Review Article on Cardiac Surgery

The changing surgical approach to proximal aortic aneurysm disease

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Abstract: Proximal aortic aneurysm can be life threatening in emergency cases when it presents with acute type A aortic dissection or rupture which requires immediate surgical intervention. However, it can be silent and be there for several years. Over the last two decades, there has been dramatic shift from a full sternotomy, elective repair of proximal aortic aneurysm to stenting the aneurysm and minimal invasive techniques to repair such pathologies. Current guidelines indicate urgent operative management for proximal aneurysmal disease when symptomatic, growth rate >0.5 cm per year or size ≥5.5 cm. However, open surgery is associated with high mortality and morbidity rates, and therefore the surgical procedures to proximal aneurysm disease has evolved. Our paper presents current literature on the changing surgical approach to proximal aneurysm disease, which cardiovascular surgeons and physicians must be familiar with for managing these highly complex cases.

Keywords: Aortic aneurysm; proximal aneurysmal disease; thoracic endovascular aortic repair (TEVAR); aortic root replacement; ascending aorta replacement; hybrid procedure

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Introduction

Current incidence of thoracic aortic aneurysm is approximately 10 in 100,000 patients per year which is increased from 5.9 in 100,000 since 1980s, this is purely because of the advancement in medical practice and imaging studies that can identify more cases of thoracic aortic aneurysm than ever before (1,2). The yearly incidence of either aortic dissection or rupture in these patients was roughly 3.5 per 100,000 patients (3).

Proximal aortic aneurysmal disease can involve any part of the ascending aorta to the proximal aortic arch up to the origin of innominate artery. It could be either segmental aneurysmal disease involving only the ascending aorta, or involve the entire proximal aorta. Proximal aortic aneurysms can be classified as true or false, with the majority being true aneurysms comprising of normal histologic components of the aorta (4). However, false aneurysms present in a minority of cases, commonly following trauma to the aortic wall (5).

Presence of proximal aortic aneurysm poses a risk for rupture or dissection if left untreated on timely manner and therefore endanger life. The mortality rate from such emergency presentations is varying, it can be as high as 50% if not treated within first 48 hours of presentation (6), while It can be less than 20% if operated on in specialized centre by an experienced surgeon (7,8). Nevertheless, in the establishment of such aneurysmal disease, prophylactic surgical intervention has played a key role in reducing the incidence of such catastrophic events (9), elective surgical

intervention at early stage have a mortality rate under 5% (9) and it can significantly reduce future chances of life threatening emergency presentation.

In the emergency setting, the gold standard method is through open repair of the dissected proximal aorta with or without utilization of brain protection mechanisms (10-12). Such form of intervention ranges from isolated replacement of the ascending aorta to a full aortic root replacement (Bentall procedure) with full-arch replacement in extreme cases (13). The decision to choose type of the procedure is multi-factorial; however the two key factors used as solid base for such decision are tear entry sites and the haemodynamic status of the patient (14).

Prophylactic root surgery

Presence of proximal aortic aneurysm mandates regular follow up and monitoring the aneurysm and careful planning for early surgical intervention prior to any catastrophic events. Current guidelines recommends an early, elective surgical repair of the aneurysm if the size is ≥5.5 cm, or there is an annual increase in aneurysm size of >0.5 cm, however the threshold is much lower in patients with connective tissue disorders such as Marfan syndrome (≥4.5 cm or an annual increase in size of 0.2 cm, class IIa, level C evidence) (15,16). However, size itself is not the only clinical factor in the entire decision process to operate on patients with established aortic aneurysm, there are other risk factors that can contribute to such process, including body surface area, positive family history of aortic dissection, presence of hypertension, having bicuspid aortic valve, connective tissue disorder, previous cardiac surgery (10,17). The recommended size for prophylactic root surgery by the guidelines has been challenged by many large studies, among them is the reported outcomes of International Registry of Aortic Dissection (IRAD) that reported 60% of their patients had aneurysm size of <55 mm (18). Several studies have published their data of performing early prophylactic aortic root replacement in the essence to reduce the chance of acute type A aortic dissection and its associated mortality and morbidities (19-21). This is of particular importance in patients with connective tissue disorders and aortopathies such as Marfan and Ehlers-Danlos syndrome (9). Aalberts *et al.* (22) studied 53 patients in planning their prophylactic root surgery based on body surface area rather than size alone, they reported satisfactory outcomes and concluded that such method can be of effective in preventing future aortic dissection. Similar favourable outcomes were reported by Shimizu *et al.* (23) in their cohort of 50 patients, the group that underwent elective surgical repair had better perioperative outcomes when compared to those who presented with emergency dissection, therefore they suggested an early aortic root operation in Marfan patients to prevent future dissection. A further study by Alexiou *et al.* (24) of 65 patients reported similar satisfactory outcomes when compared between elective repair *vs.* emergency repair of aneurysm. Furthermore, elective surgery was found to have better outcomes for patients than emergency intervention, with 5-year survival rate of approximately 85% in elective patients compared to 37% in emergency cases (25).

Open surgical approaches

The choice of surgical repair is dependent on several factors, the key ones are: surgical acuity, presence or absence of connective tissues disorders and extend of the aneurysm itself. The gold standard surgical treatment for such aneurysmal disease is aortic root and ascending aorta replacement, especially in the presence of connective tissue disorders (26-28). Isolated ascending aorta replacement is performed when there is a segmental aneurysm and in the absence of Marfan or other connective tissue disorder. However, numerous studies have reported that Bentall procedure (total aortic root replacement) and its variants as a reliable surgical procedure with excellent durability of the repair (29-32). This surgical option is limited by lifelong anticoagulation requirement and poor patient adherence when a mechanical prosthesis is used. Consequently, bioprosthetic surgical procedures have been introduced and have become an attractive alternative in patients whom lifelong anticoagulation is contraindicated, but limited tissue graft availability and its durability may contribute to its infrequent use compared to mechanical conduits (26). The choice of replacing aortic root with ascending aorta is gold standard in Marfan and other connective tissue disorders (33). Hagl *et al.* have reported excellent short and long term outcomes in utilizing Bentall procedure for proximal aortic aneurysm repair in 142 patients of their series (34).

With advancement in surgical practice and during the early 1990s, several other technical procedures have come into practice as alternate to Bentall procedure in the form of valve sparing aortic root replacements (David and Yacoub's procedures), in such procedures, the diseased aortic root is replaced while the aortic valve is spared and

thus no requirement for anti-coagulation and less risk of re-operation due structural degeneration as in biological prosthesis, additionally, lower risk of endocarditis (33). However, the major drawback of this procedure was the rate of progression of aortic valve insufficiency and requirement for re-operation at later stage which is considered as high risk (35). Kallenbach *et al.* (36) in their study of 548 patients that underwent four different techniques of open repairs, noted that all these techniques had low mortality rates and low rate of reoperation and prevent occurrence of future aortic dissection, of particular note that David's procedure showed very good early and mid-term results. Similarly, Schneider *et al.* reported comparable and very good outcomes of performing VSRR *vs.* Bentall procedure in patients with proximal aortic aneurysm (37). While de Oliveira *et al.* (38), although, has reported similar survival rates between VSRR against Bentall in 105 patients, however they reported a lower rate of valve-related complications in VSRR group of patients and thus suggested utilization of this technique when there is no crucial evidence of dilated aortic annulus.

Role of minimal access approach

Traditionally any operations on aortic root were performed through full sternotomy to have adequate exposure of the heart and great vessels. However, as with any other surgical practice, the era of practice is diverting toward minimal access surgery that aims to provide better postoperative outcomes, mainly potential shorter hospital stay, less chance of sternal wound infection, less pain and ultimately better cosmesis for the patient (39). The practice of minimal access technique in aortic root surgery has evolved dramatically over the last 10 years. The initial technique was applied to Bentall procedure through mini-sternotomy approach via upper J mini-sternotomy. Shrestha *et al.* (40) have reported their experience in utilizing mini-sternotomy *vs.* full sternotomy for VSRR procedure, their cohort were composed of 40 patients between both groups, they have noted no significant differences in the operating time between (280.3±78.9 *vs.* 248.6±32.3 minutes), although intensive care unit (ICU) stay was longer in full sternotomy (2.1±1.5 *vs.* 1.3±0.6 days respectively), however total hospital stay was shorter in full sternotomy group (9.1±2.7 *vs.* 10.4±6.8 days respectively). Based on their reported outcomes, they have recommended mini-sternotomy as safe alternative technique to full sternotomy in carefully selected patients.

In a separate study, Lentini *et al.* (41) analyzed 102 patients that underwent upper mini-sternotomy for proximal aortic surgeries; they reported ICU stay of 2.2±2.0 days while total hospital stay of 7.8±4.6 days, there was only 1 case of sternal wound dehiscence and 0% 30-day mortality. On the contrary to above, Wachter *et al.* (42) recommend J-upper mini-sternotomy for patients undergoing elective VSRR, if operated on by experienced surgeon. Their conclusion comes from the reported data of 192 patients that underwent elective VSRR and reported no difference in ICU and LOS between matched group of mini *vs.* full sternotomy group of patients (P=0.07 and 0.17 respectively). However, they reported a higher rate of additional cardiac procedures in full sternotomy patients (57.4% *vs.* 13.9%, P<0.001), there were also higher rate of blood loss (1,080±903 *vs.* 528.7±528.9 mL respectively, P<0.001) while no difference in rate of blood transfusion (59.3% *vs.* 41.7%, P=0.133). Finally, they reported no difference in 30-day mortality rates.

In the largest study of reporting outcomes between mini-sternotomy *vs.* full sternotomy in aortic root surgery by Levack *et al.* (43), they concluded that J mini-sternotomy is safe and feasible technique in isolated primary elective proximal aortic surgeries, however the choice of the technique should be carefully planned for each patient based on several pre-operative parameters. Their study was based on 966 propensity matched patients (483 patients in each group) between mini *vs.* full sternotomy. There was no difference in the post-operative rate of stroke (0.625, P=1.0), renal failure (P=0.3), sternal wound infection (0% in both) and operative mortality (0.415% *vs.* 0%, P=0.16). Intra-operatively, there was no difference in the rate of blood transfusion (P=0.08), and no difference during postoperative period (P=0.6). Finally, ICU and total hospital stay were much shorter in mini-sternotomy patients (P<0.0001 in both cases).

Stenting in proximal aneurysmal disease

Thoracic endovascular aortic repair (TEVAR) offers a minimally invasive approach in the management of proximal aneurysm disease and has evolved as an alternative procedure to open repair in selected cases (44). TEVAR has grown in popularity since its inception in the early 1990s and often became the only viable option in high-risk, inoperable patients with advanced age and severe comorbidities (45,46). Although, endovascular stent grafts of the ascending aorta are predominantly utilized in the

treatment of acute type A aortic dissection and aortic aneurysm/pseudoaneurysm (44). Current literature supports the use of endovascular therapy in the management of other thoracic aortic diseases, including intramural hematoma (47-49), aortic rupture (50-52), and penetrating atherosclerotic ulcers (53). However, no TEVAR-specific risk stratification tool is available to predict endovascular outcomes in proximal aneurysmal disease and necessitates the establishment of such tool (54).

TEVAR has relatively lower mortality and paraplegia rates compared to conventional open repair, but is not without risk or limitation (55-59). Still, endovascular therapy has anatomical restrictions and exposure of patients to extensive radiation times (60). An important complication of TEVAR to note is endoleaks which can be difficult to treat and complicated. Most endoleaks can be prevented with careful consideration to morphological details, such as landing zone length, multiple stents utilization, overlapping segments' length as well as angulation in the aorta (61).

The use of TEVAR is mainly reserved for high risk patients who present with emergency and deem inoperable for open repair in cases of acute type A aortic dissection or in cases of chronic dissection (62). Roselli *et al.* (47) analyzed 22 patients that underwent TEVAR for ATAAD, intramural haematoma, chronic dissection, pseudoaneurysm or aorta-cardiac fistula. They reported that stenting in acute or chronic diseases of ascending aorta is a feasible and reliable technique in high risk patients and can give acceptable outcomes. Similarly, Piffaretti *et al.* (63) concluded that TEVAR is a reliable, effective and safe method in treating ascending aortic pseudoaneurysm and penetrating aortic ulcers, and in highly selected patients. Finally, Muetterties *et al.* (44) performed a systematic review of stenting in proximal aortic pathologies; they have identified 52 articles with a total of 138 patients. There were different pathologies within the reported cohort, over 50% of the cases were ATAAD and 28% were aortic pseudoaneurysms. They concluded that current trends in using TEVAR in managing such patients with a range of ascending aortic pathologies are reported successfully and the reported mortality in such high-risk cohort is comparable to open repair techniques.

Conclusions

Although open proximal aortic surgery is the current gold standard treatment for proximal aneurysm disease, there is a shift in surgical approach of this complex condition. TEVAR and hybrid procedures offer safer alternatives in high-risk patients. Short-term results are encouraging for these innovative techniques, but only long-term follow-up studies will elucidate their effectiveness. Constant innovation is changing the surgical approach to proximal aneurysmal disease for optimal patient outcome.

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