A new classification system for branch artery perfusion patterns in acute aortic dissection for examining the effects of central aortic repair

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Abstract

OBJECTIVES: We developed a new classification system for branch perfusion patterns in acute aortic dissection and used it to retrospectively evaluate the perfusion status of whole aortic branches and to examine the effects of central aortic repair.

METHODS: Thirty-four consecutive patients with acute type A aortic dissection underwent emergent surgery at our institution between August 2008 and December 2011. A retrospective review of pre- and postoperative computed tomographic angiography was performed. Branch perfusion patterns were categorized into three classes: Class I, dissection involving but not extending into the branch; Class II, dissection extending into the branch and Class III, dissection causing ostial avulsion.

RESULTS: In cervical branches (total 169 branches), 70 branches (41%) presented with Class I patterns, 58 (34%) with Class II and none with Class III. In abdominal branches (total 135 branches), 76 branches (56%) presented with Class I patterns, 12 (9%) with Class II and 18 (13%) with Class III. In common iliac arteries (total 68 arteries), 14 arteries (21%) presented with Class I patterns, 24 (35%) with Class II and none with Class III. After repair, among 21 high-risk cervical branches, 14 branches (67%) showed improvement, 3 (14%) preserved distal perfusion supplied through the patent branch false lumen and 4 (19%) showed no improvement in high-risk perfusion pattern or worsened. Among 22 high-risk abdominal branches, 18 branches (82%) showed improvement, 3 (14%) preserved distal perfusion supplied through the patent branch or aortic false lumen and 1 (5%) showed no improvement in high-risk perfusion pattern.

CONCLUSIONS: To overcome malperfusion syndromes associated with acute aortic dissection, recognition of diverse branch perfusion patterns through a universal classification system is imperative.

Keywords: Acute aortic dissection • Malperfusion syndrome

INTRODUCTION

Malperfusion syndromes associated with acute aortic dissection are one of the most critical problems yet to be overcome in the field of aortic surgery [1–3], despite recent progress in endovascular intervention for rapid and less-invasive restoration of end-organ perfusion [4–7]. The spatio-temporal diversity of these malperfusions is the predominant factor affecting unfavourable outcomes. Patients often have simultaneous branch perfusion disturbances at more than one site [2, 8, 9], solitary ischaemic end-organ dysfunction can often be induced by combinations of multiple branch disturbances [10, 11], and perioperative extension of dissection or ischaemia–reperfusion injury from the restoration of blood flow can sometimes cause late manifestations of end-organ dysfunction [12]. Both unstable perioperative haemodynamics and an imbalance between end-organ blood supply and oxygen demand during warming after hypothermic cardiopulmonary bypass may cause a serious accumulation of ischaemic damage, with a late manifestation of end-organ dysfunction having untreatable and fatal consequences.

To fully comprehend the perfusion status of whole aortic branches at a glance and precisely evaluate temporal alterations, we developed a classification system for branch artery perfusion patterns by refining Beregi’s proposed classification for endovascular intervention of visceral malperfusion [13]. Our classification system places more emphasis on the physiological aspects of branch compromise, as well as the morphological findings on which Beregi’s proposed classification were based. Using this general-purpose system, we retrospectively examined the effects of central aortic repair on the branch artery perfusion. This precise assessment of pre- and postoperative status involving ‘high-risk’ situations can contribute to the refinement of strategies for the surgical and endovascular treatment of the malperfusion syndrome.
MATERIALS AND METHODS

Patients

Thirty-four consecutive patients presenting with acute type A aortic dissection underwent emergent surgery at our institution between August 2008 to December 2011 (Table 1). These patients included 15 males and 19 females (age range, 31–81 years). Ten (29%) cases were haemodynamically unstable and in shock at admission, 20 (59%) had dissection extending into cervical branches and 9 (27%) showed neurological symptoms secondary to arch vessel malperfusion, with 4 cases of transient ischaemic attack, 4 cases of left hemiplegia and 1 case of coma. There were also 18 cases (53%) of subclinical visceral branch compromise. Lower limb ischaemia was detected in 7 cases (21%; right, 3 cases and left, 4). There were no cases of coronary compromise.

There were 2 cases (6%) of in-hospital mortality from severe brain damage and intestinal necrosis and 4 (12%) of major post-operative complications such as major neurological injury (stroke; 3 cases) and paraplegia from spinal cord infarction (1 case; Table 2). First, preoperative perfusion patterns in aortic branches were retrospectively evaluated in all 34 cases using our classification system. Following this, postoperative changes in branch perfusion patterns were examined in 32 retrospective cases, excluding two hospital deaths with no available post-procedural evaluations. The approval of the institutional review board was obtained, and individual consent was waived.

Surgical techniques

All patients underwent median sternotomy with a total cardiopulmonary bypass. Although the femoral artery was used as the site of arterial cannulation in early cases, we generally select right axillary artery perfusion with side-graft cannulation and femoral perfusion (i.e. double cannulation) in recent cases at a high risk of intraoperative true lumen malperfusion due to retrograde perfusion. The brain protection method during surgery was typically deep hypothermia concomitant with retrograde cerebral perfusion, although selective cerebral perfusion was used if arch vessel reconstruction with a four-branched graft was necessary. Surgical procedures included 25 ascending or hemi-arch replacements, four total arch replacements, three partial arch replacements (reconstruction of one or two arch branches) and two Bentall procedures (Table 2). Resection of the primary intimal tear was intended for all cases.

Classification system

A retrospective review of pre- and post-procedural computed tomographic (CT) angiography imaging was performed to determine and categorize branch artery perfusion patterns in acute type A aortic dissection. Multi-detector row CT (MDCT) imaging with a 0.6 mm × 128-detector scanner was used at our institution, and MDCT images of 1.5-mm slice thickness were analysed with multi-planar reconstruction. In referred cases, digital imaging and communications in medicine CT images of 5-mm slice thickness were obtained from referring institutions and analysed for pre-procedural assessment. Evaluation included five cervical branches (brachiocephalic trunk, bilateral carotid and bilateral subclavian arteries), four abdominal branches (celiac trunk and superior mesenteric and bilateral renal arteries) and bilateral common iliac arteries.

Branch artery perfusion patterns were categorized into three classes: Class I, dissection involving but not extending into the branch artery; Class II, dissection extending into the branch artery and Class III, dissection causing branch artery ostial avulsion (Fig. 1).

Class I was divided into three subgroups. In Class I-a, branch artery perfusion supplied from the aortic true lumen was not impeded by the aortic false lumen. In Class I-b, the aortic true lumen providing the primary blood supply to a branch artery was compressed by the aortic false lumen. In Class I-c, the branch artery orifice was obstructed or narrowed by the intimal flap within the aortic lumen. Patterns I-b and I-c have a high risk of developing end-organ malperfusion.

Class II was divided into two subgroups based on perfusion of the branch artery false lumen, which can be estimated from the degree of enhancement of the branch false lumen in arterial phase CT angiography. In Class II-a, the branch false lumen was perfused as much or more than the branch true lumen due to sufficient re-entry communication in the distal branch. In Class

### Table 1: Characteristics of patients undergoing surgical repair for acute type A aortic dissection (n = 34)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N (%)</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>65 ± 12 (31–81)</td>
</tr>
<tr>
<td>Sex, male</td>
<td>15 (44%)</td>
</tr>
<tr>
<td>Shock on arrival</td>
<td>10 (29%)</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>21 (62%)</td>
</tr>
<tr>
<td>Dissection extending into the cervical branch</td>
<td>20 (59%)</td>
</tr>
<tr>
<td>Neurological symptoms (secondary to arch vessel malperfusion)</td>
<td></td>
</tr>
<tr>
<td>Transient ischaemic attack</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>Left hemiplegia</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>Coma</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Upper limb ischaemia</td>
<td>8 (24%)</td>
</tr>
<tr>
<td>Visceral branch compromise</td>
<td>18 (53%)</td>
</tr>
<tr>
<td>Lower limb ischaemia</td>
<td>7 (21%)</td>
</tr>
<tr>
<td>Interval from onset to operation</td>
<td></td>
</tr>
<tr>
<td>Within 6 h</td>
<td>24 (71%)</td>
</tr>
<tr>
<td>Within 12 h</td>
<td>29 (85%)</td>
</tr>
</tbody>
</table>

### Table 2: Surgical procedures and outcomes (n = 34)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascending</td>
<td>25 (73%)</td>
</tr>
<tr>
<td>Ascending–total arch</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>Ascending–partial arch</td>
<td>3 (9%)</td>
</tr>
<tr>
<td>Bentall</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
</tr>
<tr>
<td>Hospital death</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Severe brain damage</td>
<td>1</td>
</tr>
<tr>
<td>Intestinal necrosis</td>
<td>1</td>
</tr>
<tr>
<td>Surgical complications</td>
<td>4 (12%)</td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>3</td>
</tr>
<tr>
<td>Paraplegia</td>
<td>1</td>
</tr>
</tbody>
</table>
II-b, the branch false lumen was not perfused, or even if perfused, it is perfused significantly less than the branch true lumen due to insufficient re-entry communication in the distal branch. Class II-b was further divided into Classes II-b-1 and II-b-2. In Class II-b-1, the branch true lumen was not compressed by the branch false lumen and had its perfusion preserved. In Class II-b-2, the branch true lumen was compressed by the expanded branch false lumen and had its perfusion impeded. The II-b-2 pattern has a high risk of developing end-organ malperfusion.

Class III was divided into three subgroups. In Class III-a, branch artery perfusion was supplied from the patent aortic false lumen with or without branch artery dissection. In Class III-b, the branch artery true lumen was compressed by the expanded branch false lumen, and perfusion from the aortic false lumen was impeded. In Class III-c, branch artery perfusion supplied from the aortic false lumen was impeded by false lumen thrombosis with or without branch artery dissection. Patterns III-b and III-c have a high risk of developing end-organ malperfusion.

**Postoperative effects of central aortic repair on branch artery perfusion**

The effects of central aortic repair on branch perfusion patterns were categorized into four possible results: (i) improvement; (ii) no change in low-risk patterns, such as normal, Classes I-a and II-b-1; (iii) settled into Class II-a or III-a and (iv) no improvement in high-risk patterns, such as Classes I-b, I-c and II-b-2, or worsening. In some Class II-a cases, the branch artery false lumen is thrombosed after central repair. This postoperative, thrombosed Class II-a appears to be Class II-b-2 by CT imaging, but this is a physiologically different perfusion pattern. In Class II-b-2, the branch artery true lumen is compressed by the expanded branch false lumen, but in thrombosed Class II-a, the branch false lumen is decompressed and branch true lumen perfusion is preserved.

**RESULTS**

**Preoperative perfusion patterns in aortic branches**

**Cervical branches.** In cervical branches (total 169 branches), 70 branches (41%) presented with Class I patterns, 58 (34%) with Class II and none with Class III. Preoperative perfusion patterns for cervical branches are detailed in Figure 2. In the brachiocephalic trunk, 19 cases (57%) presented with Class II perfusion patterns, including 7 (21%) Class II-b-2 cases. In the right common carotid artery, 14 cases (41%) presented with Class II patterns, including 8 (23%) Class II-b-2 cases. Preoperative cervical branch perfusion patterns for patients with neurological symptoms are detailed in Table 3. All 9 cases (100%) presented with Class II patterns in the brachiocephalic trunk. The 8 cases (89%) of Class II patterns in the right common carotid artery were also all Class II-b-2. All 4 cases with left hemiplegia presented with a Class II-b-2 pattern in the brachiocephalic trunk and the right common carotid artery. One case presented with a preoperative coma and later died from severe brain injury (Case 1, Table 3).
Abdominal branches. In abdominal branches (total 135 branches), 76 branches (56%) presented with Class I patterns, 12 (9%) with Class II and 18 (13%) with Class III. Preoperative perfusion patterns for abdominal branches are detailed in Fig. 3. Nine (29%) and 6 (17%) cases presented with a Class III-a perfusion pattern in the celiac trunk and left renal artery, respectively. Six (18%) cases presented with Class II patterns in the superior mesenteric artery, including 3 (9%) Class II-b-2 cases. None of the cases had preoperative signs of visceral malperfusion. With regard to death from postoperative intestinal necrosis, preoperative perfusion patterns were Class II-a in the celiac trunk, Class II-b-2 in the superior mesenteric artery, Class III-b in the right renal artery and Class I-a in the left renal artery.

Common iliac arteries. Preoperative perfusion patterns for common iliac arteries are detailed in Fig. 3. Of the 7 cases with preoperative clinical signs of lower limb ischaemia, 5 presented with a Class II-b-2 perfusion pattern and 2 presented with Class I-c.

Postoperative effects of central aortic repair on branch artery perfusion

Cervical branches. In cervical branches, 21 branches (9 cases) had preoperative high-risk perfusion patterns, including 2 Class I-b and 19 Class II-b-2. Of these 21 branches, after repair, 14 branches (67%) improved, 3 (14%) settled into Class II-a and 4...
(19%) had no improvement in high-risk perfusion pattern or worsened. Of the 15 branches (7 cases) with preoperative Class II-a, after repair, 10 (67%) improved and 5 (33%) settled into Class II-a without improvement. In the right carotid artery, 7 cases had preoperative Class II-b-2 perfusion patterns; after repair, 6 cases improved. Changes between pre- and postoperative perfusion patterns in cervical branches are detailed in Fig. 4.

Of the 9 cases with neurological symptoms, 2 (5 branches) showed no improvement in cervical branch perfusion pattern. In Figure 3:

Figure 3: Preoperative perfusion patterns of abdominal branches and common iliac arteries in 34 cases. Normal (no branch dissection and no aortic dissection around the branch): white; Class I: blue; Class II: red and Class III: green. Red lettering and redlining sectors: high-risk perfusion patterns developing end-organ malperfusion (Class II-b-2, I-b or I-c). Orange lettering: perfusion patterns, in which distal perfusion was supplied through the patent branch or aortic false lumen (Class II-a or III-a). Three cases of common celiacmesenteric trunk and 2 of the double left renal artery were included in the 34 cases; therefore, the total number of celiac trunks was 31, and the total number of left renal arteries was 36.

Figure 4: Changes between pre- and postoperative perfusion patterns in cervical branches in 32 cases. White box and grey arrow: improvement; grey box and dotted arrow: settled into Class II-a or III-a; red box and red arrow: no improvement in high-risk perfusion patterns, such as Classes I-b, I-c and II-b-2, or worsening. Red lettering: high-risk perfusion patterns developing end-organ malperfusion (Class II-b-2 or I-b). Orange lettering: perfusion patterns, in which distal perfusion was supplied through the patent branch false lumen (Class II-a). One case of aberrant subclavian artery syndrome was included in the 32 cases and, therefore, the total number of brachiocephalic trunks was 31.
1 case (Case 5, Table 3), postoperative CT imaging 15 days after hemiarch replacement revealed that branch perfusion patterns did not improve in Class II-b-2 in the brachiocephalic trunk and worsened from Class II-b-1 to II-b-2 in the right subclavian artery, but improved from Class II-b-2 to II-b-1 in the right common carotid artery. The patient achieved a complete recovery from preoperative left hemiplegia and his aortic false lumen in the arch was sufficiently decompressed. Accordingly, no further procedures were attempted. After 1 year, CT imaging revealed that the aortic false lumen disappeared and branch perfusion patterns improved from Class II-b-2 to II-b-1 in the brachiocephalic trunk and right subclavian artery. In another case (Case 3, Table 3), preoperative branch perfusion patterns were Class II-b-2 in the right common carotid artery and brachiocephalic trunk, and preoperative left hemiplegia completely recovered immediately after ascending aortic replacement. One week after surgery, she had delayed the onset of stroke associated with consciousness disturbance and left hemiplegia. CT imaging revealed that branch perfusion patterns did not improve. Emergent endovascular intervention (stenting of brachiocephalic trunk and right common carotid artery) was performed, but her left hemiplegia did not recover completely.

### Abdominal branches

In abdominal branches, 22 branches (12 cases) had preoperative high-risk perfusion patterns, including 10 Class I-b, 8 I-c and 4 II-b-2. Of these 22 branches, after repair, 18 (82%) improved, 3 (13.5%) settled into Class II-a or III-a and 1 (4.5%) showed no improvement in high-risk perfusion pattern. Of 21 branches (14 cases) with preoperative Class II-a or III-a, after repair, no branch (0%) improved and all (100%) settled into the same class without improvement. Changes between pre- and postoperative perfusion patterns in abdominal branches are detailed in Fig. 5.

### DISCUSSION

Acute aortic dissection is a pleomorphic disease [14]. This pleomorphism (spatio-temporal diversity of malperfusion syndromes) is the predominant factor leading to unfavourable outcomes. Therefore, unconventional and resourceful strategies capable of flexible response to various situations are essential for treating this disease. In this study, we initially developed a classification system for branch artery perfusion patterns because precise
understanding of this pleomorphism is essential for favourable outcomes. We then used this classification system to evaluate the effects of emergent surgical central repair on branch artery perfusions.

Our classification system consists of three categories and nine total perfusion patterns. These stratified perfusion patterns, systematically defined by discriminating criteria, were comprehensive and easy to apply. A distinctive feature of our system is the inclusion of asymptomatic subclinical aortic branch compromises, such as patent branch arteries involved in dissection or perfused from the false lumen. Malperfusion syndromes associated with acute aortic dissection represent only a small proportion of whole aortic branch compromises. Precise assessment of pre- and postoperative status involving ‘high-risk’ situations can contribute to the refinement of strategies for the surgical and endovascular treatment of the malperfusion syndrome.

CT angiography was used in this study to determine and categorize branch artery perfusion patterns. CT imaging can assess whole aortic branches simultaneously and is easy to use for objective and comparative evaluations of pre- and postoperative status. The latest advanced imaging techniques, MDCT and high performance image processing, have brought about high-speed, accurate imaging and analysis. In the near future, we anticipate that CT imaging will be routinely performed to analyse delicate branch perfusion status even in emergency settings.

The aetiology of cerebral malperfusion during acute aortic dissection is multifactorial [15]. However, on the basis of the observations from this study, cerebral malperfluations were generally caused by branch artery dissection in brachiocephalic and right common carotid arteries, as described in other reports [16, 17] and had a Class II-b-2 perfusion pattern. Meanwhile, many patients with Class II-a patterns could quickly recover from cerebral perfusals with enough blood flow through the branch false lumen and sufficient re-entry communication in a distal branch, even if a transient ischaemic attack occurred at onset. Cervical branches rising directly from the aortic arch, such as the brachiocephalic trunk, left carotid artery and left subclavian artery, were rarely compromised by dynamic obstruction of Class I-b or I-c patterns.

In contrast to aortic arch branches, Class I-b and I-c patterns were more common in abdominal branches. The celiac trunk and left renal artery, in particular, also suffered from ostial avulsion, with Class III-a patterns. The superior mesenteric artery, however, rarely suffered from ostial avulsion because the celiac trunk acts as a bulwark against dissection by extending into the anterior surface of the abdominal aorta and by protecting the superior mesenteric artery behind it. Class II perfusion patterns were more common in the superior mesenteric artery and remaining abdominal branches. Our study had 6 cases (18%) with Class II patterns in the superior mesenteric artery, including 3 (9%) of Class II-b-2. These 3 cases had no preoperative visceral malperfusion symptoms, although 1 patient still had malperfusion complications in surgery that were fatal. A critical difficulty of visceral malperfusion is its assessment at an early stage due to clinical signs that are typically present later [9, 18, 19].

We observed the following regarding postoperative effects on branch artery perfusions: (i) aortic central repair acceptably restored Class II-b-2 in cervical branches and Classes I-b and I-c in abdominal branches, (ii) the effects of central repair on Class II-b-2 in abdominal branches were inconclusive and (iii) abdominal branch perfusion supplied from an aortic or branch false lumen, such as Class III-a or II-a, generally remained even after aortic central repair.

We consider the effects of central aortic repair on arch vessel perfusion to be reasonable for the reasons below. A complete resection of the primary entry tear in the ascending aorta reduced pressure in the residual aortic false lumen around arch vessels and could restore Class I-b or I-c perfusion patterns to Class I-a. Effective decompression of the aortic false lumen reduced pressure in the branch vessel false lumen and could restore Class II-b-2 patterns to II-b-1. Anastomotic leaks into the aortic false lumen or residual intimal tears in the aortic arch, however, are believed to prevent this decompression. An imperceptible but crucial concealed intimal tear in the brachiocephalic trunk might also prevent decompression. In this study, 2 cases (five branches) showed no improvement in high-risk perfusion patterns or worsening. One of these cases with Class II-b-2 in the right common carotid artery had a concealed intimal tear in the brachiocephalic trunk and a delayed onset of stroke 1 week after surgery.

The effects on abdominal branch perfusion revealed several limitations of central aortic repair. First, one or more aortic re-entry tears around abdominal branches cause incomplete decompression of the residual aortic false lumen. Despite the fact that accurate assessments of aortic re-entry tears are considered valuable, we could not assess these subjects in this study. Both transoesophageal echocardiography and transabdominal ultrasound may be more useful for assessing the size and site of aortic re-entry tears. Dynamic aortic lesions with Class I-b or I-c perfusion patterns could be restored by central repair in most of the cases, but complete decompression of the expanded branch false lumen and effective restoration of branch true lumen perfusion are theoretically more difficult with Class II patterns. Thus, Class II-b-2 patterns in abdominal branches have a high risk of the malperfusion syndrome.

Williams et al. [20] proposed dynamic and static mechanisms for malperfusion. A dynamic mechanism is secondary to intimal flap motion within the aortic lumen, which may obstruct the branch artery orifice. Dynamic malperfusion could vary based on changes in blood pressure and haemodynamic forces. A static mechanism is dissection extending into the branch artery, with obstruction or narrowing of the branch true lumen, and is unlikely to resolve with the restoration of aortic true lumen flow alone. The irreversibility of this lesion is explained as being due to thrombosis in the branch false lumen, although Shiiya et al. [21] cited branch artery dissection without thrombosis in the branch false lumen and proposed that branch artery dissection is not always static.

In our classification system, Classes I-b and I-c perfusion patterns were dynamic, but Class II-b-2 (and Class III-b) were not always static. Static lesions are Class III-c patterns in theory and very rare in practise, with Class III-c absent in our cases. The commonly accepted belief that central aortic repair is not effective with Class II-b-2 patterns because static lesions may not be correct. Class II-b-2 patterns in aortic arch vessels generally resolved after central aortic repair in our study (in 7 cases of Class II-b-2 in the right common carotid artery and 6 had improved perfusion patterns after repair). The first priority for the treatment of Class II-b-2 patterns should be to reduce the pressure of the branch false lumen connected consecutively to the aortic false lumen. The intractability of abdominal branch Class II-b-2 patterns in acute aortic dissection could result from difficult decompression of the expanded branch false lumen due to residual re-entry tears around the abdominal aorta, but likely not by static lesions.
In sum, our study suggests the following. In the cervical branch, preoperative high-risk perfusion patterns such as Classes I-b, I-c and II-b-2 should be treated with immediate central surgical repair, regardless of the presence or absence of neurologic symptoms. In the abdominal branch, preoperative high-risk perfusion patterns such as Classes I-b, I-c, II-b-2 and III-b should also be treated with central surgical repair immediately, provided that there are no signs of visceral malperfusion. In these cases, preoperative endovascular intervention might not be necessary. If signs of visceral malperfusion are evident, Classes I-b and I-c could be treated with immediate central surgical repair, with careful attention to intraoperative perfusion status. However, Classes II-b-2 and III-b should be treated with immediate preoperative endovascular intervention. The abdominal branch Class III-c pattern requires simultaneous central repair and peripheral bypass, given that endovascular intervention may not resolve this pattern.

We could not accurately conclude how to apply our classification system to symptomatic brain malperfusion (9 cases) and critical visceral malperfusion (1 case) due to the small study population. Additional evaluations involving a larger number of patients, including those presenting with symptomatic and critical malperfusion syndrome, are necessary to address this issue. Such studies will contribute not only to defining the significance of our classification system, but also to developing treatment strategies.

We developed a new classification system for branch artery perfusion patterns during acute aortic dissection. Cerebral malperfections were generally caused by branch artery dissection and had Class II-b-2 patterns. Class II-b-2 patterns in abdominal branches also had a high risk of malperfusion. To overcome malperfusion syndromes associated with acute aortic dissection, recognition of diverse perfusion patterns through a universal classification system is imperative.

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Conflict of interest: none declared.

REFERENCES

[13] Kirsch ME. Editorial comment classification system, but also to developing treatment strategies. In sum, our study suggests the following.