The Relationship between Tension and Length of the Aortic Adventitia Resected from the Aortic Wall of Acute Aortic Dissection

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Objective: To our knowledge, no previous study has described the measurement of the tensile strength of the human aortic adventitia. In the present study, we examined the relationship between the tension and length of the aortic adventitia resected from the aortic wall of patients with acute aortic dissection.

Methods: We obtained rectangular specimens from the aortic adventitia that was resected in patients with acute aortic dissection during surgery. The specimens were placed on a tension meter (Digital Force Gauge FGS-10, SHIMPO, Kyoto, Japan) within 15 min after resection and stretched until they were pulled apart, and the tension and length were recorded.

Results: We obtained 18 specimens during surgery from 11 cases of acute aortic dissection. When the specimen was being pulled apart, the mean tension recorded was 10.2 ± 4.9 N/cm specimen width, whereas the mean elongated length recorded was 4.2 ± 1.1 mm/cm specimen length.

Discussion: We determined that the aortic adventitia is elastic and expandable up to 140% of its original length. This indicates that dilation of the aorta to >4.2 cm in diameter may result in a rupture if the original aortic diameter prior to dissection was 3 cm. (*English translation of J Jpn Coll Angiol 2013; 53: 77-81)

Keywords: aortic wall tension, acute aortic dissection, aortic adventitia, relationship between tension and length

Introduction

Many points are still unclear with regard to the mechanism of development of acute aortic dissection, despite the large number of affected patients. For acute onset, treatment is performed by setting the primary target as the prevention of fatal complications, such as rupture of the aorta, cardiac tamponade, and acute myocardial infarction, but the outcome may be fatal due to rupture and dilation of the residual dissected region even if surgical treatment for the acute phase has been selected.

To prevent this, strict antihypertensive therapy is performed, but there are no clear criteria for indices of blood pressure reduction. In this study, the relationship between length and tension of the aortic adventitia was analyzed by actually measuring these in aortic adventitia specimens collected during surgery for acute aortic dissection to investigate the strength of the aortic adventitia.

Subjects and Methods

Of 16 consecutive patients who underwent surgery for acute aortic dissection at our hospital between January and December 2012, 14 patients underwent their first surgery, and samples were collected from these patients. From the ascending aorta specimen resected during emergency surgery, 1 × 6-cm rectangular aortic adventitia specimens were prepared as
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...rapidly as possible from the greater curvature of the aorta at: (1) 1 cm distal to the sinotubular junction (STJ) and (2) 2 cm central to the branching brachiocephalic artery (Fig. 1). The regions held with aortic clamp forceps were excluded, and the samples were cut out so as to set the long side of the rectangular shape at the aortic circumference. All samples were subjected to measurement within 15 min after resection from the body. A specimen was set on the exclusive table for Digital Force Gauge FGS-10 (NIDEC-SHIMPO Corp., Kyoto, Japan) (Fig. 2) and stretched in the long side direction (aortic circumferential direction), and the relationship between tension and length was investigated. One-centimeter regions at both ends of the sample were held with graspers termed chucks and set so as to adjust the length of the region to be extended at a natural length of 4 cm. The sample was extended by 3 mm approximately every second, and the increase in the tension was measured until the sample was torn. The tissue structure after measurement was pathologically investigated. Statistical analysis was performed using Excel (Microsoft Office 2010, Microsoft) and Statcel (OMS). This study was performed after obtaining consent from all patients.

Results

The tension could be measured in 27 samples out of those prepared from the 14 patients with acute aortic dissection who underwent their first surgery during the study period; however, the onset time was unclear, surgery was performed more than 24 hours after the onset, or specimens were collected from the middle region of the ascending aorta in 3 patients (9 samples), so these were excluded. The patients were 48–84 years old, and 4 patients were male. The mean time to surgery after the onset was 8.5 hours (3.5–22 hours). Ten and eight samples could be prepared from the regions near the STJ (1) and brachiocephalic artery (2), respectively. In preoperative CT images, the maximum minor axes of the specimens near the STJ (1) and brachiocephalic artery (2) were 47.4 ± 4.5 (42–58) and 47.2 ± 6.2 (40–61) mm, respectively (Table 1).

The samples were not torn at the ends held with the chucks without the influence of an external physical force, such as crushing, and all were torn in the middle region of the samples.

The relationship between length and tension was not linear, and the tension increased over the geometric progression with stretching (Fig. 3). The length at rupture was 4.1 ± 1.2 mm/cm in samples from near the STJ (1) and 4.2 ± 1.0 mm/cm in those from near the brachiocephalic artery (2), and the maximum tensions were 10.4 ± 6.9 and 9.7 ± 2.7 Newtons (N), respectively. The mean length and maximum tension of all samples at rupture were 4.2 ± 1.1 mm/cm and 10.2 ± 4.9 N, respectively (Table 1).

There were no significant differences between the specimens near the STJ (1) and brachiocephalic artery (2). The aortic adventitia rapidly lost tension and was torn after reaching the maximum tension.
prognosis. Of these treatments, antihypertensive therapy is expected to prevent aortic wall rupture and dilation of the aortic wall of the residual dissected region. However, only a few studies have investigated the strength of the aortic wall to be protected. Investigations of the aortic wall in autopsied patients\(^1,2\) and the physical properties of resected aortic or aneurysm walls after refrigeration for days\(^3,4\)\(^\) have been reported but, to our knowledge, there have been no reported studies in which the adventitia of dissected aortic walls was subjected to measurement immediately after resection to investigate it under conditions close to those in the body.

There have been many studies on methods to estimate the force loaded on the aortic wall,\(^5–7\) in which blood pressure was used an index, or various indices, such as wall and shear stresses calculated from the vascular diameter, wall thickness, blood pressure, and blood flow, were investigated; however, it was impossible to identify the limit for the aortic wall in vivo, namely, the value at which it collapses. Moreover, to our knowledge, no study has directly investigated dissected aortic adventitia, although some studies assumed individual stresses on the tunica media and adventitia and verified these by animal experiments.\(^8,9\)

It was naturally assumed that the conditions of the aortic wall varied among regions, but samples of the proximal and distal ascending aorta were prepared from aortic wall specimens that were no longer needed. There were no significant differences in the tension or length between these two sampled regions. Since the number of specimens was small, it is necessary to investigate other regions and extension in other directions.

The aortic diameter and specimen-donor sites were matched in preoperative CT images, and the relationship between the preoperative aortic diameter and room for extension was investigated using Pearson’s correlation coefficient, but no significant correlation was noted.

On pathological examination, the dissected surface of the tunica media elastic lamina was exposed, and the fiber distribution was disturbed, but no inflammation or arteriosclerotic lesion was observed in any sample. Medionecrosis was noted in three cases.

### Discussion

The cause of acute aortic dissection is still unclear, and apart from in a few cases, there is no clear inducer of its onset, and the overall number of patients is increasing. For acute onset, surgical or internal medicinal treatment is performed setting the primary target as the prevention of fatal complications, such as rupture of the aorta, cardiac tamponade, and acute myocardial infarction, to save life; however, management and treatment are still necessary after fatal complications have been avoided in order to improve the vital condition. Of these treatments, antihypertensive therapy is expected to prevent aortic wall rupture and dilation of the aortic wall of the residual dissected region. However, only a few studies have investigated the strength of the aortic wall to be protected. Investigations of the aortic wall in autopsied patients\(^1,2\) and the physical properties of resected aortic or aneurysm walls after refrigeration for days\(^3,4\)\(^\) have been reported but, to our knowledge, there have been no reported studies in which the adventitia of dissected aortic walls was subjected to measurement immediately after resection to investigate it under conditions close to those in the body.

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The tension of the aortic adventitia did not increase immediately when it was stretched, and it rapidly increased when it approached the limit, suggesting that, even though the aorta is dilated by a blood pressure load within a specific range in the body, the aortic adventitia does not receive it as tension (stress) and absorbs it. This differs from the assumption that the aortic wall is rigid, as described in reports on

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Dia. (mm)</th>
<th>Tension (N/cmW)</th>
<th>Length (mm/cmL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen 1</td>
<td>47.4 ± 4.5</td>
<td>10.4 ± 6.9</td>
<td>4.1 ± 1.2</td>
</tr>
<tr>
<td>Specimen 2</td>
<td>47.2 ± 6.2</td>
<td>9.7 ± 2.7</td>
<td>4.2 ± 1.0</td>
</tr>
</tbody>
</table>

Dia.: diameter of the aorta measured on computed tomography scan before the surgery; N/cmW: Newton/cm specimen width; mm/cmL: mm/cm specimen length
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from the non-dissected region during surgery for the acute phase in patients with acute aortic dissection. It is also ethically problematic to resect non-dissected normal aortic wall. Some resected specimens contained only the tunica media, but these were not subjected to the tension test of the tunica media because dissected tunica media floating in the blood vessel may not support blood pressure, and the sum of the measured tension of tunica media alone detached from the adventitia and that of the adventitia may not represent the tension of full-thickness aortic wall. Thus, we did not set the objective of this study to be investigation of the relationship between the length of full-thickness aortic wall and tension at the time of onset of aortic dissection.

The aortic adventitia was examined under conditions as close as possible to those in the body, but it has not yet been verified whether the tissue conditions within 15 min after resection are similar to those in the body. To verify this, we are planning histological investigation or actually to measure the tissue over time from immediately after resection.

Conclusion

The aortic wall adventitia resected immediately after the onset of acute aortic dissection was empirically shown to be extended and the actual extension length was measured in order to investigate the relationship between length and tension. The tension of the aortic adventitia rapidly increased when the length approached its limit, suggesting the presence of a limit for rupture at which the aortic adventitia collapses immediately after the onset of acute aortic dissection. On this basis, it may be necessary to manage the condition so as to prevent the length limit being exceeded in acute phase treatment. It may also be necessary to accumulate and investigate data concerning blood pressure control as an index to avoid exceeding the length limit and for setting a long-term therapeutic policy.

Disclosure Statement

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References