood pressure of 160/100) and contrast-enhanced CT of the chest along with CT aortogram was performed.

CT aortogram [Figures 1c-f and 2] showed RAA with nonmirror image branching pattern. A fusiform dilatation of the distal portion of right-sided arch extending into descending aorta (with a maximum axial dimensions of 46 mm × 44 mm) was seen with presence of an intimal flap in the lumen of the distal aortic arch and descending aorta with blood column on either side of the flap, suggesting Stanford acute Type B aortic dissection. False lumen measured 29 mm in maximum diameter in its widest portion with true lumen measuring 13 mm at this site. The dissection extended caudally to just below the origin of renal arteries. LSCA was seen to arise as the last branch of the aortic arch from the true lumen and had retrotracheal and retrooesophageal course. Bilateral carotid and right subclavian arteries were seen arising from the uninvolved portion of arch. Sagittal [Figure 2a] and coronal [Figure 2b and c] are CT reconstructions showing the RAA with extent of dissection. Note the true (single white arrow) and false lumen (double arrow) and the intimal flap (thick arrowhead) with intimal tear (black arrow) seen below the LSCA origin.

In view of refractory chest pain and hypertension with diagnosis of symptomatic acute RAA Type B dissection, the patient was scheduled for endovascular treatment with stent graft placement. Under general anesthesia, under all aseptic precautions, bilateral radial artery puncture, and right common femoral artery (rt CFA) cut down were done. Selectively, the true lumen of aorta was accessed from the left radial artery route and the wire was passed distally into abdominal aorta and was snared from the right femoral artery route, and using 6 F pigtail angiogram was done after placing another catheter from the right radial route into right subclavian artery. Digital subtraction angiography confirmed dissection and showed early filling of true lumen and delayed filling of enlarged false lumen with communication at two levels, one in arch just distal to right subclavian artery origin and another distal to LSCA origin [Figure 3]. From rt CFA cut down, Valiant Captivia Stent graft (Medtronic) 30 mm × 150 mm was taken across the dissection in arch and placed just beyond the right subclavian artery, and stent graft was deployed starting just from the caudal to the right subclavian artery origin for a length of 15 cm. Blood flow into intimal tear was thus eliminated. Check angiogram showed good apposition of stent margins to aortic wall with minimal Type I endoleak proximally and normal filling of the right subclavian artery. The right femoral artery cut down was then sutured. There was no hematoma at the site and distal pulses were well felt. Bilateral radial artery sheaths were removed, hemostasis was achieved, and patient was shifted to recovery room. No immediate postprocedure complications were noted. Minimal Type I endoleak immediately after procedure was well managed.

The patient was kept under observation in the ward for the next 2 days and was discharged with proper medical advice. The patient has shown excellent recovery during the follow-up period. Follow-up imaging after 2 months performed revealed interval reduction in size of the false lumen with patent stent and no significant endoleak as seen in Figures 4-6.

Discussion

Fiocchi and Aglietti first described about RAA. The aortic arch develops during the 3rd gestational week from six branchial arch arteries. The right fourth branchial arch artery normally regresses and the left arch artery forms the left-sided aortic arch. RAA anomaly occurs if the right fourth branchial arch artery persists while the left fourth branchial artery regresses. [34]
Laura Knight and Jesse Edwards classified RAA into three types. In Type I or mirror image branching, the left innominate, right carotid, and right subclavian arteries arise from aortic arch in that order from left to right. In Type II RAA, LSCA has an aberrant origin either arising as the last branch of RAA directly or from an aortic diverticulum called Kommerell’s diverticulum. In Type III RAA with isolated LSCA, the LSCA arises from/is connected to the left pulmonary artery via ductus arteriosus. Type I pattern of RAA is the most common type with incidence of 59% than Type II (39.5%) or Type III (0.8% incidence). In our case, we see a Type II RAA.

Aortic dissection was first classified by DeBakey in 1965 according to the site of involvement – Types I and II involve the ascending aorta. Type I involves ascending aorta and arch and can extend to the descending aorta, sometimes even up to the iliac arteries. In Type II, dissection is limited to the ascending aorta while Type III is descending aortic dissection which begins distal to the LSCA; Type IIIa type is limited to above diaphragm and Type IIIb extends below the diaphragm. A simpler classification was later proposed by Stanford which is more routinely used now – Type A involving the ascending aorta with or without involvement of descending aorta and Type B in which the ascending aorta is not affected. Stanford Type A is equivalent to DeBakey Types I and II, and Stanford Type B is equivalent to DeBakey Types IIIa and IIIb. Approximately two-third of cases of acute aortic dissection are Type A, and the rest are Type B. Aortic dissection can be acute (presenting within 2 weeks after the initial onset of symptoms), subacute (2–6 weeks), and chronic (>6 weeks). Almost 30% of patients have chronic aortic dissection. However, in cases of RAA, Type B dissection is more common as per our literature review.

Occurrence of RAA with aortic dissection has been reported in 41% of patients having Type II pattern with aberrant LSCA. Bodine et al. suggested that Type B dissection is more common than other types of dissection in patients with RAA as a result of vessel wall damage caused by the sudden change in direction of blood flow in right-sided arch due to shorter radius and more acute curvature compared to the usual gentle curve of the left aortic arch.

Cinà et al., in a review article of 32 cases of RAA with subclavian artery aneurysm as reported in literature, documented that 12 patients presented with aortic dissection and 2 patients presented with rupture. Surgical repair was performed in 29 patients.

A variety of clinical trials published in literature have reported success with endovascular therapy; however, controversy and confusion still exists regarding the overall efficacy of endovascular treatments. The trials have reiterated that operative mortality and complications such as paraplegia are significantly lower with improved survival in the endovascular group compared with the open surgical group. The strongest factor associated with postoperative success is spinal cord ischemia which is related to extent of the disease. Investigation of stent grafts in patients with Type B Aortic Dissection (INSTEAD) trial which is a prospective, randomized, controlled clinical trial that compares stent graft treatment of uncomplicated chronic Type B dissection with optimal medical therapy alone is still underway and reports are awaited.
Severe chronic obstructive pulmonary disease predisposes to thoracic aortic aneurysm rupture and is also a risk factor for open surgery. For older patients above 75 years of age, stent grafting is associated with lower morbidity and mortality than open surgical repair. Not only does the hospital stay get reduced but also recovery is faster, thus reducing the postoperative complications associated with prolonged hospital stay in open cardiovascular surgeries. This is especially true in Type B thoracic aortic dissections and abdominal aortic dissections in middle-aged and elderly patients with associated comorbidities.

The first successful stent grafting of patients in acute Type B aortic dissection was reported by Dake et al. in Stanford in 1999. Okada et al. had performed endovascular repair in a 76-year-old male with an aneurysm involving RAA. Yamazaki et al. first reported a successful stent-graft treatment in a 56-year-old male suffered from Type B aortic dissection involving an RAA. Nomura et al. have reported two cases of thoracic aortic aneurysm with an RAA and right-sided descending aorta treated with thoracic endovascular aortic repair.

**Role of endovascular treatment in acute Type B dissection**

Complicated acute Type B dissection is characterized by either refractory acute chest pain despite proper medical therapy with negative ionotropic/antihypertensive...
agents or acute enlargement of false lumen or contained mediastinal hematoma or visceral, renal, or limb ischemia (malperfusion syndrome). These patients require emergency intervention by surgery or endovascular approach.\cite{46}

The Stanford Cardiovascular Surgery and Interventional Radiology Group recommends emergency endovascular stenting in acute Type B (or retro-A) aortic dissection with life-threatening critical complications such as trunk or limb malperfusion caused due to compressed true lumen; aortic rupture or impending rupture; and refractory chest pain or uncontrollable severe hypertension as endovascular management can be lifesaving in these conditions and helps in stabilizing the patient. Endovascular technique has been shown to be successful particularly in acute Type B dissection. Surgical treatment is preferred in case of intramural hematoma or aortic leak resulting in large para-aortic mediastinal hematoma.\cite{47}

The principle of endovascular stenting in aortic dissection is that coverage of primary intimal tear by stent graft obliterates blood flow into the false lumen, thus relieving the compression of true lumen. Subsequent thrombosis of false lumen aids in aortic remodeling. Sometimes, in acute dissection, the endovascular stenting may not eliminate all blood flow from the false lumen, but coverage of primary intimal tear helps to relieve the malperfusion. Even partial thrombosis of the false lumen helps in the reduction of aortic diameter, thus preventing rupture. By excluding antegrade or retrograde flow into false lumen, stenting thus helps to prevent early and late complications.\cite{38,47}

According to guidelines by the Society of Thoracic Surgeons endovascular task force, stent grafting is a safe therapeutic option for high surgical risk patients with subacute or chronic aortic dissection who have:
- A patent false lumen and an identifiable, proximal entry tear which can be covered by stent graft placement
- Maximum thoracic aortic diameter of 5.5 cm or more
- Documented increase in aortic diameter of >1.0 cm within 1 year
- Resistant hypertension in spite of antihypertensive treatment associated with a small true lumen or renal malperfusion
- Recurrent episodes of refractory chest/back pain not caused by other conditions.\cite{38}

All symptomatic dissecting aneurysms need to be treated irrespective of the size; provided there are no other contraindications as symptoms often herald rupture. Complicated acute Type B aortic dissections are associated with >50% mortality risk and patients require emergency endovascular or open surgical treatment.\cite{59}

A meta-analysis performed by Eggebrecht et al. involving Type B (96%) and retrograde Type A (4%) aortic dissection has revealed 98% success with endovascular treatment with low mortality of 5%.\cite{46} In another study done by the EUROSTAR and UK Thoracic Endograft Registries, procedural success was achieved in 89% of cases, while in 11% cases, there was either incomplete coverage of the entry tear, persistent flow with only partial thrombosis of the thoracic false lumen, no expansion of the true lumen, or endoleaks with drastically reduced incidence of postprocedural neurological complications such as stroke or paraplegia and reduced mortality.\cite{46}

These studies have demonstrated that stent graft treatment of Type B dissection is feasible, with high technical success rates and acceptable short-term outcomes. Endovascular treatment can be used to treat most complications and it avoids the major trauma of open surgery associated with surgical management.

**Role of endovascular treatment in subacute and chronic dissection**

Nienaber et al., in a comparative trial of stent grafting versus open surgery in 24 patients with subacute or chronic aortic Type B dissection, have shown that stent grafting was successfully performed in 12 patients with no morbidity or mortality while adverse outcome was noted in 12 surgically treated patients with 4 deaths and 5 developing serious complications within 12 months. They suggested that endovascular stenting might be a safer procedure in selected patients with subacute/chronic dissection.\cite{50} Complications of endovascular stenting in symptomatic patients with subacute and chronic dissection (presenting before 8 weeks from symptom onset) are low compared to cases of acute dissection as blood flow in segmental arteries arising from the false lumen is not eliminated due to retrograde flow up the false lumen. However, efficacy of stenting in chronic dissection of more than 8 weeks is controversial as the intimal flap may be fibrosed and not pliable; hence, surgery may be better option in these patients.\cite{38}

**Role of endovascular treatment in right aortic arch dissection**

Use of endovascular treatment in RAA aneurysm or dissection helps to avoid thoracotomy or median sternotomy and avoid cardiopulmonary bypass or circulatory arrest, which is required for open surgical approach. Compared to a left-sided aortic arch dissection, surgical treatment of RAA dissection faces technical difficulties as usually RAA is associated with aberrant LSCA with/without retroesophageal aortic (Kommerell’s) diverticulum which is frequently involved in dissection. Further, as Type B dissection is more common with involvement of the descending aorta, surgical approach is difficult and requires bilateral thoracotomy. However, with advent of endovascular stenting which is a noninvasive procedure, complications are less.\cite{90} Furthermore, if the aortic dissection entry point is beyond the aberrant LSCA...
origin, it is easier to do endovascular stenting as we get an adequate landing zone and obviates the need of a left subclavian-carotid bypass.[50]

**Role of endovascular treatment in acute Type A dissection**

Endovascular treatment of acute Stanford Type A dissection is generally not recommended by experts and is controversial. However, Kato et al. have achieved successful endovascular stent repair in 10 patients of retrograde Type A dissection where the primary intimal tear was located in the descending aorta with retrograde involvement of the ascending aorta with no clinical evidence of cardiac tamponade or severe aortic regurgitation and have achieved entry closure and complete thrombosis of the false lumen of the ascending and descending aorta with no mortality or rupture even after a mean follow-up of 20 months.[51] Sato et al. have performed hybrid surgical and endovascular treatment of acute Type A aortic dissections with the primary tear located in the ascending aorta.[27]

**Role of hybrid surgical and endovascular procedures**

Sometimes, in patients with Type B aortic dissection, the proximal entry tear is located around the LSCA origin. In these patients to achieve complete closure of primary tear by endovascular stenting, the proximal landing zone in the aortic arch must be secured by hybrid surgery. This hybrid procedure involves combined use of surgical procedure with endovascular stenting for securing landing zone and reconstruction of aortic branches. Svensson has experimented with elephant trunk procedure for aortic arch aneurysms which allows proximal anchorage of stent grafts or subclavian artery transfers for aberrant subclavian artery and secures positioning of stent grafts in the distal aortic arch.[52] Chiesa et al. have also reported about a one-stage hybrid surgical and endovascular procedure for RAA aneurysm with anomalous origin of the supra-aortic vessels where complete surgical rerouting of the supra-aortic vessels was performed, later followed by stent grafting.[53] Hybrid treatment is specially required in patients with multisegmental thoracic aortic dissection, in which otherwise a two-step surgical treatment is required involving arch replacement in the first step and open descending repair in the second step.[58,52]

**Recommendation for management of intrathoracic aortic dissections**

Decision about the type of management of aortic dissection should be made depending on the patient’s age, comorbidities, clinical experience of performing surgeon and interventional radiologist, and the availability and cost of the surgery/endovascular therapy. Hybrid procedures comprising one stage or two-stage stent graft and open surgical procedures should be considered to tackle the disadvantages of the either procedures if performed in isolation.

Expert consensus from the American Society of Cardiology[64] have finalized the following guidelines and recommendation for management of patients with aortic dissection:

- Endovascular interventions are useful in Stanford Type B acute dissections particularly if the patients’ comorbidities make it a high-risk case for surgical intervention
- For Stanford Type A dissection involving ascending aorta, surgery is better as it allows resection of involved dissected portion with total or partial repair and grafting
- In the presence of intimal defect without intramural hematoma in ascending aorta, emergency surgery is recommended while endovascular stenting is preferred in descending aorta involvement. In the presence of intimal defect with intramural hematoma in ascending aorta, patient needs to be stabilized first and definitive treatment delayed until hematoma resorbs. Once patient is stabilized, endovascular treatment is preferred in descending aorta involvement
- In asymptomatic patients with descending thoracic aortic aneurysms <5 cm who have very low risk of rupture, it is recommended that endovascular stenting need not be performed until other indications apply such as malperfusion syndrome, risk of aortic rupture, refractory chest pain, or uncontrollable severe hypertension despite medical therapy
- Elective procedure either open surgery or endovascular treatment needs to be performed when maximum orthogonal aortic diameter is >5.5 cm even in an asymptomatic patient
- Endovascular stenting of saccular aneurysms is ideal as they are localized aneurysms and aorta cephalad and caudal to the aneurysm is usually normal providing a good landing zone for the stent graft.

Before performing thoracic aortic stent grafting, CT angiogram must be carefully reviewed to evaluate for (i) morphology of the aortic arch, (ii) site of origins of main aortic arch branches with respect to superior margin of the aneurysm, (iii) tortuosity and ectasia of the descending aorta along its entire length, (iv) site of mesenteric vessel origins relative to the inferior margin of the aneurysm, (v) comparative diameters of proximal and distal landing zones, (vi) tortuosity and diameter of the iliofemoral arteries, and (vii) presence of graft in abdominal aorta. In cases where graft needs to cover the LSCA origin, bilateral vertebral arteries and basilar artery should also be evaluated.[59]

**Problems associated with endovascular treatment**

- Complications of endovascular treatment.

Problems during procedure: Stent graft migration or
tortion, complications related to size of the stent graft, presence of occult intimal tear in the descending aorta, Type I endoleak.

Problems during follow up: Post implantation syndrome, neurological complications, persistent Type I endoleak, Type II endoleak, progressive aneurysm, new intimal tear or mechanical failure of the stent graft.[38]

- Cost of endovascular treatment: high cost as compared to surgery prevents more widespread use especially in developing countries.

Regardless of whether surgical or endovascular treatment method was used, if residual dissection remains, then the patient can develop late aneurysmal degeneration and rupture of the false lumen. Hence, these patients require serial follow-up imaging, regular blood pressure monitoring, and negative inotropic medical therapy. Follow-up study is required for at least 3–5 years to look for endoleak and stent dislodgment or migration as aneurysms can increase in length causing kinking or foreshortening of stent.[38]

Summary

The management of acute aortic dissection involves either open surgical approach or endovascular approach with stent graft placement. However, with advances in interventional radiology, endovascular approach is sought more often. Various studies have reiterated the fact that endovascular approach in case of aortic dissection is feasible with fewer complications and reduced morbidity and mortality and better outcomes as compared to the open surgical approach, especially in elderly or patients with comorbidities. This is especially true with right aortic dissections where Type B dissection is more common with associated aberrant LSCA with/without Kommerell’s diverticulum causing technical difficulties for open surgical approach.

We have reported our experience of treating acute complicated Type B dissection in a 45-year-old male who had Type II RAA branching pattern associated with aberrant LSCA. This case report is first of this kind from India demonstrating complete endovascular treatment of Type B dissecting aortic aneurysm involving aortic arch and descending aorta and abdominal aorta up to the level of renal arteries by deploying endovascular stent graft. We were also successful in avoiding a left subclavian-carotid bypass in a dissection involving arch and descending aorta with two entry points of intimal tear, one of which located distal to the right subclavian artery origin would have otherwise required bypass if treated surgically.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Hastreiter AR, D'Cruz IA, Cantez T, Namin EP, Licata R. Rightsided aorta. I. Occurrence of right aortic arch in various types of congenital heart disease. II. Right aortic arch, right descending aorta, and associated anomalies. Br Heart J 1966;28:722-39.
2. Bavaria JE, Appoo JJ, Makaronou MS, Verter J, Yu ZF, Mitchell RS. Gore TAG Investigators. Endovascular stent grafting versus open surgical repair of descending thoracic aortic aneurysms in low-risk patients: A multicenter comparative trial. J Thorac Cardiovasc Surg 2007;133:369-77.
3. Bodine JA, D'Souza VJ, Formanek AG. An unusual type of dissecting thoracic aneurysm in association with right aortic arch. Vasa 1982;11:223-8.
4. Roan P, Parish S, Buja LM, Estrera A, Mills L, Atkins J, et al. Dissecting aortic aneurysm involving a right-sided aortic arch. Am J Cardiol 1979;44:381-4.
5. Floten HS, Rose DM, Cunningham JW Jr. Surgical therapy of a dissecting aortic aneurysm involving a right-sided aortic arch. J Am Coll Cardiol 1984;4:1058-61.
6. Obteki H, Itoh T, Watanabe Y, Ueno T, Minato N, Natsuki M. A dissecting aneurysm involving a right-sided arch, right descending aorta and mitral regurgitation. Thorac Cardiovasc Surg 1987;35:235-7.
7. Sugiwa T, Yasuda R, Maqara T, Nishikawa T. Surgical therapy of ruptured aortic aneurysm involving a Shuford type-3 right-sided aortic arch. Vasa 1990;38:2474-8.
8. Maeda M, Murase M, Tomida Y, Murakami F, Teranishi K. A successful surgical case of DeBakey IIIb dissecting aortic aneurysm in association with right aortic arch. Vasa 1990;38:1231-5.
9. Fukushima K, Yamauchi T, Take A, Misawa Y, Katoh M, Hasegawa T. Two cases of dissecting aortic aneurysm associated with the right-sided aortic arch. Vasa 1991;39:2255-60.
10. Kanoh M, Hasegawa T, Katoh M, Kamisawa O, Kawashima T, Fuse K. Rupture of dissecting aortic aneurysm associated with the right-sided aortic arch and anomalous course of the left brachiocephalic vein – A case report. Vasa 1995;43:1086-91.
11. Osako M, Ueda T, Mori A, Mitsumaru A, Yozu R, Kawada S. A successful surgical case of a dissecting aortic aneurysm with right-sided aortic arch and right-sided descending aorta. Nihon Kyobu Geka Gazaki Zasshi 1996;38:1231-5.
12. Masiello P, Mastrogiovanni G, Santoro G, Triumbi F, Naimoli G, Di Benedetto G. Type B aortic dissection involving an isolated right-sided aortic arch. Ann Thorac Surg 1996;62:887-8.
13. Ko SF, Ng SF, Fu M, Lo PH, Cheng YF, Lee TY. Dissection of retrooesophageal aortic diverticulum and descending aorta in a patient with right aortic arch: Magnetic resonance demonstration. CardioVascular and Interventional Radiology 1996;19:438-41. doi:10.1007/BF02577635.
14. Senthil V, Treasure T. Type B dissection involving a right-sided aortic arch. Eur J Cardiothorac Surg 1996;10:477-9.
15. Nomoto T, Ueda Y, Sugita T, Izumi C. A case of type A dissection involving right aortic arch. Eur J Cardiothorac Surg 1997;12:922-4.
16. Moizumi Y, Komatsu T, Nagaya K, Sawamura Y, Sakurai M.
Tabayashi K. Type A aortic dissection involving a right-sided aortic arch. J Cardiovasc Surg (Torino) 1999;40:117-9.
17. Minato N, Rikitake K, Murayama J, Ohnishi H, Takarabe K. Surgery of the dissecting aneurysm involving a right aortic arch. J Cardiovasc Surg (Torino) 1999;40:121-5.
18. Kuki S, Taniguchi K, Miyagawa S, Takano H. Dissecting thoracoabdominal aortic aneurysm associated with an isolated right-sided aortic arch. Eur J Cardiothorac Surg 2000;17:614-6.
19. Yamazaki I, Imoto K, Ichikawa Y, Kondo J, Takashani Y. Stent-graft treatment of type B aortic dissection involving the right aortic arch: Case report. Jpn Circ J 2000;64:727-8.
20. Tsunemi K, Hasegawa S, Horimoto H, Nishimoto Y, Fukumoto H, Asada K, et al. A successful surgical case of chronic DeBakey IIIb dissecting aortic aneurysm associated with right-sided aortic arch. Kyobu Geka 2001;54:1053-7.
21. Kaneda T, Lemura J, Zhang Z, Inoue T, Onoe M, Kitayama H, et al. A case of Standford type B aortic dissection involving a right-sided aortic arch with mirror-image branching and right-sided descending aorta. Thorac Cardiovasc Surg 2001;49:51-3.
22. Born C, Forster A, Rock C, Pfeifer KJ, Rieger J, Reiser M. A case of an upper gastrointestinal bleeding due to a ruptured dissection of a right aortic arch. Cardiovasc Intermed Radiol 2003;26:506-9.
23. Paziourou KE, Siminelakis S, Sismanidis S, Dismitsas L, Matsagas M, Papadopoulos G, et al. Successful full repair of an acute type A dissecting aortic aneurysm associated with a right-sided aortic arch and right-sided descending thoracic aorta. J Cardiovasc Thorac Surg 2005;128(4, MeetingAbstracts):4165-4165.
24. Hori D, Tanaka M, Yamaguchi A, Adachi H. Type A aortic dissection, right-sided aortic arch, and thoracic aortic aneurysm. Asian Cardiovasc Thorac Ann 2004;40:670-9.
25. Kim SY, Lee YS, Bae KR, Lee JB, Lee S, Kwon OC. A case of type B dissecting aneurysm involving right sided aorta with Kommerel’s diverticulum. Korean J Intern Med 2010;25:327-30.
26. Obitsu Y, Koizumi N, Iwahashi T, Saiki N, Shigematsu H. Surgical repair for aortic dissection accompanying a right-sided aortic arch. J Cardiothoracic Surg 2010;5:35.
27. Sato S, Matsuda H, Fukuda T, Ogino H. Staged hybrid repairs of acute type A aortic dissection involving the right aortic arch with retroesophageal aortic segment. EJVES Extra 2011;21:e13-6.
28. Kim JB, Yang DH, Kang JW. Right aortic arch and an aberrant left subclavian artery arising from a Kommerell diverticulum complicated by acute aortic dissection. J Thorac Cardiovasc Surg 2012;144:978-9.
29. Croccia MG, Levantino M, Cioni R, Bortolotti U. Endovascular stenting for type B dissection involving a right-sided aortic arch. Interact Cardiovasc Thorac Surg 2012;15:304-6.
30. Ebnner L, Huber A, Christie A. Right aortic arch and Kommerell’s diverticulum associated with acute aortic dissection and pericardial tamponade. Acta Radiologica Short Reports. 2013;2:2047981613476283. doi:10.1177/2047981613476283.
31. Zhou W. Endovascular repair of a type B aortic dissection with a right-sided aortic arch: Case report. J Cardiothoracic Surg 2013;8:18.
32. He H, Yao K, Nie WP, Wang Z, Liang Q, Shu C. Endovascular treatment for acute type B aortic dissection involving a right-sided aortic arch and Kommerell’s A case report and review of the literature. Ann Vasc Surg 2015;29:841.e5-12.
33. Hsu HL, Huang CY, Chen JS. Total endovascular repair for acute type B dissection in the setting of right aortic arch with aberrant left subclavian artery and Kommerell diverticulum. J Thorac Cardiovasc Surg 2015;150:409-11.
34. Kau T, Sinzig M, Gasser J, Lesnik G, Rabitsch E, Celedin S, et al. Aortic development and anomalies. Semin Intervent Radiol 2007;24:141-52.
35. Knight L, Edwards JE. Right aortic arch. Types and associated cardiac anomalies. Circulation 1974;50:1047-51.
36. Cinà CS, Althami H, Pasenau J, Abouzaher L. Kommerell’s diverticulum and right-sided aortic arch: A cohort study and review of the literature. J Vasc Surg 2004;39:131-9.
37. Criado FJ. Aortic dissection: A 250-year perspective. Tex Heart Inst J 2011;38:694-700.
38. Svensson LG, Kouchoukos NT, Miller DC, Bavaria JE, Coselli JS, Curi MA, et al. Expert consensus document on the treatment of descending thoracic aortic disease using endovascular stent-grafts. Ann Thorac Surg 2008;85 1 Suppl: S1-41.
39. Conrad MF, Ergul EA, Patel VJ, Paruchuri V, Kwolek CJ, Cambria RP. Management of diseases of the descending thoracic aorta in the endovascular era: A Medicare population study. Ann Surg 2010;252:603-10.
40. Gopaldas RR, Huh J, Dao TK, LeMaire SA, Chu D, Bakaeeen FG, et al. Superior nationwide outcomes of endovascular versus open repair for isolated descending thoracic aortic aneurysm in 11,669 patients. J Thorac Cardiovasc Surg 2010;140:1001-10.
41. Greenberg RK, Lu O, Roselli EE, Svensson LG, Moon MC, Hernandez AV, et al. Contemporary analysis of descending thoracic and thoracoabdominal aortic repair: A comparison of endovascular and open techniques. Circulation 2008;118:808-17.
42. Nienaber CA, Zannetti S, Barbieri B, Kische S, Scharek W, Rehders TC. INSTEAD study collaborators. Investigation of the INSTEAD trial – a prospective, multicenter, European randomized trial. Am Heart J 2005;149:592-9.
43. Dake MD, Kato N, Mitchell RS, Semba CP, Razavi MK, Shimo T, et al. Endovascular stent-graft placement for the treatment of acute aortic dissection. N Engl J Med 1999;340:1546-52.
44. Okada K, Sueda T, Orihashi K, Watari M, Naito A. Endovascular stent-graft repair for thoracic aortic aneurysm associated with right-sided aortic arch. J Thorac Cardiovasc Surg 2001;122:185-6.
45. Nomura Y, Yuri K, Kamura H, Itoh S, Matsumoto H, et al. Endovascular repair of thoracic aortic aneurysm associated with right-sided aortic arch: Report of two cases. Gen Thorac Cardiovasc Surg 2010;58:556-61.
46. Tran TP, Khoynezhad A. Current management of type B aortic dissection. Vasc Health Risk Manag 2005;5:53-63.
47. Rousseau H, Cosin O, Marcheix B, Chabbert V, Midulla M, Dambrin C, et al. Endovascular treatment of thoracic dissection. Semin Intervent Radiol 2007;24:167-79.
48. Eggebrecht H, Nienaber CA, Neuhausé R, Baumgart D, Kische S, Schmermund A, et al. Endovascular stent-graft placement in aortic dissection: A meta-analysis. Eur Heart J 2006;27:489-98.
49. Leurs LJ, Bell R, Degrieck Y, Thomas S, Hobo R, Lundbom J. EUROSTAR: UK Thoracic Endograft Registry Collaborators. Endovascular treatment of thoracic aortic diseases: Combined experience from the EUROSTAR and United Kingdom Thoracic Endograft registries. J Vasc Surg 2004;40:670-9.
51. Kato N, Shimono T, Hirano T, Ishida M, Yada J, Takeda K. Transluminal placement of endovascular stent-grafts for the treatment of type A aortic dissection with an entry tear in the descending thoracic aorta. J Vasc Surg 2001;34:1023-8.

52. Svensson LG, Kim KH, Blackstone EH, Alster JM, McCarthy PM, Greenberg RK, et al. Elephant trunk procedure: Newer indications and uses. Ann Thorac Surg 2004;78:109-16.

53. Chiesa R, Melissano G, Bertoglio L, Calliari F. Hybrid repair of an aortic arch aneurysm with complex anatomy: Right aortic arch and anomalous origin of supra-aortic vessels. J Vasc Surg 2007;46:128-30.

54. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE, et al. Guidelines for the Diagnosis and Management of Patients with Thoracic Aortic Disease. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM. Wolters Kluwer Health Medical Research, Lippincott Williams and Wilkins, American College of Cardiology Foundation and American Heart Association; March, 2010.

55. Findeiss LK, Cody ME. Endovascular repair of thoracic aortic aneurysms. Semin Intervent Radiol 2011;28:107-17.

56. Won JY, Lee DY. Problems encountered during and after stent graft treatment of aortic dissection. In: Thoracic Aortic Diseases. 2006, Springer Berlin Heidelberg publisher; Edited by: Rousseau H, Jean-Philippe V, Jean-Francois H. Ch. 21. p. 209-2. doi: 10.1007/3-540-38309-3_21.