Management of non-cerebral malperfusion complicating acute type A dissection

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The author declares that there is no conflict of interest.

Abstract

Vital organ malperfusion in acute type A aortic dissection is associated with worse outcomes, especially when multiple organ systems are involved, and when coronary or mesenteric malperfusion is present. To achieve the two goals of central aortic repair and adequate and timely reperfusion, mechanism and organ-specific strategy in the methods and sequence of repair should be considered. For dynamic aortic malperfusion, reperfusion can be quickly achieved by femoral artery perfusion, and the fenestrated frozen elephant trunk operation, in which the proximal end of device is secured to zone 1 or 2 and distal 1 or 2 supra-aortic vessels are preserved by fenestration of the fabric, seems optimal as a method of central aortic repair. For coronary malperfusion, percutaneous coronary intervention before central aortic repair may have a role. However, it should be kept in mind that the door-to-unloading time is also important to reduce the area of myocardial infarction, and retrograde cardioplegia is not distributed to most of the right ventricle, which can be critical when right coronary malperfusion is present. Static mesenteric malperfusion should be addressed first, and second look laparotomy should not be hesitated after central aortic repair. The use of a hybrid operating room may be an optimal solution to achieve both goals.

Key words: acute type A aortic dissection, malperfusion, frozen elephant trunk, percutaneous mesenteric stenting, percutaneous coronary intervention, hybrid operating room

Vital organ malperfusion in acute type A aortic dissection is associated with worse outcomes, especially when multiple organ systems are involved[1, 2], and when coronary[3] or mesenteric[2] malperfusion is present. In the German registry, hospital mortality rate reached 43% when three organ systems were involved[1]. In the Italian registry, it reached 86% when three or more organ systems were involved[2]. This is because we have to achieve two goals simultaneously; central aortic repair to prevent cardiac tamponade and reperfusion within the golden time of involved organs. Persistent coronary or mesenteric malperfusion after aortic repair has been reported to be associated with high mortality rate[1, 3].

One of the reasons for persistent malperfusion is the fact that it is not always relieved by central aortic repair alone. Williams and colleagues have proposed a simple classification dividing the mechanisms of abdominal organ malperfusion into dynamic and static[4]; static malperfusion cannot be solved by central repair alone, and requires direct intervention to the involved vessels. Since the safe duration of ischemia is organ-specific, mechanism and organ-specific strategy is mandatory in the methods and sequence of repair to achieve the two goals of central repair and adequate and timely reperfusion.

Mechanism of malperfusion

Neri and colleagues have proposed a classification dividing the mechanism of coronary malperfusion into three types, with an individual repair technique for each mechanism[5]. Type A is ostial dissection, which was be repaired by conjoining the two dissected layers. Type B lesion has a coronary false channel, which was repaired by longitudinal incision and patch repair. In type C lesion, circumferential detachment is present with an intimal intussusception. The dissected coronary artery segment was replaced by a saphenous vein graft. In the real world, all these types are most frequently managed by bypass grafting, especially when aortic root replacement is not necessary. In our own experience, type A lesion may sometimes be resolved by supra-coronary replacement alone, while direct intervention is always required for type B and C lesion.

Concerning malperfusion of the abdominal organs, it is not clear enough in the Williams classification what lesion is static. Static obstruction was described as follows; “the line of dissection intersected the vessel origin and the aortic hematoma propagated into the vessel wall and constricted the lumen. The description of dynamic obstruction was “the line of dissection spared the vessel, but the dissection flap was positioned across the vessel origin like a curtain”[4]. We have previously reported that abdominal organ malperfusion caused by ostial dissection (branch-orifice type) may be either dynamic or static, while it is always static when the dissection extends into the abdominal branch vessels (branch-distal type), irrespective of the presence or absence of thrombus (hematoma) in the false channel within the branch vessel[6]. We think that the behavior of malperfusion after false lumen decompression depends on the size of involved vessels; while the branch-distal type malperfusion is always static in the small to middle size vessels, it may be dynamic in the large size vessels (Figure 1). Circumferential detachment can be a cause of obstruction in the small size vessels, such as the Neri type C lesion in the coronary arteries, but not in the middle to large size vessels; in the latter case, these branches are perfused by the false lumen. We would emphasize here that malperfusion should be regarded as static if it is not resolved within the golden time of involved organs.

Reperfusion strategy

1) Methods of reperfusion: the mechanism-specific strategy

Dynamic obstruction

Dynamic obstruction can be relieved by false lumen decompression procedures such as entry closure or fenestration. In acute type A aortic dissection, in which central aortic repair is usually mandatory, entry closure during central aortic repair is effective to reverse dynamic obstruction, as long as no anastomotic leakage is present. In addition, arterial return through the femoral artery connecting to the true lumen can easily and effectively reperfuse the distal organs immediately after starting surgery. Therefore, the role of percutaneous fenestration [7] is limited to the cases with combined dynamic and static malperfusion that requires simultaneous direct peripheral vascular intervention, in addition to false lumen decompression. Similarly, although thoracic endovascular aortic repair (TEVAR)-first strategy has been reported for mesenteric malperfusion complicating acute type A aortic dissection[8], its role is limited to the combined dynamic and static malperfusion necessitating simultaneous direct peripheral intervention. When dynamic aortic obstruction is the sole cause of mesenteric malperfusion, femoral artery perfusion can resolve it as quickly as TEVAR.

To reverse dynamic aortic obstruction, hemiarch replacement may suffice when entry tear is present in the ascending aorta. However, it may not be effective in some patients (Figure 2), since anastomotic leakage into the false lumen is present in a significant proportion of patients. A more aggressive approach is the application of the frozen elephant trunk combined with total arch replacement, which has been shown to improve the thoracic false lumen obliteration rate[9] and long-term event-free survival[9, 10]. However, the need for total arch replacement may be troublesome in these patients because they are usually critically ill. The fenestrated frozen elephant trunk operation[11, 12], in which the proximal end of device is secured to zone 1 or 2 and distal 1 or 2 supra-aortic vessels are preserved by fenestration of the fabric, may be a solution for this dilemma, because it obviates the need for reconstructing all the three arch vessels and keeps the merits of the frozen elephant trunk (Figure 3).

Static obstruction

For the static malperfusion, direct peripheral intervention is necessary to restore flow within the golden time. Percutaneous intervention such as stenting is generally preferred since it is more quick and less invasive. Pump reperfusion may also be possible for limbs or intestines. Uchida and colleagues have reported a technique to reperfuse the superior mesenteric artery immediately before central aortic repair using a heart-lung machine[13].

2) Sequence of intervention: the organ-specific strategy

Since the golden time for myocardial and mesenteric reperfusion is short and left coronary and mesenteric malperfusion are associated with high mortality rate if they are treated after central aortic repair, endovascular reperfusion procedures before central aortic repair have been proposed[13-16]. In these reports, patients without recovery after endovascular intervention did not undergo central aortic repair.

Although the golden time for renal reperfusion is also short, bilateral renal malperfusion is usually dynamic, which can be quickly addressed by femoral artery perfusion during central aortic repair. Unilateral renal malperfusion is usually static and is not relieved by central aortic repair. Delayed reperfusion will result in functional loss of the affected kidney. However, this will not significantly influence the postoperative course of the patients, unless the preoperative renal function is severely impaired. Therefore reperfusion-first strategy is not widely adopted for kidneys if malperfusion of other organs is not present.

Since the safe duration of limb ischemia is not less than six hours, limb malperfusion is usually addressed after central aortic repair, if it persists. Near infrared spectroscopy of the limb muscle is useful to monitor the effectiveness of reperfusion. When preoperative duration of ischemia is considerably long, pump perfusion of the affected limb through a femoral artery or femoro-femoral crossover bypass grafting, when the ischemia is unilateral, is considered. In such cases, delayed reperfusion may result in tissue loss and myonephropathic metabolic syndrome with multi-system failure. Controlled reperfusion and hemodiafiltration may be useful to attenuate the injury, but in some occasions, amputation is necessary to save the patient's life. Fasciotomy should be performed without delay for limb salvage.

Coronary malperfusion

Right coronary malperfusion can usually be tolerated unless it is superdominant. Therefore, percutaneous coronary intervention (PCI) before central aortic operation is not widely adopted. However, right heart failure may compromise the postoperative course. In this regard, special care mut be taken to protect the right ventricle since veins draining more than two-thirds of the right ventricular muscles empty directly into the right atrium[17] and therefore, retrograde cardioplegia is not distributed to most of the right ventricle. Uchida and colleagues have reported that PCI-first strategy reduced mortality even in case of right coronary malperfusion[14]. However, the potential benefit should be weighed against the risk of PCI, since PCI for the right coronary artery is generally more difficult than that for the left in the setting of aortic dissection[14]. Right ventricular myocardial protection should be optimized before adoption of the PCI-first strategy for the right coronary artery.

For left coronary malperfusion that is usually accompanied by cardiogenic shock, PCI-first strategy is more widely adopted than that for right coronary malperfusion. However, time to PCI may not be shorter than time to operation in many centers. Recently, the door-to-unloading time has been considered more important than the door-to-reperfusion time to reduce the area of myocardial infarction[18]. Since only the establishment of cardiopulmonary bypass can safely achieve left ventricular unloading in acute type A aortic dissection, we should be careful in adopting the PCI-first strategy, comparing the time to PCI and time to unloading according to the situation of the hospital. The use of a hybrid operating room may be an optimal solution to achieve both goals.

Mesenteric malperfusion

Endovascular mesenteric reperfusion by stenting, fenestration, or both, and delayed central aortic repair has been proposed by the Michigan group[15]. They reported 39% in-hospital mortality (32 of 82 patients), and 31 of them died without central aortic repair due to organ failure or aortic rupture[16]. TEVAR-first strategy followed by delayed central aortic repair for mesenteric malperfusion has also been reported by the Emory group[8]. They reported 46% in-hospital mortality (3 of 13 patients), and 3 of them died without central aortic repair. Although the reperfusion-first strategy is effective in reducing the mortality and selecting the patients for definitive repair, delayed central aortic repair carries the risk of aortic rupture. Endovascular mesenteric reperfusion followed by immediate central aortic repair in a hybrid operating room may improve the overall outcomes.

Our experiences

Figure 4 summarizes our current strategy for non-cerebral organ malperfusion complicating acute type A aortic dissection, which is based on the mechanism of malperfusion and the involved organ systems.

Aortic dynamic malperfusion

The fenestrated frozen elephant trunk operation is our current treatment of choice, when the dissection process does not extend into the branches of the aortic arch to be preserved. We preserve one or two distal branches by fenestration, while the innominate artery is always reconstructed by a separate tube graft (Figure 3). At the beginning of surgery, arterial perfusion to the femoral artery connecting to the true lumen is established as soon as possible to reperfuse the distal organs.

Coronary malperfusion

Left coronary malperfusion is addressed before central aortic repair in the situation that the diagnosis of aortic dissection is made in the catheter laboratory (Figure 5). Right coronary malperfusion is managed during central aortic repair. Since supracoronary aortic replacement may reverse Neri type A lesion, coronary artery bypass grafting is added when necessary, after an aortic clamp was released. For type B/C lesion and left coronary malperfusion, we perform coronary artery bypass grafting during perfusion cooling. We always use antegrade delivery of cardioplegia either through the coronary ostia or through the bypass graft, in addition to the retrograde delivery. This is of particular importance to protect the right ventricle when right coronary malperfusion is present. We frequently use the femoral artery as an arterial inflow because it is the quickest way of establishing total cardiopulmonary bypass to unload the left ventricle.

Mesenteric malperfusion

Branch-distal-type mesenteric malperfusion is always static in our experience. Therefore, peripheral vascular surgery is performed prior to the central aortic repair either through percutaneous mesenteric stenting or bypass grafting (Figure 6). A second look laparotomy is performed to confirm intestinal integrity and to resect necrotized bowels.

Other organs

Concerning unilateral renal malperfusion, we usually leave it and perform central aortic operation alone. Resultant functional loss of the affected kidney did not significantly influence the postoperative course of the patients, unless the preoperative renal function is severely impaired.

For unilateral lower limb malperfusion, perfusion through the ipsilateral femoral artery is performed for early reperfusion. If perfusion pressure or tissue oxygen saturation by near infrared spectroscopy does not improve after central aortic repair, femoro-femoral crossover bypass grafting is performed.

Operative results

Among the 127 patients who were hospitalized with acute type A aortic dissection from 2009 to September 2021, preoperative malperfusion was present in 37 (29%). Involved vessels were coronary in 5, cerebral in 12, visceral in 2, renal in 5, and lower limb 19. All the 127 patients underwent emergent central aortic repair. Hospital mortality rate was 3.1%; 8.1% (3/37) in patients with malperfusion and 2.2% (2/90) in patients without it. The cause of death was multiple non-cerebral malperfusion (coronary, renal, and lower limb malperfusion), cerebral malperfusion, and preoperative rupture in patients with malperfusion, while it was due to preoperative rupture and coincidental postoperative cerebral bleeding in patient without malperfusion. These results may suggest the appropriateness of our strategy.

Conclusions

For non-cerebral malperfusion complicating acute type A aortic dissection, mechanism and organ-specific strategy should be considered. For dynamic aortic malperfusion, reperfusion can be quickly achieved by femoral artery perfusion, and the fenestrated frozen elephant trunk operation seems optimal as a method of central aortic repair. For coronary malperfusion, PCI before central aortic repair may have a role. However, it should be kept in mind that the door-to-unloading time is also important to reduce the area of myocardial infarction, and retrograde cardioplegia does not protect the right ventricle, which can be critical when right coronary malperfusion is present. Static mesenteric malperfusion should be addressed first, and second look laparotomy should not be hesitated after central aortic repair. The use of a hybrid operating room may be an optimal solution to achieve the two goals of central aortic repair and adequate and timely reperfusion.

Declarations

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declaration of Conflicting Interests

The author declares that there is no conflict of interest.

Ethical approval

Not applicable.

Informed consent

Not applicable.

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Figure legends

Figure 1. Dynamic vs static malperfusion according to the size of involved vessels and morphology of branch vessel dissection

Aortic malperfusion may be static when the false lumen is thrombosed.

Figure 2. A case of persistent dynamic aortic malperfusion after hemiarch replacement due to anastomotic leakage

Malperfusion was relieved by bare stent implantation.

Figure 3. A case of left lower limb malperfusion treated by the fenestrated frozen elephant trunk operation

A Frozenix device (Japan Lifeline, Tokyo) was fenestrated to preserve flow to the left common carotid and subclavian arteries.

Figure 4. Our current strategy

FA: femoral artery, PCI: percutaneous coronary intervention, RCA: right coronary artery, LCA: left coronary artery, CPB: cardiopulmonary bypass

Figure 5. A case of bilateral coronary malperfusion due to Neri type B lesion

The patient was a pregnant woman with Marfan syndrome, and the diagnosis was made in the catheter laboratory. After a failed attempt of percutaneous coronary intervention, a perfusion catheter was placed in the left anterior descending branch. She fell in cardiac arrest during transfer to the operating room. She underwent Caesarian section and the Bentall operation combined with triple coronary artery bypass grafting. Both the mother and the baby were discharged home.

AOG: aortography, LCA: left coronary artery, RCA: right coronary artery

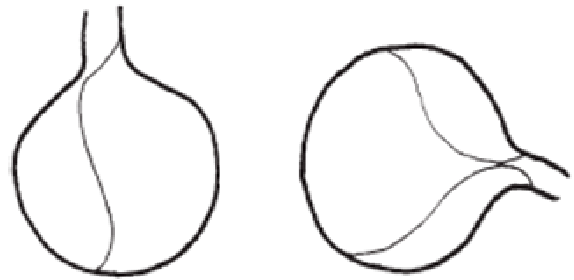
Figure 6. A case of branch-distal type mesenteric malperfusion

The patient underwent sequential bypass grafting to the celiac and superior mesenteric arteries immediately before hemiarch replacement. During the second look operation, intestinal resection was performed. The patient eventually recovered and was discharged home.

SMA: superior mesenteric artery

Figure 1.

Vessels		Dynamic	Static
Aorta		○	△
Large	Innominate	○	△
	Common iliac	△	△
Middle	Abdominal		
	Branch-orifice	△	△
	Branch-distal	×	○
Small	Coronary		
	Neri A	△	△
	Neri B	×	○
	Neri C	×	○



Branch-orifice

Branch-distal

Figure 2.

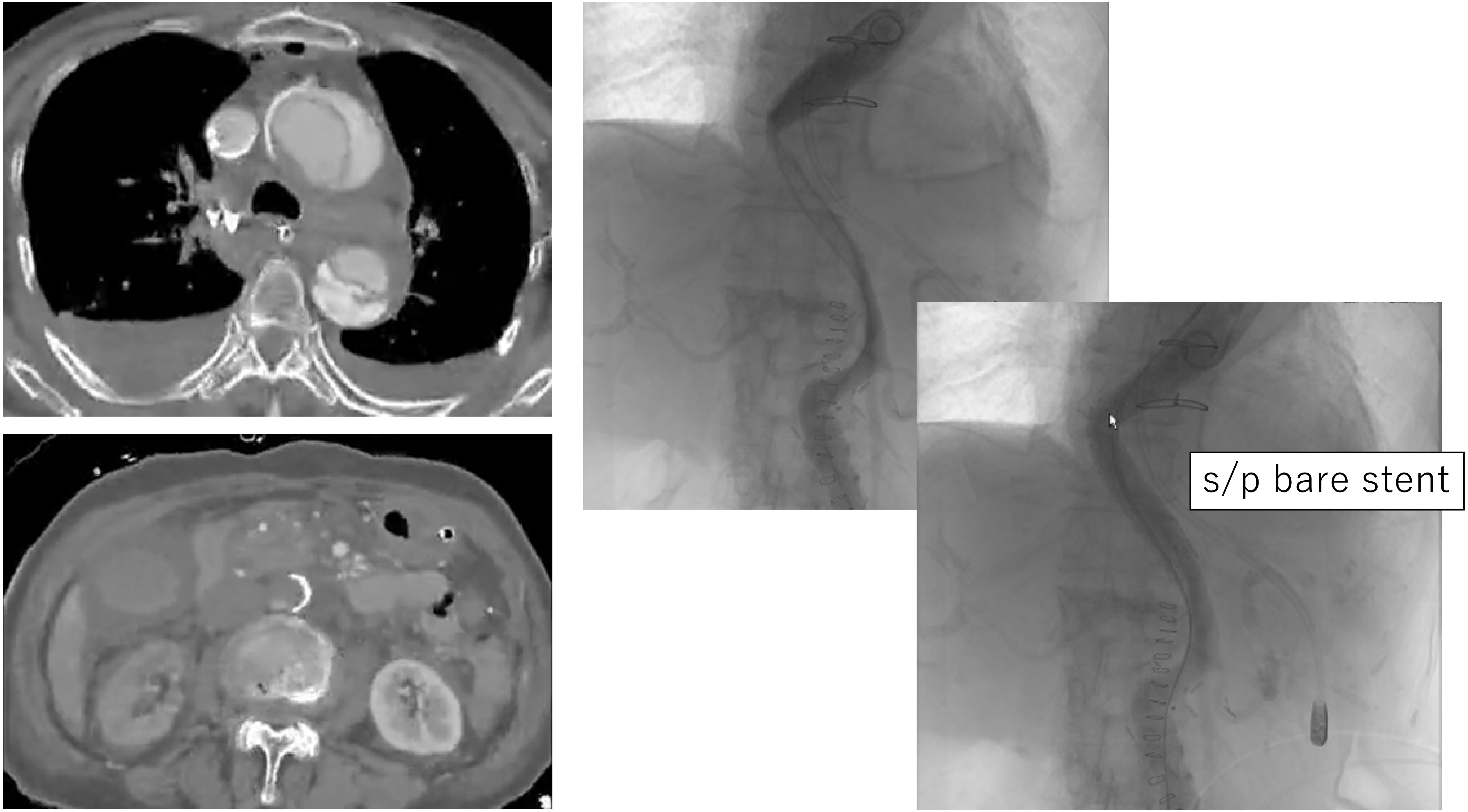


Figure 3.

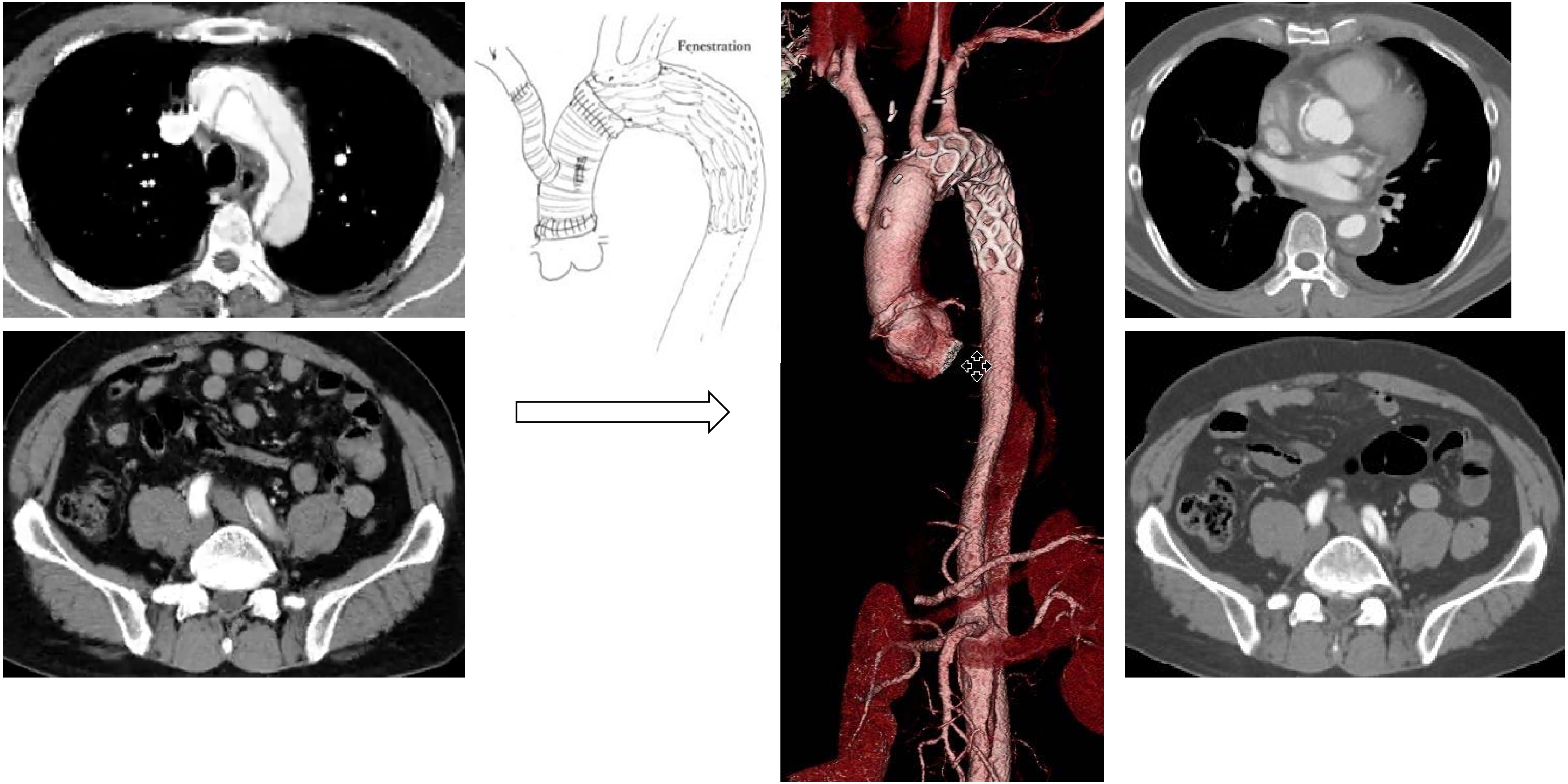
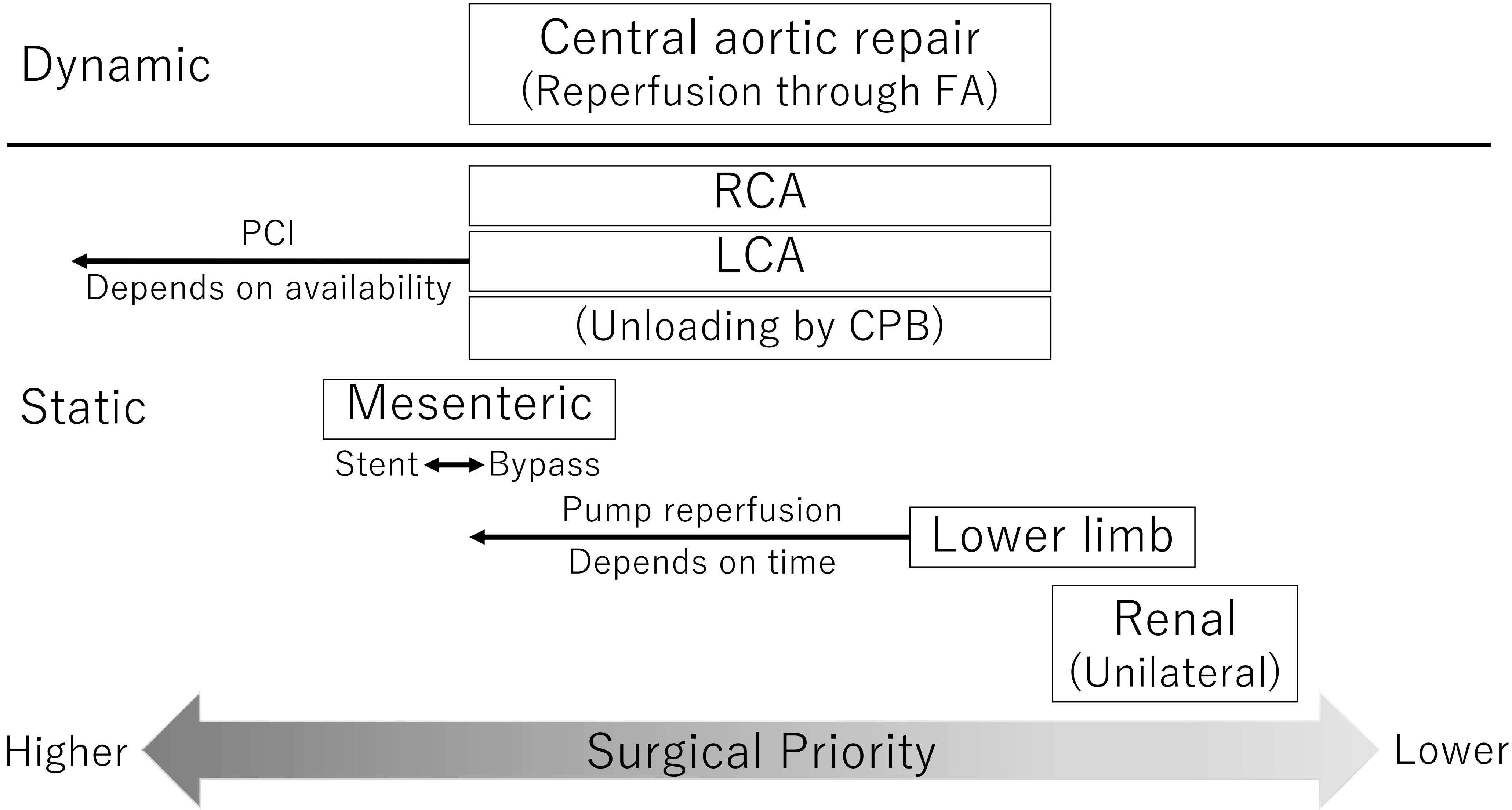


Figure 4.



Dynamic
Central aortic repair
(Reperfusion through FA)
RCA
PCI
LCA
Depends on availability
(Unloading by CPB)
Static
Mesenteric
Stent
Bypass
Pump reperfusion
Lower limb
Depends on time
Renal
(Unilateral)
Higher
Surgical Priority
Lower

Figure 5.

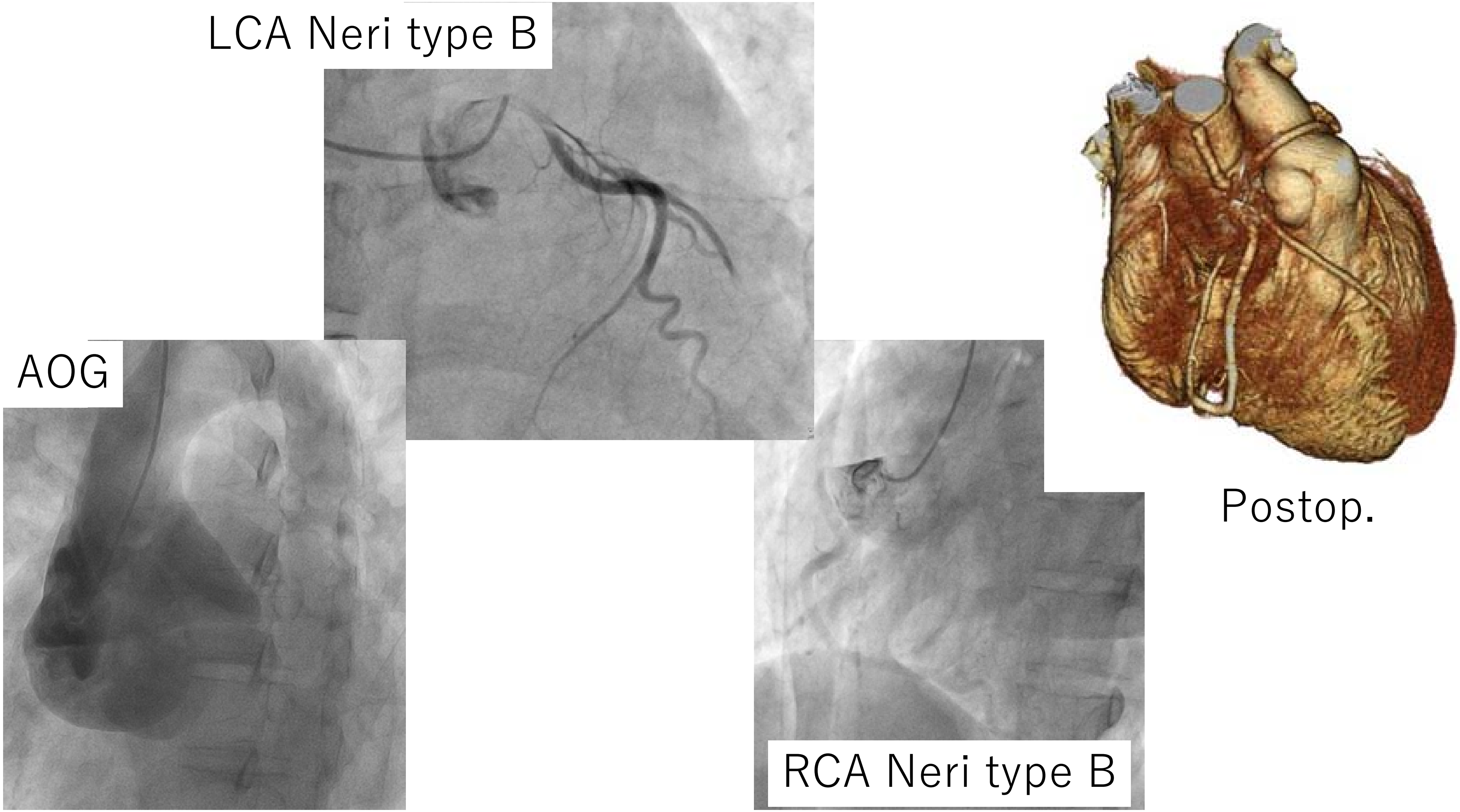


Figure 6.