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REVIEW ARTICLE

Coronary artery disease in aortic aneurysm and dissection

Joon Chul Jung[1] · **Kay-Hyun Park**[1]

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Abstract
Coexisting coronary artery disease is a significant risk factor of untoward outcomes after surgical and endovascular aortic repair. This article reviewed the data, consensus, and remaining controversy about the diagnosis and management of coexisting coronary artery disease in the patients who require intervention for aortic aneurysm and dissection. It can be summarized as follows: (1) the current guidelines generally recommend the same diagnostic algorithm, including indications of coronary artery angiography, as one for non-surgical patients; (2) they also recommend the same indications of coronary revascularization; and (3) there are minor, but important, remaining issues regarding the details of management and surgical techniques most of which are still at the discretion of individual surgeons and institutions. Because it is not likely to get large-scale investigational data about these issues, the collection of individual experiences should be promoted in future scientific meetings to build up the consensus.

Keywords Coronary artery disease · Aortic aneurysm · Aortic dissection · Coronary artery

Introduction

Surgical and endovascular repair of aortic aneurysm and aortic dissection still carry a significant risk of morbidity and mortality [1, 2]. Coexisting coronary artery disease (CAD) is one of the important risk factors of untoward outcomes after aortic interventions and its prevalence is increasing in parallel with the increasing number of interventions and age of the patient. The purpose of this article is to summarize the data, consensus, and remaining controversy about the diagnosis and management of combined CAD and aortic diseases.

Prevalence of CAD and impact of perioperative myocardial infarction

The prevalence of CAD differs according to the etiology and location of the aortic aneurysm. CAD is common in patients having an abdominal aortic aneurysm (AAA), descending thoracic aneurysm (DTA), or thoracoabdominal aortic aneurysm (TAAA). The reported prevalences range from 31 to 90% [3–5] and 25 to 51%, respectively [6]. Considering that degenerative or atherosclerotic aneurysm is the prevailing etiology in those locations, such a high prevalence is not surprising because CAD shares the common risk factors with AAA and DTA/TAAA. On the contrary, an aneurysm of the ascending aorta or aortic arch is less frequently associated with CAD and the prevalence was reported as below 20%. The lower incidence is explained by the different pathological backgrounds, as medial degeneration is the most important cause of aneurysms in this location [7]. Furthermore, even a protective effect of ascending aortic aneurysm against CAD and myocardial infarction (MI) has been suggested [8]. While aortic dissection is also less frequently associated with CAD with the prevalence ranging from 12.7 to 42.9% [7, 9], type B aortic dissection shows a higher prevalence of CAD and aortic atherosclerosis than that of type A aortic dissection [10, 11].

✉ Kay-Hyun Park
drkhpark@gmail.com

[1] Department of Thoracic and Cardiovascular Surgery, Seoul National University Bundang Hospital, Seoul National University College of Medicine, Bundang-gu, Seongnam-si, Gyeonggi-do 13620, Republic of Korea

In large series of AAA and DTA/TAAA repairs, the incidence of perioperative myocardial infarction (PMI) has been reported as 3% [12, 13]. The incidence of PMI in surgical repair of the ascending aorta or aortic arch does not seem to differ [14]. Once PMI occurs, it has a significant negative impact on both early and late survival [15].

Management of coexisting CAD in elective aortic surgery

Preoperative evaluation for CAD

The current guidelines categorize aortic surgery into high-risk surgery for cardiac complications [16–18]. Considering the high prevalence of CAD and the negative impact of PMI, it is important to detect and appropriately manage the significant CAD. Coronary artery angiography (CAG) is the gold standard for the diagnosis of CAD, and it is a common practice to perform preoperative CAG for aged patients who undergo elective aortic surgery via median sternotomy, although the age criteria vary from 50 to 60 years old among centers. However, for surgical or endovascular repair of descending aorta, preoperative CAG is not recommended routinely but only according to the results of first-line non-invasive testing.

In the European Society of Cardiology (ESC) and the European Society of Anaesthesiology (ESA) guidelines, non-invasive testing including echocardiography, dipyridamole myocardial perfusion imaging, stress echocardiography, and cardiac magnetic resonance imaging are recommended first in the presence of two or more cardiac risk factors and poor functional capacity [16]. The American guideline is stricter and recommends exercise or pharmacologic stress testing only if they will impact the physician's decision or perioperative care [17]. The Japanese guideline is not different in this context [18].

The availability and preference of non-invasive diagnostic tools vary among centers. Lacking in the previous studies and current guidelines is the safety of the examinations provoking myocardial stress such as dobutamine stress echocardiography, especially in patients who have symptomatic aneurysms or signs of impending rupture. Therefore, the details of the diagnostic algorithm must be tailored considering the institutional circumstances and individual patient factors.

The current guidelines do not consider that the indications of CAG are different between the patients who undergo aortic surgery and the general patients who do not have aortic diseases (non-surgical patients). CAG is not recommended unless they have a recent MI, unstable chest pain, or myocardial ischemia proven by non-invasive testing. The patient with stable chest pain is also not recommended to undergo CAG [16]. This recommendation is based on the randomized controlled trials which demonstrated no benefit of routine coronary artery revascularization before elective vascular surgery in terms of PMI and death [19, 20].

Coronary computed tomography (CT) angiography has emerged as a non-invasive alternative to conventional CAG for screening of CAD in general patients and even for preoperative evaluation before cardiac and aortic surgery. Although no recommendation is found in the current guidelines, evidence on the usefulness and validity of coronary CT angiography is increasing. In patients with stable angina, coronary CT angiography showed an excellent role as a gatekeeper before invasive CAG and as a potential alternative to functional stress testing [21–24]. We think that concomitant evaluation of the coronary arteries with an appropriate protocol is beneficial if the patient is to undergo a high-resolution CT scan for aortic imaging. In the authors' practice, preoperative CAG is omitted if significant CAD can be ruled out by coronary CT angiography. Even in the absence of coronary CT angiography, we also tend to omit preoperative CAG if the coronary arteries are completely free from calcified plaques, which would be visible in the high-resolution CT scan.

Preemptive or concomitant coronary artery revascularization

Most previous studies investigated the patients with AAA. Recent randomized controlled trials showed no benefit of routine coronary revascularization in stable patients with coexisting CAD and AAA [19, 20]. All guidelines recommend that the indication for preoperative coronary artery revascularization in high-risk surgery is similar to the patients in the non-surgical setting, especially for stable or asymptomatic patients [16–18]. In patients with recent MI, the safety of delaying elective aortic surgery should be discussed by the expert team, while prophylactic coronary artery revascularization is recommended in selected cases. In some studies, prophylactic percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG) did not improve the long-term outcomes, compared to the medical treatment, even though it was performed only in the patients with angina, ischemia proven by stress testing, reduced ejection fraction, or multi-vessel coronary stenosis [25].

Selection of intervention type

Once the decision has been made to perform coronary revascularization before aortic surgery, there are still a few issues to be addressed: (1) the type of intervention (PCI vs. CABG); (2) appropriate interval between the coronary revascularization and aortic surgery; (3) selection of coronary

stents or bypass conduit; (4) safety of discontinuing antiplatelet medications, especially after PCI using drug-eluting stent (DES); and (5) risk of bleeding in aortic surgery performed in patients continuing antiplatelet medications.

As for the selection of intervention type, it would be reasonable to assume that the long-term cardiac outcomes would not be much different from that of the general patient population who do not undergo aortic surgery. There is also the same room for controversy which exists in the non-surgical settings. The Bypass Angioplasty Revascularization Investigation (BARI) trial demonstrated no significant difference in mortality, nonfatal MI, and length of hospital stay between CABG or PCI performed before noncardiac surgery [26]. In a study from Veterans Affairs Cooperative trial, CABG showed a significantly lower rate of PMI compared to PCI in elective vascular surgery cases. This result was attributed to more complete coronary revascularization achieved by CABG [27].

The other issues remain more controversial because of the paucity of data. Girardi et al. reported the results of PCI before elective open repair of DTA and TAAA. In 44 patients who underwent aortic surgery at 4 to 6 weeks after PCI using bare metal stents, no incidence of aortic rupture was reported during the interval. Stent thrombosis or MI did not occur after the aortic surgery, either [28]. A small series reported by Rajbanshi et al. also showed the safety of deferring DTA/TAAA repair for a median of 37.2 days after preoperative coronary revascularization, most of which were CABG [29]. The above data is far from being sufficient in answering the questions raised in real-world practice. As it is not likely to get large-scale data regarding these issues, collection of personal and institutional experiences and establishing some kind of expert consensus would be more practical for guiding less experienced colleagues.

Concomitant CABG and aortic surgery

CABG can be performed concomitantly with ascending aortic and aortic arch replacement. Concomitant CABG with elective total arch replacement, which carries the highest risk among the proximal aortic surgery, recorded acceptable mortality in the range of 3.6% and 7.6% in the previous studies [30–32]. The slightly higher mortality was attributed to the higher prevalence of comorbidity than to the CABG itself.

Because coronary arteries can be approached by the left thoracotomy, concomitant CABG and DTA/TAAA repair is a feasible option. However, there have been no large-scale studies that investigated the safety and risk of this strategy. A few reports can be found regarding concomitant CABG and AAA repair. When selectively performed in fit patients with few morbidities, the outcome seems to be acceptable [33].

The most common scenario of combined CABG would be one performed with ascending aorta and/or arch replacement, in which myocardial protection becomes an important issue. In this scenario, the basic principles and the individual surgeon's preferred strategy of myocardial preservation would not be much different from that for isolated CABG procedures. However, while adequate myocardial protection must be ensured, attention should also be paid to minimize the duration of myocardial ischemia and cardiopulmonary bypass. Because moderate or deep hypothermia is adopted in most cases of proximal aortic repair, making the best use of cooling and rewarming time for coronary artery graft anastomoses can enhance the procedural efficiency and reduce myocardial ischemic time. In this context, a combination of the different technical options such as performing anastomosis in the beating heart, cold fibrillating but perfused heart, or in cardioplegic arrest comes in handy especially when multi-vessel grafting is needed.

In Fig. 1, we summarized our decision-making algorithm for diagnosis and management of asymptomatic CAD in the patients scheduled for elective aortic intervention. In our institution, we apply the same indication and type of coronary revascularization regardless of the presence of an aortic aneurysm. The coexistence of CAD does not much affect the choice of the type of aortic intervention among open repair vs. endovascular repair. For DTA/TAAA repair, we often perform concomitant CABG even when PCI is deemed feasible. Besides the long-term benefit, CABG can eliminate the issues related to perioperative antiplatelet medications. In such cases, selective revascularization of the left anterior descending artery (LAD) with the pedicled left internal thoracic artery (LITA) is preferred to complete revascularization to minimize the additional complexity and excessive prolongation of the surgical procedure. In the patients with combined AAA and severe CAD, in whom staged intervention carries a significant risk of either coronary or aortic events during the interim period, we select PCI shortly followed by open AAA repair without discontinuing antiplatelet agents or minimally invasive CABG (LITA-LAD) shortly followed by open AAA repair.

Management of patients with previous coronary revascularization

Status post PCI

The major issue regarding the perioperative management of the patients who underwent prior PCI is the antiplatelet medications. As the current guidelines recommend the continuation of dual antiplatelet agents (DAPT) at least 12 months after DES implantation to prevent stent thrombosis [34], it is not uncommon to see a candidate of aortic surgery who is on long-term DAPT medication. On the other hand, antiplatelet

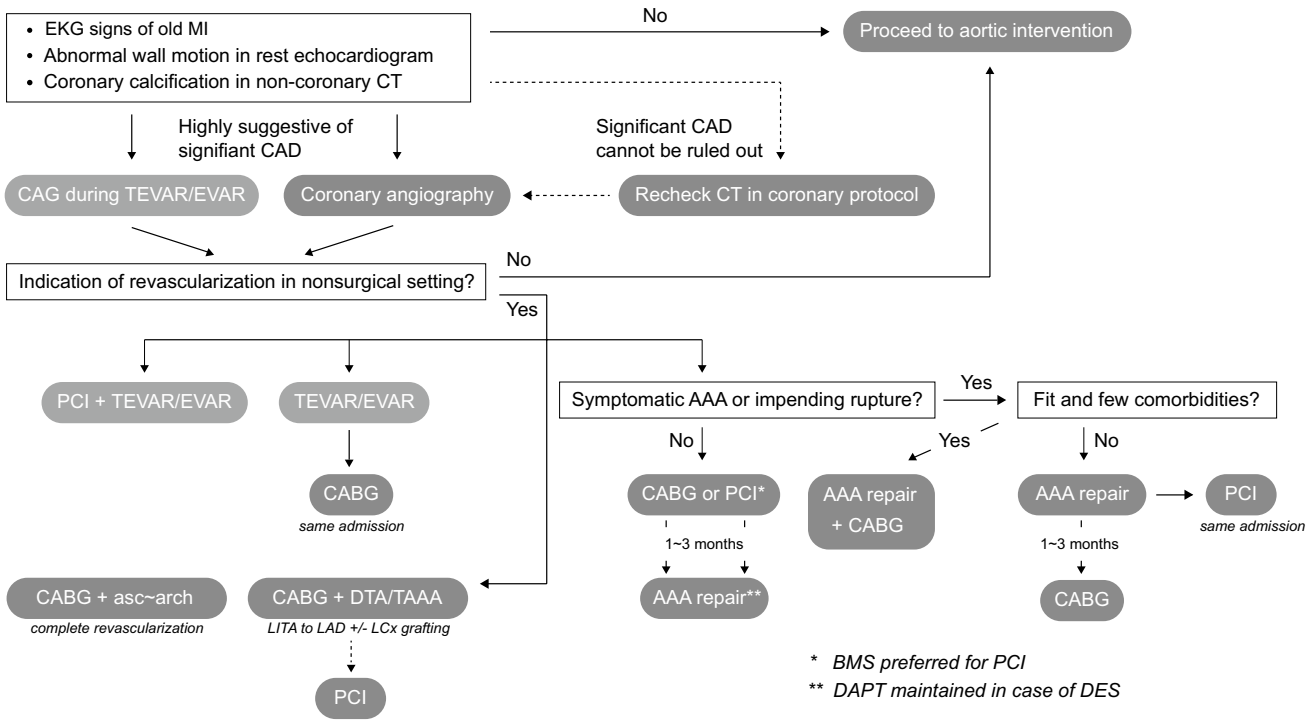

Fig. 1 Decision-making on the management of asymptomatic coronary artery diseases in the patient requiring elective aortic intervention (Seoul National University Bundang Hospital). AAA abdominal aortic aneurysm, Asc ascending aorta, BMS Bare-metal stent, CABG coronary artery bypass grafting, CAD coronary artery disease, CAG coronary angiography, CT computed tomography, DAP dual antiplatelet therapy, DES drug-eluting stent, DTA descending thoracic aneurysm, EKG electrocardiography, EVAR endovascular aneurysm repair, MI myocardial infarction, PCI percutaneous coronary intervention, TAAA thoracoabdominal aortic aneurysm, TEVAR thoracic endovascular aortic repair

medications increase the risk of surgical bleeding and have to be stopped, if it is tolerable. Therefore, it is recommended to optimally delay major elective noncardiac surgeries for 12 months, or at least 6 months in case of relatively urgent surgical procedures [17, 35]. In this context, the use of bare-metal stents may be advantageous for PCI in patients with known aortic aneurysms, because the antiplatelet medication is less critical than after DES implantation. When the safety of delaying the aortic intervention is in doubt, endovascular aneurysm repair (EVAR) may be the first choice, even in the patient with marginal anatomical feasibility [36]. There is a study which reported that a shorter (8 weeks) waiting interval before discontinuing DAPT for AAA repair did not increase the risk of cardiac events [37]. Such a challenge to the current guidelines may have to be scrutinized by more studies on a larger scale.

Status post CABG

Only a few studies specifically investigated the impact of previous CABG on the outcomes of open aortic surgery. In the recent publication from Mayo Clinic, patients with previous CABG accounted for 7% of those who underwent aortic arch surgery. They reported a 20% and 13% incidence of low cardiac output syndrome and operative mortality, respectively [38]. This data suggest that aortic surgery after prior CABG can be performed with an acceptable risk of mortality in experienced centers.

There are some technical issues. First, the importance of safe re-sternotomy cannot be emphasized too much. In this regard, 3D-reconstructed coronary CT angiography may be advantageous over conventional CAG, and even mandatory, because it visualizes the relationship between the bypass grafts and adjacent structures and thereby helps to avoid graft injury. Second, retrograde cardioplegia may be an essential component of myocardial protection during proximal aortic repair [38, 39]. Third, it is recommended that the patent LITA pedicle graft should be isolated and clamped. However, in our experience, leaving LITA open in a hypothermic state did not result in a negative outcome. In case the back bleeding from the left coronary ostium obscured the operative field, occlusion with a balloon catheter solved the problem. Fourth, the management of patent aortocoronary grafts remains at the individual surgeon's discretion. The degree of saphenous vein degeneration and patient characteristics have to be considered to determine to reattach the graft onto the prosthetic aortic graft or to replace it with a new conduit. Fifth, adequate measures are required during

proximal descending aortic surgery, which necessitates temporary occlusion of the left subclavian artery inflow to a patent LITA to LAD graft, while the heart is beating. In our experience, selective perfusion of the left subclavian artery is a simple and easy solution.

Considerations in acute type A aortic dissection

Generally, CAG is omitted in the patients who undergo emergency surgery for acute type A aortic dissection (ATAAD). Previous retrospective comparative studies did not demonstrate the benefit of preoperative CAG, even in the patients with a history of previous MI. Without affecting the incidence of CABG concomitantly performed with the aortic repair, preoperative CAG resulted in a significant delay of surgery [40–42].

Coronary malperfusion occurs in 6.1 to 14.5% of ATAAD patients, and it is a risk factor of both early and late mortality when it results in PMI [43–47]. Although the majority of coronary malperfusion is reversible just by aortic replacement and obliteration of the false lumen, some lesions require an additional procedure. Even with the absence of signs of myocardial ischemia, it is important to keep the possible need for coronary artery procedure in mind, if extensive dissection of the aortic sinuses is visible in the CT scan. Among the various techniques such as direct repair (reattachment) of the ostial dissection, patch repair of the proximal coronary artery, graft interposition, and bypass grafting to non-dissected segment, the selection can be made only after intraoperative assessment of the extent of dissection involving coronary artery [48]. If addressed with appropriate techniques, coronary malperfusion may not increase the mortality rate unless it has already caused severe myocardial damage before surgery [49].

There is room for debate regarding ATAAD patients with overt signs of myocardial ischemia, especially severe shock or impending cardiac arrest. As with the debates over aorta-first vs. branch-first strategy for severe malperfusion of other organs, the benefit of PCI before the aortic repair has been suggested by some centers [50]. Although such a coronary-first strategy is not accepted as the standard practice, it may affect the management strategy of ATAAD patients, who have been wrongly diagnosed with acute coronary syndrome initially. Based on its safety and palliative effect shown by Uchida et al., [50] PCI can be performed once the patient with coronary malperfusion is already in the angiography suite.

In ATAAD patients with coronary or cerebral malperfusion, DAPT is frequently prescribed to patients due to misdiagnosis as an acute coronary syndrome or stroke. The proportion of misdiagnosis has been reported to be from 10 to almost 50% [51, 52]. Patients who are on long-term antiplatelet or other antithrombotic medications for various medical reasons are also increasing. These medications aggravate the already existing risk of bleeding caused by fibrinolytic system activation and platelet dysfunction which have been demonstrated in ATAAD [53, 54]. Such risk was evident in the reports by Chemtob [51] and Hansson [52], in which they demonstrated increased bleeding and transfusion amount in the patients who took DAPT shortly before ATAAD repair. However, DAPT did not increase the operative mortality in the reports mentioned above and it does not justify delaying the aortic repair. To shorten the operation time and prevent the problems associated with massive transfusion, a few surgical measures have been introduced. In our experience, adopting the original concept of Cabrol shunt, covering the peri-graft space with a patch, and putting a decompressing shunt between the closed space and the right atrium is an effective and efficient method [55–57].

Conclusion

Despite the potentially negative impact of CAD on the outcomes of the intervention, the current guidelines regarding the management of CAD coexisting with aortic diseases are not much different from the recommendation for the general non-surgical settings. However, there are still minor but important and remaining issues regarding the details of patient management and surgical techniques. Because it is not likely to get large-scale investigational data about these issues, exchange and collection of individual experiences should be promoted in future scientific meetings to build up the consensus.

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Code availability Not applicable.

Declarations

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Ethics approval Not applicable being a review artcle.

Consent to participate Not applicable.

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