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<td>Author(s)</td>
<td>Takagi, Toshihiro</td>
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<tr>
<td>Citation</td>
<td>Acta medica Nagasakiensia. 1980, 25(1-4), p.54-75</td>
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<td>Issue Date</td>
<td>1980-10-25</td>
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Pathomorphological Study on the Changes of Human Intra-abdominal Umbilical Artery with Aging

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Received for publication, July 1, 1980

A part of this work was presented at the 11th Annual Meeting of the Clinical Electron Microscopy Society of Japan, October 18, 1979 and the 69th Annual Meeting of the Japanese Pathological Society, June 27, 1980.

SUMMARY

The human intra—abdominal umbilical artery by the ligation of the umbilical cord soon after the birth becomes a lateral umbilical ligament in adults. The specimens of the human intra—abdominal umbilical artery obtained from cases ranging in age from 18 weeks of menstrual age to 74 years old were examined light and electron microscopically in search of changes as part of the series of study on the vascular aging phenomena. On the other hand, the vein, the artery in the vulval cyst wall, and the pulmonary vessels of the cases of bronchiectasis and lung cancer were also examined for comparison.

In the adventitia in the umbilical and intermediate parts of the intra—abdominal umbilical artery, smooth muscle cells appeared and then became involuted. Since smooth muscle cells were observed in the adventitia of the above artery and pulmonary vessels examined, the artery might react to produce smooth muscle cell bundles in the adventitia. Moreover, since the vein physiologically contains smooth muscle cell bundles, the presence of smooth muscle cell bundles in the artery may suggest that the artery became similar to the vein.

In the media of the umbilical and intermediate parts, elastosis was noted and smooth muscle cells were atrophied. Complete obliteration was barely induced so as to see patent lumen even in aged cases.

The narrowing of the lumen was due to intimal thickening and thrombi. The internal iliac arterial part showed only intimal thickening and no other remarkable changes.

* 高木 敏博

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INTRODUCTION

The umbilical artery and vein play an important role in the fetal circulation. There have been a variety of reports on the intima, media, Wharton’s jelly and epithelium of the umbilical cord in the fetal period\(^{10-9}\).

The fetal circulation changes remarkably with the birth. In humans, the birth immediately results in the commencement of pulmonary breathing, ligature of the umbilical cord and discontinuation of placental blood circulation. In the course of these changes at the time of birth, the structure of the wall of the intra-abdominal umbilical artery and vein and the ductus arteriosus Botalli is remodeled. Our department has been studying the vascular aging\(^{10,11}\), as part of the series of the departmental study, the author paid attention to the human intra-abdominal umbilical artery where the wall is remodeled in a relatively short period, and made observations of the course from 18 weeks of menstrual age to 74 years of age.

The intra-abdominal umbilical artery is connected from the internal iliac artery to the umbilicus and later it becomes a fibrous cord-shaped lateral umbilical ligament. During the observation of this process, attention was paid to the smooth muscle cell bundles that would appear in the external layer of the circularly arranged medial smooth muscle cells, i.e., in the adventitia. To elucidate the significance of these smooth muscle cell bundles, light and electron microscopic observations were made of the vein physiologically containing smooth muscle cell bundles in the adventitia\(^{12}\), and also of the artery in the vulval cyst wall and part of the pulmonary vessels for comparative study.

MATERIALS AND METHODS

The specimens of the human intra-abdominal umbilical artery were obtained from cases of various ages ranging from 18 weeks of menstrual age in a case of therapeutic abortion to a 74-year-old autopsy case. The collected cases were divided into six groups: fetal period up to 40 weeks of menstrual age, neonatal period from the 1st day to the 14th day after birth, infant period from 15 days to 1 year of age, childhood from age 1 to 11, puberty from age 11 to 19, and sexual maturity after age 19. There were 5 cases in the fetal period, 5 cases in the neonatal period, 8 cases in the infant period, 6 cases in the childhood, 2 cases in the puberty, and 15 cases in the sexual maturity, totalling 41 cases. These cases are shown in Table 1.

The intra-abdominal umbilical artery is connected from the internal iliac artery to the umbilicus. However, in preparation of specimens, the sampled artery was grossly divided into 3 parts, namely, umbilical part, intermediate part, and internal iliac arterial part (Fig. 1).

On the other hand, observation was made on the specimens of the inferior vena cava and the renal vein obtained from autopsy cases aged 9, 56, 66, 69 and 69.
Table 1 Classification of Developmental Groups

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<th>fetal period</th>
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<th>puberty</th>
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<td>8</td>
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<tr>
<td>15days-12months</td>
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<td>2w</td>
<td>1y</td>
<td>13y</td>
<td>31y</td>
<td>59y 63y</td>
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<td>1-11 years</td>
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<td>67y 74y</td>
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Observation was also made on the artery in the cyst wall of a vulval biopsy case in a 53-year-old female with the diagnosis of Bartholin's duct cyst, and on the artery in the vulva in the equivalent region of an autopsy case in a 9-year-old female. Moreover, the pulmonary vessels obtained from 30- and 60-year-old autopsy cases with bronchiectasis and from a 62-year-old pulmonary biopsy case with the diagnosis of adenocarcinoma were also examined.

These tissue specimens were fixed with 10% formalin, embedded in paraffin, cut into 3 μ sections, and stained with Hematoxylin and Eosin, and with Elastic−van Gieson for light microscopic examination. The specimens for electron microscopic examination were fixed with 1.5% glutaraldehyde in pH 7.4 and then postfixed with 1% osmic acid, dehydrated with ethanol, embedded in Epon, and cut into ultrathin sections. These ultrathin sections were double-stained with uranyl acetate and some parts were stained with tannic acid for observation of elastic fibers. Most of these specimens were oriented so as to give transverse sections. The ultrathin sections were prepared with a Sorvall "Porter−Blum" Ultra-Microtome MT-1 and were examined with JEM-7A and JEM-100B electron microscopes.

RESULTS

The intra-abdominal umbilical artery varied in wall structure by region and age. To facilitate the understanding of the morphological changes of the intra-abdominal umbilical artery, description is made here separately for the adventitia, media, and intima and lumen.
1. Intra-abdominal umbilical artery

1) Changes in the adventitia

The major changes in the adventitia were the appearance of smooth muscle cell bundles and small vessels. In the fetal period, the umbilical and intermediate parts showed that the circularly arranged medial smooth muscle cell layer was surrounded by a layer of loose connective tissue and a few small vessels, and the outermost layer was covered with mesothelial cells. Electron microscopic observation of the loose connective tissue layer in the intermediate part at 18 weeks of menstrual age (Fig. 2a) disclosed that spindle-shaped fibroblasts with abundant rough endoplasmic reticula and relatively abundant glycogen granules were scattered in the broad intercellular space consisting of amorphous materials and a small quantity of collagen fibers (Fig. 3a). Occasionally, rounded cells with dense attachment were seen. The adventitia in the internal iliac arterial part was more abundant in collagen fibers than the loose connective tissue in the umbilical and intermediate parts.

In the neonatal period, the umbilical and intermediate parts began to have cells with rounded cytoplasm and increased small vessels in the layer of the loose connective tissue, i.e., in the adventitia. The internal iliac arterial part revealed numerous collagen fibers and increased small vessels in the adventitia.

In the infant period, the umbilical and intermediate parts showed rounded cells that appeared in the adventitia and were mutually grouped into a bundle shape so as to occupy the most part of the transverse section. Small vessels and collagen fibers also increased. In an infant 3 weeks after birth, circularly arranged medial smooth muscle cell layers were surrounded by small vessels and rounded cells. Electron microscopic examination disclosed that these rounded cells were smooth muscle cells with dense attachment and basal lamina as well as with rough endoplasmic reticula and glycogen granules. The intercellular space showed an increase of collagen fibers compared with that in the fetal period (Fig. 3b). Increased rounded smooth muscle cells and many small vessels were observed in a case 5 weeks after birth (Fig. 2b). Electron microscopic examination of this part revealed mutual grouping of smooth muscle cells into a bundle shape and appearance of fibroblasts (Fig. 3c). The small vessels consisted of endothelial cells being surrounded by a layer of smooth muscle cells. The endothelial cells were bright and large in size having microvilli and marginal folds facing the lumen. It was particularly noteworthy that electron dense rod shaped bodies, i.e., Weibel–Palade bodies were seen more abundantly in the cytoplasm (Fig. 4). In the umbilical part of an infant 8 months after birth, smooth muscle cell bundles occupied most of the intra-abdominal umbilical artery.

During the childhood, the smooth muscle cell bundles of the umbilical and intermediate parts gradually separated from one another. Small vessels also decreased. In the intermediate part in a 1-year-and-1-month old child, the adventitia was thickened and electron microscopic examination of the adventitia revealed numerous smooth muscle cells (Fig. 3d). In the longitudinal sections of the adventitia in the
umbilical part of a 5-year-old child, slender smooth muscle cells having cytoplasm with filament and also having dense body, dense attachment and basal lamina were numerously observed. In the umbilical part of a 9-year-old child, the smooth muscle cells formed groups of several cells and each bundle was somewhat separated from the others (Fig. 2c).

The separation of smooth muscle cell bundles was remarkable in the umbilical and intermediate parts in puberty and sexual maturity. In the umbilical part of a 67-year-old man, the smooth muscle cell bundles were all separated and the interspace was filled with increased collagen fibers (Fig. 2d). The adventitia in the internal iliac arterial part showed no remarkable changes after the infant period.

2) Changes in the media

The major changes in the media were seen in elastic fibers and smooth muscle cells. In the media of the umbilical and intermediate parts in the fetal period, there were observed several layers of circularly arranged medial smooth muscle cells and no distinct external elastic lamina despite the Elastic—van Gieson staining which is for the staining of elastic fibers but only several lightly stained layers of elastic fibers were seen. The media of the intermediate part at 18 weeks of menstrual age is shown in Fig. 2a. Elastic fibers were more abundant in the internal iliac arterial part than in the umbilical and intermediate parts, and the internal elastic lamina was seen in some cases.

In the neonatal period, elastic fibers increased in the umbilical and intermediate parts. In the internal iliac arterial part, the external elastic lamina as well as the internal elastic lamina were clearly seen in some cases.

In the infant period, the internal elastic lamina in the umbilical and intermediate parts became continuous being surrounded by many elastic fibers and manifesting elastosis. In electron microscopic observation, they were irregular in size, ruptured and tortuous in shape, and degenerated. The smooth muscle cells became atrophic with the torn cytoplasm and decreased in number. In the umbilical part of a case 5 weeks after birth, a large continuous internal elastic lamina and circularly arranged medial smooth muscle cells were observed (Fig. 2b) and several layers of elastic fibers were recognized in Elastic—van Gieson staining. In the umbilical part 8 months after birth, elastosis as well as slight calcification were seen even in the media. In the media of the internal iliac arterial part, elastosis was not recognized but elastic fibers, internal and external elastic laminae were seen, indicating an intermediate type between the elastic type and muscular type.

In the childhood, the umbilical and intermediate parts showed advanced degeneration of elastic fibers and remarkable atrophy of smooth muscle cells, some of which having formed bundles. The intermediate part of a 1-year-and-1-month-old child showed elastosis resulting in indistinct demarcation of the internal elastic lamina. Electron microscopic observation of this part of elastosis upon staining with tannic acid revealed that elastic fibers were ruptured and bent appearing electron dense. Smooth
muscle cells became atrophic. In this external region with less elastic fibers, slender circularly arranged smooth muscle cells were observed (Fig. 5).

In the puberty and sexual maturity, the umbilical and intermediate parts showed reduced area of the media. The region of elastosis caused shrinkage toward the lumen. Smooth muscle cells became bundle-shaped and atrophic, decreasing in number upon aging. The internal iliac arterial part remained intermediate between elastic type and muscular type, showing no remarkable change with aging.

3) Changes in the intima and lumen

The major changes in the intima and lumen were intimal thickening and thrombi. In the fetal period, a layer of endothelial cells and patent lumen were observed but no intimal thickening nor thrombi (Fig. 2a).

In the neonatal period, the umbilical and intermediate parts showed fibrin thrombi in the lumen. Intimal thickening was seen in the internal iliac arterial part in some cases.

In the infant period, the umbilical and intermediate parts showed organized thrombi and numerous small vessels seemingly produced by recanalization. Intimal thickening was also seen. Calcification was noted in some cases. Some of the small vessels penetrating through the intima advanced to the adventitia and media, and even invaded the intima beyond the internal elastic lamina. In a 3-week-old infant, the thrombi began to be organized and spindle-shaped cells were forming a new lumen. Fibrin thrombi were seen also in this new lumen. Some cases showed red blood cells in the new lumen with blood circulation and completed recanalization (Fig. 6). In the umbilical part of a 5-week-old infant, the original lumen was filled with bright loose tissue and small vessels with the flow of red blood cells were seen scatteringly (Fig. 2b). The cells filling the original lumen were mostly fibroblast-like cells with expanded rough endoplasmic reticulum, histiocytes with cytoplasm containing lipids and numerous red blood cells. These fibroblast-like cells gathered together and were surrounded by basal lamina-like materials. This seemed to be the beginning of the formation of new vessels. Amorphous materials and collagen fibers were seen in the intercellular space (Fig. 7). In the intermediate part 4 months after birth, small vessels were seen to have invaded the intima from the media through the internal elastic lamina (Fig. 8). In the umbilical part 8 months after birth, calcification of the intima was seen. In the internal iliac arterial part, intimal thickening was seen and the cells in the innermost layer were arranged circularly.

During childhood, the original lumen of the umbilical and intermediate parts was filled with thrombi and intimal thickening only leaving small vessels. The intermediate part at age 5 disclosed small vessels consisting of a layer of endothelial cells and surrounding 2 layers of smooth muscle cells. Weibel-Palade bodies were scanty. The external surface of these small vessels was constituted by collagen fibers with few cells. This was distinctly demarcated from the layer of medial elastosis (Fig. 9). In the region of intimal thickening of the internal iliac arterial part at 1 year and 1 month of
age, the picture of medial smooth muscle cells seemingly penetrating the internal elastic lamina into the intima was seen scatteringly.

In the puberty and sexual maturity, small vessels surrounded by the media with elastosis were barely found in the umbilical and intermediate parts. The umbilical part in a 67-year-old case showed patent lumen. The lumen of small vessels can be seen if the part of elastosis is properly obtained as a specimen. In the childhood and thereafter, the internal iliac arterial part showed intimal thickening as its major change with no other remarkable changes.

The above major changes are summarized in Table 2.

| Table 2 Findings in Umbilical and Intermediate Part of Intra—abdominal Umbilical Artery |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Age                             | Pental Period                  | Neonatal Period                | Infant Period                  | Childhood                      | Puberty                        | Sexual Maturity                 |
| Intima                          | intimal                        | (-)                            | (±)                            | (+)                            | (+)                            | fibrous                         | fibrous                         |
| &                              | thickness                      |                                 |                                |                                |                                |                                 |                                 |
| Lumen                          | thrombi                        | (-)                            | (±)                            | fibrinous                      | (+)                            | recanalization                 | fibrous                         | fibrous                         |
| Media                          | internal elastic lamina         | (-)                            | (±)                            | discontinuous                  | (+)                            | continuous                     | indistinguishable               | indistinguishable               | indistinguishable               |
| elastosis                      | (-)                            | (-)                            | (+)                            | (+)                            | (+)                            | (+)                            | (+)                            | (+)                            |
| Adventitia                     | muscle bundles                 | (-)                            | (-)                            | (+)–(++)                       | (++)                           | (++)                           | (++)                           |
| small vessels                  | (±)                            | (++)                           | (++)                           | (++)                           | (++)                           | (++)                           | fibrous                        |

(-): no visibility                  (+): slight visibility            (+): moderate visibility
(++): marked visibility

2. Vein

The structure of the vein and its change with aging are described below. A moderate size vein in the surroundings of the vena cava of a 9-year-old girl showed a layer of endothelial cells and six layers of circularly arranged medial smooth muscle cells being surrounded by thick adventitia. In the adventitia, many smooth muscle cell bundles were seen and their interspace was filled with some collagen fibers (Fig. 10a). The inferior vena cava was basically the same structure but it contained a continuous large elastic lamina like the internal elastic lamina and thicker adventitia (Fig. 10b).
It was confirmed by electron microscopy that this thick adventitia was comprised with smooth muscle cell bundles. In the inferior vena cava in a 69-year-old case, the interspace of the smooth muscle cell bundles in the adventitia was filled with many collagen fibers (Fig. 10c). This indicates that the aging of the inferior vena cava results in the separation of the adventitial smooth muscle cell bundles and filling of the interspace with collagen fibers. The intima also became thickened. Similar aging phenomena were also seen in the renal vein.

3. Arteries in the vulval region and pulmonary vessels

The arteries in the vulval region showed the following findings. In the artery on the wall of the Bartholin’s duct cyst in a 53-year-old female, a continuous internal elastic lamina and a circularly arranged smooth muscle cell layer were surrounded by a thick layer of smooth muscle cell bundles (Fig. 11a). Such a layer of smooth muscle cell bundles was not observed in the artery of the vulval region near the Bartholin’s gland in a 9-year-old female.

Then, the pulmonary vessels were reviewed. In the artery found in pulmonary adenocarcinoma in a 52-year-old male, there were observed a continuous internal elastic lamina, a circularly arranged smooth muscle cell layer, and an external elastic lamina, surrounded by a thick layer of smooth muscle cell bundles (Fig. 11b). The artery with a thick layer of smooth muscle cell bundles around the layer of circularly arranged smooth muscle cells was also formed in a 30-year-old male and a 69-year-old female with bronchiectasis. A pulmonary vessel, though not confirmed to be an artery or a vein, was found to have smooth muscle cell bundles around the layer of circularly arranged smooth muscle cells (Fig. 11c).

The artery of the vulval cyst wall and the pulmonary vessel in the cases of bronchiectasis and lung cancer disclosed a thick layer of smooth muscle cell bundles around the layer of circularly arranged smooth muscle cell bundles.

**DISCUSSION**

Morphological changes due to aging of the umbilical artery were observed remarkably in the umbilical and intermediate parts but the changes in the internal iliac arterial part were not remarkable. Consequently, discussion is made here on the changes of these three sections, i.e., adventitia, media, and intima and lumen.

1. Changes in the adventitia

Although a few smooth muscle cells were seen in the adventitia which had been a loose connective tissue in the fetal period, there appeared more smooth muscle cells in the neonatal period. These smooth muscle cells increased in number forming groups or bundles in the infant period. These smooth muscle cell bundles began to be separated from one another and were further separated with the advancement of stage to
puberty and sexual maturity. The scheme from the childhood is shown in Fig. 12. The artery in the internal iliac arterial part was characterized by both elastic type and muscular type; both internal and external elastic laminae were seen, and lamellar elastic fibers were abundant in the media. In the intermediate part, the thick adventitia showed many smooth muscle cell bundles and the smooth muscle cells of the media also formed bundles. In the umbilical part, most of the transverse-sectional surface of the umbilical artery was occupied by smooth muscle cell bundles of the adventitia. It appears that these adventitial smooth muscle cell bundles are called lateral umbilical ligament. However, this region is not a ligament but longitudinally arranged smooth muscle cells as confirmed electron microscopically in this study and as described by NISHIMOTO\(^{14}\), but there is no description on its significance.

In comparison between the smooth muscle cell bundles of the adventitia of the umbilical artery and the smooth muscle cell bundles seen in the artery of the vulval cyst wall and in the pulmonary vessel in a case of bronchiectasis and lung cancer, the following common findings were seen: the bundles were arranged longitudinally outside the circularly arranged smooth muscle cell layer several times thicker, forming groups of tens of bundles with collagen fibers in their interspace. However, while the adventitial smooth muscle cells in the intra-abdominal umbilical artery were separated and atrophied with aging, changes with aging in the artery of the vulval cyst wall and in the pulmonary vessels examined could not be verified because of the small number of cases. In view of the fact that the smooth muscle cell bundles of the umbilical artery and the artery in the vulval cyst wall and the pulmonary vessels examined had the above common features, it is speculated that the artery may possibly react to assume such a morphology. SPENCER\(^{15}\) stated that chronic pulmonary hypertension might result in the development of longitudinal muscle bundles both inside the internal and outside the external elastic laminae of the muscular arteries, and further that the presence of such longitudinal spiral muscle bundles might be unconnected with hypertension but might be indicative of an increased longitudinally applied stress to the vessel because arteries subjected to intermittent excessive longitudinal stretch (i.e., in emphysema) developed longitudinal mural muscle bundles. AIHARA\(^{16}\) and KATASE\(^{17}\) having measured the length of the intra-abdominal artery indicated that the artery increased in size with body growth. NAKAYAMA et al\(^{18}\) made observations of fetus and neonates from 6 months of the fetal period to 1 month after birth and supposed remarkable elongation of the upper half of the umbilical side of the umbilical artery. It is more reasonable to assume that the intra-abdominal umbilical artery increased its length by its excessive elongation rather than by active growth of the dysfunctioned vessel. The stress of this longitudinal elongation might have served to enhance the development of the smooth muscle cell bundles of the umbilical arterial adventitia. It was imagined that the artery in the vulval cyst wall was considerably affected by the stress of the enlarged cyst and probably also by the tumor as seen in the pulmonary vessels though this is no more than a speculation. It is difficult to clarify the cause-effect relationship in the
pulmonary vessels as they show the development of longitudinal muscles by various stimulations.

It may be considered from the comparison of the physiological evidence of thick smooth muscle cell bundles in the adventitia of the vein and the changes of the intra—abdominal umbilical artery, that such changes of the intra—abdominal umbilical artery might reflect the behavior of the artery resembling that of the vein. There is a report showing the difference between the artery and the vein by the functional difference of medial smooth muscle cells between the two vessels, but the author found a common feature of the intra—abdominal umbilical artery and the vein examined in that both formed bundle shapes of smooth muscle cells.

Small vessels of the adventitia already observed in the fetal period increased in the neonatal and infant periods and gradually decreased thereafter. SATO studied the process of obliteration of the umbilical artery and vein of the rabbit and reported that new vessels were observed transiently. KANAMARU in his study of the process of obliteration of the umbilical artery of the rabbit reported that new vessels invaded the media from the adventitia. Both of these investigators considered that the new vessels supply nutrients to the umbilical artery and vein with disturbed blood flow and moreover actively participate in fibrosis of the umbilical artery and vein by carrying mesenchymal cells to the region of disturbed blood flow. It is readily speculated that hypoxia due to sudden block of blood flow after birth may result in an increase of such small vessels, bringing forth mesenchymal cells and inducing fibrosis, and as the fibrosis of the umbilical artery and vein advances and the amount of nutritional demand decreases, these small vessels also decrease and disappear. It seems noteworthy that Weibel—Palade bodies were relatively abundant in the infant period when small vessels increased in number.

II. Changes in the media

Among the changes in the media, interesting would be those of elastic fibers and smooth muscle cells. The media of the umbilical and intermediate parts in the fetal and neonatal periods showed no elastic fibers large enough to be called internal elastic laminae but only some layers of elastic fibers stained lightly by elastic fiber staining. In the infant period, the elastic fibers of the innermost layer developed continuously forming the internal elastic lamina. The internal elastic lamina was surrounded by increased elastic fibers showing the picture of elastosis. Elastic fibers were irregular in size, ruptured and tortuous in shape, and degenerated. Since childhood, the layer with elastosis was gradually reduced in size but the lumen was not completely closed. The smooth muscle cells that had been recognized in these parts became atrophic and reduced in number. NISHIMOTO, AIHARA, KATASE and MIYAKE have also described the changes of elastic fibers of the media without comment on the significance. In electron microscopic observation of the ductus arteriosus Botalli, we obtained the findings that elastic fibers were more in the patent cases than in the closed cases. It is interesting to note that the of lumen becomes difficult with an increase
of elastic fibers in the intra—abdominal umbilical artery. Whereas there is a report on life—time patency of the intra—abdominal segment of the umbilical vein except the paraumbilical segment, patency of the umbilical artery was often observed in aged cases in the present study.

Changes in the intima and lumen

There was seen no intimal thickening nor formation thrombi in the fetal period. In the neonatal period, slight intimal thickening was seen in the umbilical, intermediate and internal iliac arterial parts. Thrombi were recognized in some cases. In the infant period, these thrombi were organized in the umbilical and intermediate parts and were further recanalized to show several lumens. However, at the sites only several millimeters apart, there were seen no thrombi but more intimal thickening. In other words, a lumen of the umbilical artery has several scattered thrombi and also intimal thickening. Consequently, the lumen was narrowed or obliterated by organized thrombi and intimal thickening varying in their ratio by region. ARiyoshi having studied the process of thrombi formation of the femoral artery and vein of the rabbit by silver nitrate indicated that the new vessels in the organized thrombi of the vein were formed by the grouping of young fibroblasts. The findings in the present study were the same. However, he considered that the arterial thrombi would be lysed. This is contradictory to the formation of thrombi in the intra—abdominal umbilical artery but it is likely that the formation of thrombi in the intra—abdominal umbilical artery is liable since the blood pressure and blood flow in this artery are similar to that in the vein. As stated above, this lumen is hardly closed so as to be seen even in aged cases. The change in the iliac arterial part was mostly intimal thickening but penetration of the medial smooth muscle cells through the internal elastic lamina was also seen scatteringly. These findings were the same in BALK’s report on pulmonary arterial intimal fibrosis as well as in the arteries of other regions.

There have been reports emphasizing the contraction of the vascular wall in the process of closure the intra—abdominal umbilical artery. They acquired the concept of contraction in view of the endothelial cells protruding into the lumen and convoluted elastic fibers, but this concept cannot be finalized since it is possible that the endothelial cells might have protruded due to the decreased pressure of the lumen after the collapse. BHawan et al observed the process of arterial shrinkage upon ligature of the carotid artery of the rat at two sites. They attributed the vascular contraction to the elastic structure and the function of the media and lumen themselves. Since most of the smooth muscle cells of the media disappear in 7 days, it is doubtful if such smooth muscle cells have contractile force as they themselves pointed out. The author considers that the decreased internal pressure due to discontinuation of blood flow is the greatest factor of the vascular shrinkage. The intra—abdominal umbilical artery provides a good example.

The intra—abdominal umbilical artery varies in morphology by age and site. It is interesting to note that AIHARA analyzed the morphological differences upon
dividing the process of closure of the intra-abdominal umbilical artery into three stages as described below. The first period is that of intimal thickening, the second period is that of proliferation of medial elastic fibers mostly characterized by medial elastosis, and the third period is that of fibrosis. The internal iliac arterial part remains in this first period throughout life; the intermediate part advances with age to the first and second periods but stays in the second period; and the umbilical part advances through the three periods. This analysis seems reasonable.

As described above, the author studied the morphological changes of the intra-abdominal umbilical artery with the lapse of time in comparison with other vessels, and obtained some interesting findings. It is believed that this study is useful in providing basic data for various vascular lesions.

CONCLUSION

The author examined the human intra-abdominal artery obtained from 41 cases ranging in age from 18 weeks of menstrual age to 74 years old, in comparison with the vein, artery in the vulval region and pulmonary vessels, and obtained the following conclusion.

1) The umbilical and intermediate parts of the intra-abdominal umbilical artery with thick smooth muscle cell bundles in the adventitia resembled the observed artery in the vulval cyst wall, pulmonary vessels in cases of bronchiectasis and lung cancer, and pulmonary vessels in reported cases of pulmonary hypertension. The artery may assume such morphological changes having smooth muscle cell bundles in the adventitia. The morphological changes to produce smooth muscle cell bundles in the artery suggest that the artery followed similar changes to those in the vein as revealed by the comparison with the vena cava and the vein of moderate size.

2) The morphological changes in the adventitia of the intra-abdominal umbilical artery may possibly be caused by longitudinal stress applied to the artery and by hypoxia.

3) Degeneration of elastic fibers was seen in elastosis of the media and smooth muscle cells in that region became atrophic.

4) It is interesting to note that elastic fibers increased in the cases of patent ductus arteriosus Botalli and that elastic fibers also increased even in the intra-abdominal umbilical artery causing difficulty in closure of the lumen. Patency was seen even in aged cases.

5) Intimal thickening was observed in all the umbilical, intermediate and internal iliac arterial parts. Thrombi were present in the umbilical and intermediate parts, inducing narrowing or obliteration.
ACKNOWLEDGEMENT

The author wishes to express his deepest appreciation to Professor Issei NISHIMORI of the Department of Pathology, Atomic Disease Institute, for his kind guidance in the study and review of paper. Appreciation is also due to Assistant Professor Nobuo TSUDA of Central Clinical Laboratories, and also to all the staff members of the Department of Pathology, Atomic Disease Institute and the Scientific Date Center of Atomic Bomb Disaster for their cooperation. The author is grateful to those who provided specimens for this study.

REFERENCES


Fig. 1 A Simplified Scheme of the Fetal Circulation Illustrated by G. Reid. A: umbilical part  B: intermediate part  C: internal iliac arterial part

Fig. 2 Developmental Changes in Different Periods. (X 25) Smooth muscle cell bundles are seen in adventitia (arrows). 2a. fetal period, 18 weeks, intermediate part (H&E) 2b. infant period, 5 weeks, umbilical part (H&E) 2c. childhood, 9 years, umbilical part (H&E) 2d. sexual maturity, 67 years, intermediate part (EVG)
Fig. 3 Smooth Muscle Cells in Adventitia. (X 2,100) 3a. fetal period, 18 weeks, intermediate part. Fibroblasts are scattered in the broad intercellular space. 3b. infant period, 3 weeks, umbilical part. Smooth muscle cells with increased collagen fibers.
Fig. 3c. infant period, 5 weeks, umbilical part. Grouping of smooth muscle cells in a bundle shape. 3d. childhood, 1-year-and-1-month, intermediate part. Numerous smooth muscle cells in bundles.
Fig. 4 A Small Vessel in Adventitia of Umbilical part. infant period, 3 weeks (X 8,300) Weibel–Palade bodies are seen more abundantly in the cytoplasm.

Fig. 5 Elastosis in Media of Intermediate Part. childhood, 1–year–and–1–month, tannic acid staining for elastic fibers (X 2,100) Smooth muscle cells (arrows) are atrophic or slender with electron dense elastic fibers.
Fig. 6 Recanalization of Thrombus. infant period, 3 weeks (X500) Completed recanalization with red blood cells in a new lumen (arrow).

Fig. 7 Beginning of the Formation of New Vessel. infant period, 5 weeks, umbilical part (X 5,400) Fibroblast-like cells gathered together and were surrounded by basal lamina-like materials.
Fig. 8 A small vessel invades the intima from the media through the internal elastic lamina. Infant period, 4 months (EVG, X500)

Fig. 9 A small vessel consisting of a layer of endothelial cells and surrounding 2 layers of smooth muscle cells. Demarcation between the intima and the medial elastosis is distinct. Childhood, 5 years, intermediate part (X 2,100)
Fig. 10 Smooth Muscle Cell Bundles in the Adventitia of Veins. (X40) 10a. a moderate size vein, 9-year-old girl. 10b. inferior vena cava, 9-year-old girl. 10c. inferior vena cava, 69-year-old case.

Fig. 11 Smooth Muscle Cell Bundles. (x125) 11a The artery on the wall of the Bartholin’s duct cyst in a 53-year-old female.
Fig. 11b The artery in pulmonary adenocarcinoma in a 52-year-old male. 11c The pulmonary vessel with bronchiectasia in a 69-year-old female.

Fig. 12 A Scheme of Intra-abdominal Umbilical Artery. A: umbilical part  B: intermediate part  C: internal iliac arterial part