

[ Original Paper ]

The prevention of malperfusion of the vertebral arterial system  
during cross-clamp of the left subclavian artery  
in the treatment of thoracic aortic aneurysms

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SUMMARY

In order to evaluate cerebral circulation, preoperative cerebral digital subtraction angiography (DSA) as a prospective study was performed from January, 1985 to December, 1999 in 119 patients, who underwent thoracic aortic repair requiring cross-clamp of the left subclavian artery (LSA). The results showed that the left vertebral artery (VA) was dominant in 33 patients (27.7%) including the super-dominant left VA in 12 (10.1%), poor communication between the left and right VA in 8 (6.7%), and occlusive lesions in 3 patients. According to the results of preoperative cerebral DSA findings, additional perfusion to the left VA was performed in 22 patients (18.5%) during cross-clamp of the LSA. Although postoperative overall neurological complications occurred in 17 patients (14.3%) in this series, no neurologic dysfunction was observed in vertebrobasilar area in patients maintained vertebral flow during cross-clamp of the LSA. Preoperative cerebral DSA is useful for the evaluation of cerebral circulation as well as decision making of the necessity of additional perfusion to the left VA to prevent possible malperfusion of the vertebral arterial system during cross-clamp of the LSA.

**Key words :** Cerebral angiography, Vertebral artery, Thoracic aortic aneurysm, Selective cerebral perfusion, Neurological complication

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武内重康, 中島伸之<sup>1)</sup>, 沖本光典<sup>2)</sup>, 安藤太三<sup>3)</sup>: 左鎖骨下動脈遮断を要する胸部大動脈瘤手術における椎骨動脈血流不全の防止について.

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## I. Introduction

In 1984, we experienced a case of intraoperative cerebral complication which occurred immediately after the cross-clamp of the left subclavian artery (LSA) during descending aortic aneurysm repair. In this particular case, postoperative cerebral computed tomography (CT) showed the presence of left brain stem infarction and 4-vessel study revealed poor communication of the left and right vertebral arteries (VA) with dominant left VA. This bitter experience made us investigate for the prevention of malperfusion of the vertebral arterial system during thoracic aortic surgery requiring cross-clamp of the LSA.[1] In order to evaluate status of cervical branches as well as cerebral circulation and to decide the necessity of perfusion to the left VA, cerebral digital subtraction angiography (DSA) has been performed as prospectively since 1985. The aim of this report is to evaluate the role of preoperative cerebral DSA and to discuss how to prevent possible neurologic complication induced by cross-clamp of the LSA during thoracic aortic repair.

## II. Materials and Methods

From January 1985 to December 1999, cerebral DSA was performed prospectively as the preoperative evaluation of cerebral circulation in 119 patients who underwent operation for thoracic aortic aneurysms repair requiring cross-clamp of the LSA during surgical procedure. The angiographic findings evaluated in this study were, 1) status of left and right VA, especially whether left dominant were present or not, 2) intracerebral communication of basilar arteries via Willis circle. There were 91 men (76.5%) and 28 women (23.5%), with a mean age of  $61.4 \pm$

10.7 years (range 28-80 years). Forty-three patients (36.1%) were treated for aortic dissection (Stanford type A in 27, Stanford type B in 16), 74 (67.2%) for true aneurysms (Ascending aneurysms in 11, Arch in 43, and Descending in 20), and 2 (1.7%) for pseudoaneurysms at descending aorta. Ninety patients (75.6%) were operated on electively, and 29 (24.4%) had emergency operation (26 for acute aortic dissection, 2 for aneurysm rupture, and 1 for impending rupture of traumatic pseudoaneurysm). History of cerebrovascular disease was present in 12 patients (10.1%), including cerebral infarction in 9, cerebral bleeding in 2, and subarachnoidal hemorrhage in 1 patient.

The graft replacement for aortic reconstruction was performed in 103 patients (86.6%). With respect to the extent of replacement, ascending aorta and hemiarch replacement was used in 18 patients, total arch replacement in 43, and descending aortic replacement in 42 patients. Patch angioplasty was applied in 15 patients. In one case, operation was interrupted because of the disappearance of somatosensory evoked potential, which was monitored during descending aortic repair. Concomitant procedures were included as composite graft implantation (modified Bentall procedure) in 8, mitral valve replacement in 1, and coronary artery bypass grafting in 1 patient. As the assist circulation for operations on the thoracic aorta, total cardiopulmonary bypass (CPB) with antegrade selective cerebral perfusion (SCP) was used in 83 patients (69.7%) for the surgical repair of ascending aorta and aortic arch. For the surgical repair of descending aorta, temporary bypass (Axillo-femoral bypass) was applied in 12 patients (10.1%), partial CPB (Femoro-femoral bypass) in 7 (5.9%), and left heart bypass using centrifugal pump in 17 (14.3%).

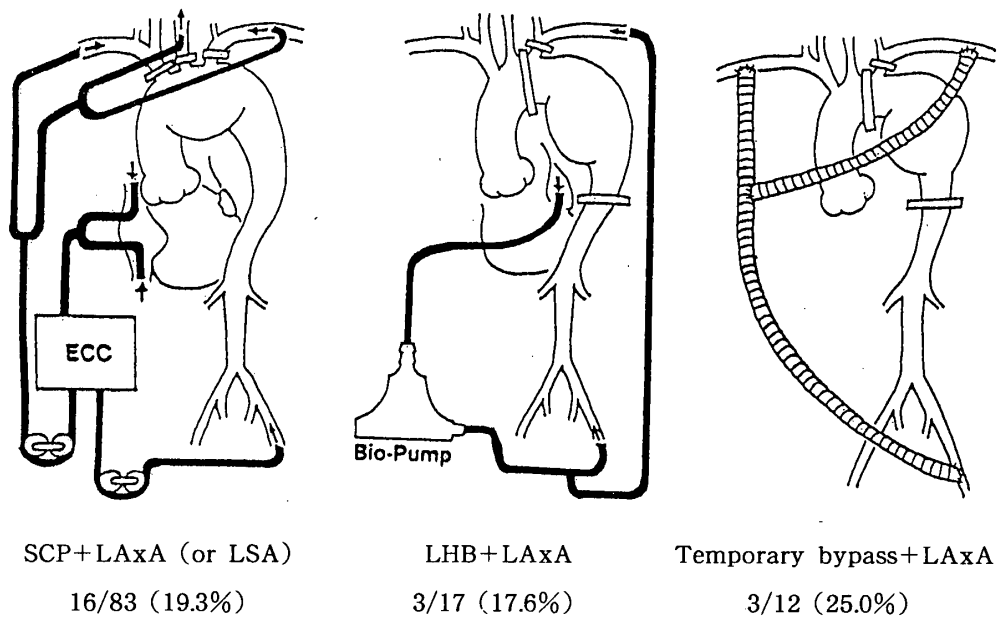


Fig. 1 Methods of additional perfusion to the LVA during cross-clamp of the LSA in operations

SCP: Selective cerebral perfusion, LAXA: Left axillary artery,  
LSA: Left subclavian artery, LHB: Left heart bypass,  
LVA: Left vertebral artery

Cerebral DSA was undertaken simultaneously with aortography, pig-tail catheter was positioned at aortic arch and all of the four cerebral branches as well as intracranial communication were imaged to evaluate, 1) the dominant site of VA, 2) intracerebral communication via Willis circle, 3) occlusive or stenotic lesion of VA. All of the findings of cerebral DSA was interpreted by neurologist. On the base of the findings of cerebral DSA, we decided whether the perfusion to LSA was better to be maintained during the cross-clamp of LSA. The perfusion technique to maintain LSA perfusion was illustrating in Fig. 1. The perfusion flow to LSA was not determined nor calculated during the procedure.

### III. Results

The overall hospital mortality rate was 10.1% (twelve of 119 patients), including

9.3% (four of 43) for aortic dissection, 10.8% (eight of 74) for true aneurysms, and 0% (zero of 2) for pseudoaneurysms. (Table 1)

All of the preoperative cerebral DSA study were performed without complication. Findings of the vertebral arterial system indicated by cerebral DSA are shown in Table 2. The left dominant VA was seen in 33 patients (27.7%) and 12 patients (10.1%) of them had the super-dominant (defined as larger more than twice in diameter of VA) left VA. Poor communication between the left and the right VA was diagnosed in 8 patients (6.7%), which included occlusion of the right VA in 3, occlusion of the left VA in 1, and the left VA only terminated to the left posterior inferior cerebellar artery in 3 patients. On the other hand, significant occlusive or stenotic lesions were seen in 4 patients, significant stenosis of the LSA was seen in 2 patients, occlusion of the LSA in 1, and occlusion of the brachiocephalic artery in 1 patient. In

Table 1 Patients, hospital mortality and neurological outcome

Etiology	No. of patients	Hospital mortality	Permanet neurological dysfunction	Temporary neurological dysfunction
Dissecting aneurysm	43	4 ( 9.3%)	3 ( 7.0%)	4 ( 9.3%)
Stanford type A	27	2 ( 7.4%)	3 (11.1%)	3 (11.1%)
Stanford type B	16	2 (12.5%)	0 ( 0%)	1 ( 6.3%)
True aneurysm	74	8 (10.8%)	5 ( 6.8%)	5 ( 6.8%)
Ascending	11	0 ( 0%)	1 ( 9.1%)	1 ( 9.1%)
Arch	43	4 ( 9.4%)	2 ( 4.7%)	2 ( 4.7%)
Descending	20	4 (20.0%)	2 (10.0%)	2 (10.0%)
Pseudoaneurysm	2	0 ( 0%)	0 ( 0%)	0 ( 0%)
Total	119	12 (10.1%)	8 ( 6.7%)	9 ( 7.6%)

Table 2 Preoperative cerebral DSA findings of the vertebral arterial system

Dominance of the VA		Communication between the left and right VA		
Dominant VA	No. of patients	+	-	Unclear
Right dominant	20 (16.8%)	13	3	4
Equivalent	66 (55.5%)	62	1	3
Left dominant	33 (27.7%)	25	4	4
[ Left super-dominant ]	[ 12 ] (10.1%)	[ 11 ]	[ 1 ]	[ 0 ]
Total	119	100 (84.1%)	8 ( 6.7%)	11 ( 9.2%)

VA: Vertebral artery

Table 3 Abnormal or aberrant findings of the preoperative cerebral DSA

Findings	No. of patients
Super-dominant left VA	12
Occlusion of the right VA	3
Left VA only terminated to the left PICA	3
Stenosis of the LSA	2
Occlusion of the LSA	1
Occlusion of the left VA	1
Occlusion of the left BCA	1
Total	23

VA: Vertebral artery,

PICA: Posterior inferior cerebellar artery,

LSA: Left subclavian artery,

BCA: Brachiocephalic artery

totally, abnormal or aberrant findings including super-dominant left VA, were observed in 23 patients (19.3%). (Table 3) Because of artifacts or other reasons, we could not confirm the intracranial communication between the left and right VA in 11 patients (9.2%).

According to the results of preoperative cerebral DSA findings, the LSA or the left axillary artery (AxA) was perfused additionally in 22 patients (18.5%) during the period of cross-clamp to the LSA. These patients were included as follows, poor communication between the bilateral VA in 7 patients, the super-dominant left VA in 11, the left dominant VA with unclear communication in 3, and the left dominant VA with brachiocephalic artery occlusion in 1 patient. As for the

method of maintaining the circulation of the left VA during cross-clamp of the LSA, additional perfusion to the LSA or to the left AxA using SCP was applied in 16 patients, additional perfusion to the left AxA with left heart bypass using centrifugal pump in 3, and side branch to the left AxA with temporary bypass (axillo-femoral bypass) in 3 patients. (Fig. 1)

Postoperative permanent neurological complications occurred in 8 of 119 patients (6.7%), and temporary neurologic dysfunction was observed in 9 patients (7.6%). The overall incidence of postoperative neurologic dysfunction was 14.3% (17 of 119 patients). (Table 1) Causes of postoperative neurological complications in 17 patients were diagnosed as embolism in 12 patients (70.6%), hypotension during operation (massive bleeding in 1, perioperative myocardial infarction in 1) in 2, spinal ischemia in 1, preoperative shock in 1, and the incidence of traumatic dissection to the left common carotid artery by cannulation in 1. In 22 patients, who were intentionally maintained perfusion to the LSA or to the left AxA during cross-clamp of the LSA in aortic repair, cerebral infarction which presumably considered to be caused by atheromatous emboli occurred in one patient. Except for this patient, no postoperative neurological complications caused by vertebrobasilar insufficiency was observed.

#### IV. Discussion

In early stage of our experience for aortic surgery, we did not pay particular attention for the cross-clamp to the LSA during thoracic aortic repair. In 1984, we encountered a case of left brain stem infarction occurred by cross-clamp to the LSA during descending aortic surgery. Since we experienced this unexpected case, we have paid attention for the

maintenance of vertebrobasilar circulation during cross-clamp to the LSA in the treatment of thoracic aortic surgery in certain circumstances. In addition to our experience, Tabayashi and Mohri[2] reported postoperative cerebral complication which supposed to cause by lack of perfusion to the left dominant VA, as well as Kazui and colleagues[3] also reported postoperative cerebellar infarction which seemed to occur by insufficient perfusion to the left VA.

Preoperative cerebral DSA was taken to evaluate cerebral circulation and to decide the necessity of perfusion to the left VA during operations. We diagnosed whether the dominant VA was present, patency of the Willis circle, as well as presence of occlusive lesions in cervical branches in consideration to clarify intracranial circulation. Tsuchida and colleagues[4] analysed preoperative 4-vessel study in 28 patients who underwent aortic arch and descending aortic repair, and reported that a poor communication between the left and right vertebrobasilar arteries was observed in 7.1% of patients. In our series, we recognized a poor communication between the left and right VA in 6.7% (8 of 119 patients). As for the dominance of the VA in which diameter of one side of VA was significantly larger than the other, the left dominant VA was observed in 27.7% of patients, especially the super-dominant left VA was seen in 10.1%. Abnormal or aberrant findings were also found in 19.3%. Although cross circulation between the left and right VA could not be clearly demonstrated in 9.2% of patients, we still consider that preoperative cerebral DSA is useful and significant for the evaluation of cervical branches as well as intracranial communication and confirmation of safety of cross-clamp to the LSA during surgical procedure. We also consider that our method is more

convenient and safer than conventional 4-vessel study which have the risk of embolic events.

On the basis of findings of preoperative cerebral DSA, such as poor or lack of communication between the bilateral VA, occlusion of the right VA, and the super-dominant left VA, we perfused to the LSA or to the left AxA additionally in 22 patients (18.5%) to obtain sufficient blood flow distribution during cross-clamp to the LSA. Because of prevention of vertebrobasilar ischemia, it was thought to be appropriate to perfuse to the left VA in certain circumstances such as described above.

As the methods of assist circulation, which performed to obtain additional perfusion to the left VA, SCP was used in 16 patients, left heart bypass with centrifugeal pump in 3, and temporary bypass in 3. Tsuchida and colleagues[4] reported temporary ascending aorta-LSA bypass during cross-clamp of the LSA. Mogi and colleagues[5] reported LSA-left common carotid anastomosis during surgical repair for type-III dissecting aneurysm. We consider that it is very important to avoid malperfusion of the vertebral arterial system during cross-clamp to the LSA especially under the normothermic condition. The arch vessels used for cerebral perfusion differ from institution to institution when SCP is applied. Although the necessity of perfusion to the LSA during SCP has been discussed since early period of aortic surgery [6,7], it is still controversial. As for the site of arterial cannulation for SCP, the innominate artery (or the right AxA) and left common carotid artery are generally simultaneously used[8-11]. However, Shiya and colleagues[12] recommended to perfuse routinely to the LSA during SCP to achieve an even distribution of blood flow. Several authors also have applied perfusion for all

three arch vessels for SCP[13-15]. We use routinely the innominate artery (or the right AxA) and left common carotid artery as the site for perfusion when SCP is established. However, in order to prevent malperfusion of the vertebral arterial system, we perfuse additionally to the LSA or to the left AxA according to the result of the evaluation of preoperative cerebral DSA. Although postoperative neurological complications occurred in 14.3% of patients in our series, no neurologic dysfunction was observed postoperatively by insufficient blood distribution to the vertebral arterial system during cross-clamp of the LSA in the treatment of thoracic aortic aneurysms.

Although cerebral DSA is important to evaluate cerebral circulation, it cannot always be performed preoperatively in the case of an emergency operation. Recently, many of the emergency operations have been performed only by the diagnosis of enhanced CT and echocardiography without DSA. In those circumstances we perfused for all three aortic arch branches prophylactically to obtain even distribution of blood flow, or maintained deep hypothermic circulation before the initiation of SCP with routine cannulation technique and kept hypothermic until reconstruction of LSA was completed.

At the present, magnetic resonance angiogram (MRA) has been performed frequently to evaluate cerebral circulation [13,16,17]. MRA is considered to be more convenient and less invasive examination than cerebral DSA, and especially it is beneficial for a patient with the presence of renal dysfunction. We have routinely taken MRA for prerequisite to DSA in order to obtain adequate information of intracranial circulation.

In conclusion, it was important to maintain sufficient blood flow distribution to the

vertebral arterial system during thoracic aortic repair. Results of the present report suggested that preoperative cerebral DSA was useful for the evaluation of cerebral circulation and decision making of the necessity of perfusion to the left VA during cross-clamp to the LSA. Our strategy appeared to be effective for the prevention of postoperative neurological complications, associated with malperfusion induced by the cross-clamp of the LSA in the treatment of thoracic aortic surgery.

### 要 旨

1985年1月から1999年12月までに、術中左鎖骨下動脈の遮断を要した胸部大動脈瘤手術症例中、119例に術前DSAによる脳血管造影を施行した。その内訳は、男女比91:28, 平均年齢61.4歳(28~80歳)で、解離性大動脈瘤43例(Stanford A型27例, B型16例), 真性大動脈瘤74例(上行11例, 弓部43例, 下行20例), 仮性大動脈瘤2例であった。緊急手術例は、29例で、脳血管障害の既往を12例に認めた。施行した術式は、人工血管置換103例, パッチ閉鎖15例, 試験開胸1例であった。病院死亡を12例(10.1%)に認めた。術前のDSAによる脳血管造影所見では、左椎骨動脈優位型を33例(27.7%)に認め、うち12例(10.1%)は著しく左側優位であった。椎骨動脈の左右の交通性を認めない例を8例(6.7%), 他の閉塞性病変も3例に認めた。術前の脳血管造影所見に基づき、119例中22例(18.5%)に術中左鎖骨下動脈遮断中、左椎骨動脈に灌流を追加し、血行の維持に努めた。術中の左椎骨動脈灌流法は、脳分離体外循環を使用した例が16例, 左心バイパス法3例, 一時バイパス法3例であった。術後脳脊髄障害を17例(14.3%)に認めたが、術中の左鎖骨下動脈遮断による椎骨脳底動脈系の灌流不全が原因と思われる症例はなかった。術中左鎖骨下動脈の遮断を要する胸部大動脈瘤手術症例では、術前脳血管造影による評価を行い、左鎖骨下動脈遮断の安全性を確認し、術中椎骨動脈の血行を維持することにより、椎骨動脈の血流低下が原因となる脳脊髄障害を防止することができると考えられた。

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