Structures and Flow Dynamics of False Lumen in Aortic Dissection: Transesophageal Color Flow Doppler Ultrasonographic Study

Shoji Suzuki

Abstract: Seventeen patients with aortic dissection, three with DeBakey type I, two with type II, twelve with type III, were studied by transesophageal color flow doppler ultrasonography. The structures of dissected aorta, flow dynamics in false lumen, and changes in ultrasonographic findings during follow-up periods were observed.

A tri-luminal structure was revealed, and blood flow through the initial tear and re-entry site, biphasic flow, stagnant flow, and thrombus formation in false lumen were visualized. Spontaneous echoes in false lumen were observed in ten patients. Furthermore, the spontaneous thrombosis of false lumen without surgical intervention, which is regarded as a "thrombo-occluding type dissection", was observed in seven patients.

In conclusion, transesophageal color flow doppler ultrasonography was a convenient and useful method not only for diagnosis, but also for estimating flow dynamics in the aortic dissection. It also contributed to satisfactory follow-ups.

Key words: Aortic Dissection, Transesophageal color flow doppler ultrasonography, Tri-luminal structure of dissected aorta, Spontaneous echoes in false lumen, Thrombo-occluding type dissection

Introduction

Aortic dissection is a serious disease which is often fatal. Even now, surgical and medical treatments are not always successful. Prompt and accurate diagnosis and timely treatment should reduce the mortality rate of this disease. Adequate methods for estimating intra-aortic flow dynamics during follow-up periods are indispensable.

For the past few years, transesophageal two-dimensional ultrasonography has frequently been reported to have a high diagnostic value for patients with aortic dissection\(^1-4\). This method is non-invasive, yet allows a clear visualization of the descending thoracic aorta behind the heart\(^5\). Recently, transesophageal color flow doppler ultrasonography, which can visualize blood flow, was developed. Many advantages for diagnosis of aortic dissection have been pointed out\(^6,7\). However, use of this method for observing changes in flow dynamics, such as the persistent patency of false lumen, is still in the early stage.

In this report, we discuss the use of transesophageal color flow doppler ultrasonography to observe structures in the dissected aorta and to estimate flow dynamics in false lumen in patients with aortic dissection. We also discuss the echographic signs which may affect the fate of false lumen.

Materials and Methods

Since February 1987, seventeen patients, eleven males and six females, ranging in age...
from 45 to 74, were studied. All of them were also examined by conventional methods, i.e., transcutaneous echocardiography performed from the left parasternal and supra sternal notch approach, cineangiography from the percutaneous transfemoral approach, and computed tomography performed at 1 or 2-cm intervals from the aortic arch to the distal part of aorta before and after injection of contrast media. They were diagnosed with aortic dissection by a combination of these methods.

Three of the patients, two with DeBakey type I and one with type III, were observed during post-surgical follow-ups. In the remaining patients, one with DeBakey type I, two with type II, and eleven with type III, the necessity of surgical treatment was not determined at the time of this study. Six patients were later operated upon, seven treated medically, and one patient, with type II, is currently a waiting surgery. Follow-up studies were also performed on seven patients. Clinical details are summarized in Table 1.

The apparatus used in this study was a transesophageal color flow doppler ultrasonograph with a “UST-5220-5” probe by Aloka Co., Ltd. The probe has an ultrasound frequency of 5 MHz and an effective view field angle of 90 degrees.

The patients fasted for several hours before this procedure. With local anesthesia on the throat, the probe was placed in the esophagus, as for a gastroendoscopy, in the left lateral decubitus position. Premedication was usually not required. All ultrasonic images were stored on a video tape recorder.

First, the structure of the aorta was observed using the two-dimensional method. Placement of the probe was approximately 45 cm distal to the incisor teeth. By withdrawing it gradually,
to approximately 20 cm, the proximal abdominal aorta, the descending aorta, and the aortic arch were visualized. Then, inserting the probe again, and rotating it anteriorly, cross-sectional images of the aortic valve were obtained. Withdrawing it again, the aortic root and the lower part of the ascending aorta were detected. By the above procedure, almost the entire thoracic aorta, except for the upper part of the ascending aorta behind the trachea and the proximal abdominal aorta, could be visualized.

Next, using the color flow doppler, flow signals in the dissected aorta were recorded. If the initial tear or re-entry sites were found, flows through them were also observed. On the display screen, blood flow toward the probe was indicated in red and blood flow away from the probe was shown in blue. The brightness of each color represented the velocity of blood flow.

The diagnosis of aortic dissection was based on the recognition of an intimal flap. The false lumen was differentiated from the true lumen on the basis of the transesophageal ultrasonographic findings. That is, true lumen shows expansion in the systolic phase, and/or the brightness of flow signals in true lumen increases in the systolic phase.

In follow-up studies, the ultrasonographic images were recorded repeatedly at the same level, and changes in structures and flow signals were compared.

Results

Structures of dissected aorta

Intimal flaps were recognized in fifteen cases, but not found in the remaining two patients (Case 11, 15), who had been diagnosed with aortic dissection by conventional methods, prior to this study.

The images of dissected aorta were commonly composed of true and false lumens partitioned by the intimal flap. A tri-luminal structure, composed of one true lumen and two false lumens, was observed in the proximal part of the descending aorta with type III dissection (Case 16, Fig. 1). In a different case, in the middle descending aorta, the false lumen was so overwhelmingly dominant that the true lumen was partially compressed and divided into two compartments (Case 12, Fig. 2). These atypical findings could not be confirmed by any other conventional method.

The entry site to the false lumen was demonstrated in eight of fifteen patients (Case 4, 6, 7, 9, 12, 13, 14, 16). The jet flow through the initial tear was visualized in seven of the eight. However, in the remaining case (Case 4), the initial jet flow could not be recorded. The typical initial tear in a patient with type III dissection is shown in Fig. 3 (Case 9).

Small re-entries were clearly observed in two cases (Case 9, 16). There was no re-entry in the thoracic aorta, which went undetected by this method but was detected by other conventional methods. An example of a small re-entry in the middle of the descending thoracic aorta is shown in Fig. 4 (Case 9).

In the two patients whose intimal flaps were not detected, vestiges of false lumens were observed. The initial tear had developed to a saucer-like appearance (Fig. 5).

These ultrasonographic results are summarized in Table 2.

Flow dynamics in false lumen

By using the color flow doppler, several specific images representing blood flow in the false lumen were recorded.

A "to and fro phenomenon" or biphasic flow pattern was observed in four cases (Case 9, 10, 12, 16). That is to say, the false lumen was indicated in blue in the diastolic phase, but in red in the systolic phase. This means that the direction of blood flow in the false lumen had reversed. Furthermore, a rapid movement of the intimal flap which synchronized with the cardiac cycle was also observed. The images recorded from a patient with type III dissection in the acute state are shown in Fig. 6 (Case...
Low density spontaneous echoes were found in false lumens in ten cases (Case 1, 2, 3, 5, 6, 9, 10, 12, 13, 16). These echoes could be distinguished from those of true thrombus because of the changes in configuration, the lack of a well-defined border, and doppler signals of blood flow. The typical spontaneous echoes obtained from a patient with type III dissection are shown in Fig. 7 (Case 16). These echoes were stationary, although they contained signals of blood flow.

The hyperdynamic spontaneous echoes, which drifted or curled up, and changed their acoustic intensity, were observed in the persistent false lumen in type III dissection after surgical closure of the initial tear (Case 9, Fig. 8). These echoes also contained signals of blood flow.

Thrombus formations were observed in ten patients. In seven of them (Case 3, 4, 7, 11, 14, 15, 17), the false lumens were completely or partially thrombosed without surgical intervention. The partially thrombosed false lumen presented a double barrel structure. In the remaining three patients (Case 2, 5, 9), thrombus formations were observed after surgical treatments.

Blood flow in residual false lumen was distinguished from the true thrombus by the
Fig. 2. A type III patient five days after the onset of symptoms (Case 12). This patient suffered from severe ischemia in both legs as an additional complication.

T: true lumen F: false lumen

Changes in ultrasonographic findings during follow-up periods

Follow-up studies were carried out on seven patients. Two patients were observed during post-operative periods, three patients during medical treatments, and two patients during pre- and post-operative periods.

Spontaneous echoes appeared during the
Fig. 3. A type III patient about two weeks after the onset of symptoms (Case 9). The jet flow, colored in red from the initial tear to the false lumen, is clearly visualized. This jet flow is also detected by cineangiography. (See arrow.)
Fig. 4. A type III patient about two weeks after the onset of symptoms (Case 9).
A small re-entry in the middle thoracic aorta was confirmed by cineangiography. (See small
arrow.) The tear in this figure is consistent with the root of a torn-off intercostal artery.
Fig. 5. A type III patient (Case 15).

This patient was diagnosed with aortic dissection by computed tomography. Six weeks after the onset of the disease, this study was performed, and the disappearance of the false lumen was noticed. The saucer-like appearance can be observed in the aortic arch. (See arrows.)

post-operative observation in a patient with type I dissection (Case 1, Fig. 10). About one year following surgery, no spontaneous echoes were observed in the false lumen. After an additional year, spontaneous echoes were obviously shown in the same lumen.

In another type I patient, treated medically, spontaneous echoes disappeared and developed into a true thrombus after an interval of sixteen months (Case 3).

In the two patients who were examined in both pre- and post-operative periods, thrombus formations after surgical treatments were observed (Case 5, 9).

**DISCUSSION**

Aortic dissection can now be promptly and accurately diagnosed by a combination of non-invasive diagnostic procedures. Transesophageal echocardiography is an important component of this combination.
Transesophageal echocardiography was developed to minimize the limitations of transthoracic echocardiography. The first M-mode transesophageal echocardiography was attempted in 1976\(^1\), and two-dimensional transesophageal echocardiography was performed in 1980\(^2\). Recent advances in imaging techniques have contributed to its successful use in the diagnosis of aortic dissection.

Recently, the transesophageal color flow doppler method has come into use. Although this method can visualize both structures and blood flow, there are only a few reports aimed at the changes in flow dynamics during the course of aortic dissection\(^3\)\(^-\)\(^4\), most reports emphasizing detection of the entry site.

In this study, several specific findings were obtained. This method revealed tri-luminal structure for the first time. Up until now, the cleavage plane has usually been single and continuous from the initial tear to the end site of the dissection. This finding could not be confirmed by computed tomography, possibly because the rapid movement of the intimal flaps interfered with its detection.

The fast flow, including the “jet flow” through the entry site, and the slow flow, such as the “to and fro phenomenon”, were detected by this method. Furthermore, spontaneous echoes were visualized.

In some previous reports, spontaneous echoes were found in the dysfunctional left ventricle\(^5\), the left atrium in cases of mitral valve disease\(^6\), and also in the dissected aorta\(^7\)\(^-\)\(^9\). These spontaneous echoes have been called “Moya-moya echoes” or “Drifting dregs-like echoes” in some reports\(^20\)\(^21\). These echoes have been considered to represent the stagnant flow associated with thrombus formation clinically and experimentally.

However, spontaneous echoes in the dissected aorta were regarded as rare since only

---

Table 2. Ultrasonographic results

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>Type</th>
<th>Intimal flap</th>
<th>Entry</th>
<th>Re-entry</th>
<th>Spontaneous echoes</th>
<th>Thrombus</th>
<th>AR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69</td>
<td>F</td>
<td>I</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>64</td>
<td>F</td>
<td>I</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>63</td>
<td>M</td>
<td>I</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>M</td>
<td>III*</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>67</td>
<td>F</td>
<td>II</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>67</td>
<td>F</td>
<td>II</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>53</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>63</td>
<td>F</td>
<td>III</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>58</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>74</td>
<td>M</td>
<td>III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>12</td>
<td>54</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>49</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>72</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>74</td>
<td>M</td>
<td>III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>16</td>
<td>45</td>
<td>M</td>
<td>III</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>17</td>
<td>51</td>
<td>F</td>
<td>III</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

KEY

+; visualized −; not visualized 0; no entry site after surgical treatment AR; aortic regurgitation
Fig. 6. A patient with type III dissection (Case 10).
In the systolic phase, the true lumen was expanded and the intimal flap moved towards the false lumen. Blood flow in both lumens is shown in red. The brightness of flow signals indicates that the amplitude of flow velocity in the true lumen is increased in the systolic phase. During the diastolic phase, the true lumen seems to be compressed by the false lumen, which is shown in blue.
Fig. 7. A type III patient, five weeks after the onset of symptoms (Case 16). The spontaneous echoes are shown in the false lumen. By using the color flow doppler, the blood flow in the false lumen is visualized. (See bottom image.) These echoes represent the stagnant flow in the false lumen.
These serial images were recorded in approximately one cardiac beat cycle. The blood flow is indicated in blue. (See right image.) They represent the slow turbulent flow in the false lumen.

three cases have been previously reported\textsuperscript{17-19}. However, in this study, those echoes were observed in ten patients. These results show that the spontaneous echoes are more common in false lumen than formerly expected. Furthermore, appearance of the spontaneous echoes during follow-up periods and the development into true thrombus were observed for the first time in this study. Although a relationship between the level of spontaneous echoes and the possibility of later thrombus formation has not been clearly demonstrated, these echoes are considered to represent a regional stasis of blood flow in false lumen.

Spontaneous thrombosis of false lumen, without surgical intervention, was observed in seven out of seventeen patients. The shrinkage or disappearance of false lumen was detected by computed tomography in four of thirteen patients a few months after onset\textsuperscript{22}, and was also seen in one case report\textsuperscript{23}. In our cases, the most rapid thrombosis of false lumen was found in a patient with type III dissection, only five hours after the onset of symptoms. Such a rapid thrombosis was revealed for the first time in this study. These findings are expected to be the initial signs of a spontaneous resolution, called "Thrombo-occluding type dissection". Therefore, these results suggest that the spontaneous resolution is not rare, and many patients with aortic dissection might have been previously overlooked.

We considered the persistent patency of
false lumen to be very important in managing patients with aortic dissection because persistent blood flow in the false lumen increases the risk of aortic rupture. Transcutaneous echocardiography can adequately estimate flow dynamics in the aortic root, but cannot obtain any information in most of thoracic aorta. Cineangiography can provide a considerable amount of essential information about flow dynamics in the entire aorta, but it is an invasive and inconvenient technique. Computed tomography can identify thrombus formation in false lumen, but it cannot provide thorough information about blood stasis. It also requires some contrast media, which may be contraindicated in patients with aortic dissection involving renal arteries. However, transesophageal color flow doppler ultrasonography is non-invasive and can obtain considerable data related to the fate of false lumen, namely the fate of aortic dissection.

Therefore, medical observation of patients with thrombosing or disappearing false lumen can be maintained, while we consider additional treatments including surgical intervention. This method is useful in satisfactory follow-ups.

Fig. 9. A type III patient two months after the onset of symptoms (Case 7). The false lumen is partially thrombosed, and the blood flow is clearly visualized by color flow doppler. Cineangiography failed to yield useful information about blood flow in the false lumen. (See left image.)
Fig. 10. A type I patient in post-operative periods (Case 1).
An emergency operation was performed using a ringed intraluminal vascular graft. Although
the patient's post-operative state was stable, the false lumen still persisted in the descending
thoracic aorta. When the first study was performed about one year after surgery, no
spontaneous echoes were observed in the false lumen (top), however after two years,
spontaneous echoes were clearly observed (bottom). Three years after surgery, the lumen was
still patent.
Transesophageal Color Flow Doppler Ultrasound

CONCLUSION

Transesophageal color flow Doppler ultrasound is a convenient and useful method not only for diagnosis, but also for estimating flow dynamics in aortic dissection. This method can visualize blood flow through the initial tear, the re-entry site, biphasic flow, stagnant flow, and thrombus formation in false lumen. It is superior in detecting spontaneous echoes associated with the thrombus formation. It can be applied to follow-up studies, and assess the indication of medical and surgical treatments.

REFERENCES


23) Hoshino T, Ohmae M, Sakai A. Spontaneous resolution of a dissection of the descending aorta after medical treatment with a β blocker and a calcium antagonist. Br Heart J 1987; 58: 82–84.