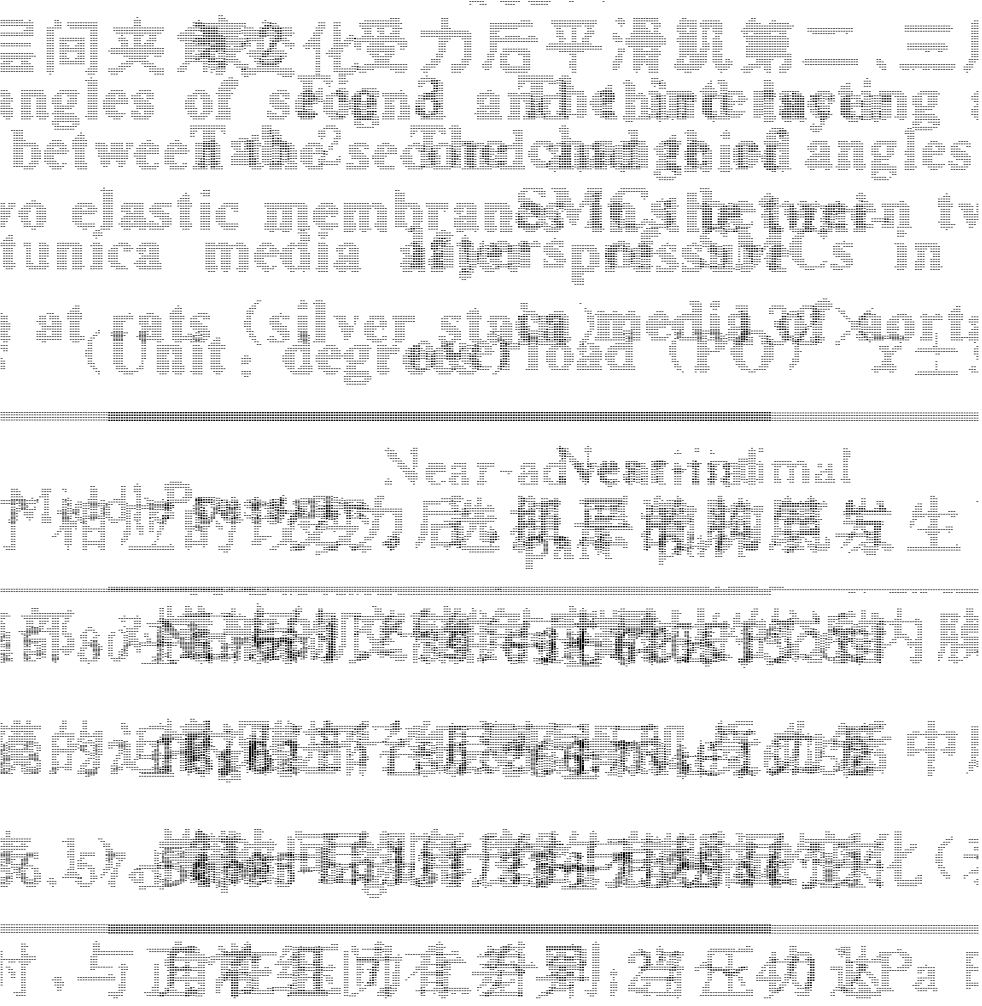
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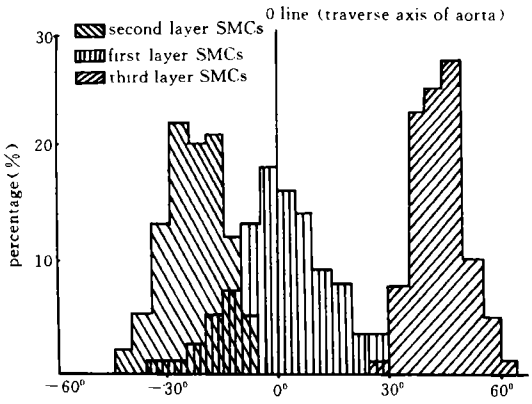


图4　正常压三层平滑肌纤维长径与主动脉横轴间夹角的百分率分布

Fig 4　Percentage distribution of angles between the longest diameter of three layer SMCs and the traverse axis of aorta under the normal pressure

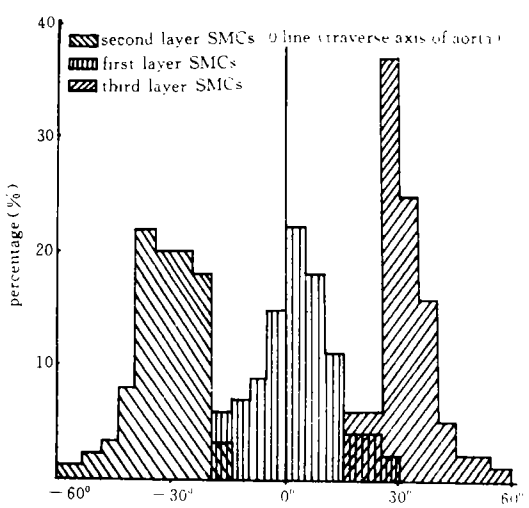


图5　高压三层平滑肌纤维长径与主动脉横轴间夹角的百分率分布

Fig 5　Percentage distribution of angles between the longest diameter of three layer SMCs and the traverse axis of aorta under the high pressure

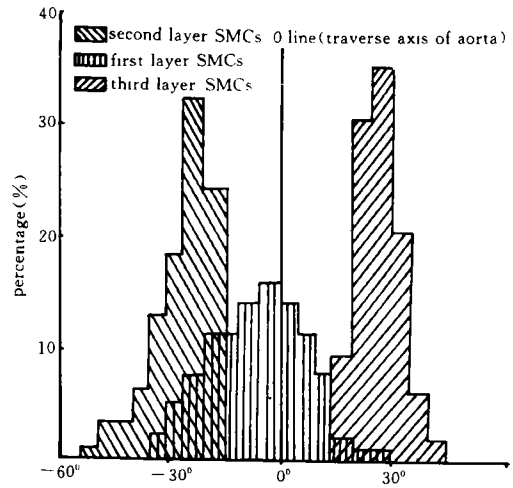


图6　超高压三层平滑肌纤维长径与横轴间夹角的百分率分布

Fig 6　Percentage distribution of angles between the longest diameter of three layer SMCs and the traverse axis of aorta under the super-high pressure

3　讨论

大鼠胸主动脉中膜两弹力膜间的平滑肌分层排列，细胞呈环形或螺旋形缠绕于血管壁。同一层平滑肌细胞的走向一致，不同层间的走向不同，构成了相互交错的网络状结构，以承受血管内的血液压力。正常状态下，内层平滑肌呈环形走向，中层呈反时针负螺旋方向，外层则呈顺时针正螺旋方向，三者与血管横轴的夹角（螺旋角）分别是1°、−22°和32°左右。随着血管的承压状态不同，管壁肌层构筑要发生相应的变化。

3.1　压力负荷下主动脉平滑肌配布变化趋向

早在1951年，Burton[9]就提出，血管壁的稳定性是由产生主动张力的平滑肌细胞和被动张力的弹性纤维、胶原纤维共同维持的。Patel[10]进一步证实，产生被动张力的弹性纤维是呈对称分布。由此推测，产生主动张力的平滑肌也应呈对称分布。否则，分离的血管干的游离端就会发生扭曲。要维持血管的稳定与平衡，平滑肌细胞应是全呈环行配布，若呈螺旋行走向，必须有约一半的细胞为正螺旋方向，另有一半的细胞为反螺旋方向。本实验对正常压、高压和超高压的大鼠主动脉肌层纤维走向的研究结果，证实了正、反螺旋方向各约占

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一半的推论。但各层平滑肌的走向并非恒定的完全对称，正常压时，肌层间的交错角度，总的趋势是顺时针方向螺旋的肌纤维角度明显大于反时针方向，此时如果产生被动张力的弹性纤维完全对称，而由于平滑肌纤维行向不完全对称，管壁结构本身会使主动脉有一定程度的扭曲。随压力的增高，肌层间纤维走向更趋于对称，在高压和超高压状态下，各肌层的走向均发生相应变化，其平均螺旋角差值由正常时的11°左右调整为1°左右。因此承压后的管壁，比松弛的管壁稳定性更大。

3.2 受力后肌层配布的变化有利于血管壁环向张力的产生

相互交错的肌纤维，赋予了中膜肌层较大的强度及张力，随着管腔内压力的变化，肌层配布将发生相应的改变，即功能状态不同，血管壁肌层构筑有异。Wolinsky[11]对兔主动脉的研究发现，在血管压力10.64 kPa时，肌纤维走向与横轴垂直或斜行，当压力上升到10.64 kPa以上时，肌纤维走向呈螺旋形。本研究则显示，随着压力的逐渐增高，肌层配布随之发生变化，平均螺旋角差值由正常压11°调整至±1°左右，平滑肌的走向逐渐趋向环行。按照力作用的一般法则，在血管壁内环行走向的平滑肌，比斜行走向的平滑肌收缩时使管腔缩小的效率更高，因此血管压力增加后，平滑肌纤维配布的变化，使血管壁具有更大的收缩效能。由于第二、三层肌层正、反螺旋方向排列的肌纤维与血管横轴的夹角几乎相等，当两层肌纤维同时收缩时，彼此斜行收缩产生的合力，相当于环向收缩力。环向收缩是血管的主要特性，肌纤维走向从螺旋到趋向于环形，增大了主动脉的环向收缩力。压力使血管结构和构筑发生了变化，而构筑的变化又使血管壁的力学特性发生改变，适应了升高的管腔内压。

参考文献

1 冯元桢，著. 生物力学. 北京：科学出版社，1983：168～170

2 Burton AC. Relation of structure to function of the tissues of the wall of blood vessels. Physiol Rev，1954，34(4)：619～642

3 Somlyo AP，Somlyo AV. Vascular smooth muscle. 1. Normal structure，Pathology biochimistry and biophysics. Pharmacol Rev，1968，20：197～230

4 Todd ME，Laye CG，Osborne DN. The dimensional characteristics of smooth muscle in rat blood vessels. A computer-assisted analysis. Circ Res，1983，53：319～331

5 Weiss Leon. Histology 5th ed. Macmillan Press Inc. New York，1983：372～394

6 Walmsley JG. Vascular smooth muscle orientation in straight portions of human cerebral arteries. J Microscopy，1983，131(pt3)：361～375

7 Cope DA，Roach MR. A scanning electron microscopy study of human cerebral arteries. Can J Physiol Pharmacol，1975，53：651～659

8 Fujiware T，Uebara Y. The cytoarchitecture of the medial layer in rat thoracic aorta：a scanning electron-microscopic study. Cell Tissue Res，1992，270(1)：165～172

9 Burton AC. On the physical equilibrium of small blood vessel. Am J Physiol，1951，164：319～329

10 Patel DJ，Fry DL. The equilibrium of arterial segments in dogs. Circ Res，1969，24：1～6

11 Wolinsky H. Structural basis for the static mechanical properties of the aortic media. Cire Res，1964，14：400～413

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A study of structural and architectural changes of aortic muscular layer under pressure overloading in rats

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Astract The structural and architectural changes of the smooth muscle cells (SMCs) of the thoracic aorta of male wistar rats were observed after the animals were exposed to pressure overloading. The aorta was cut open longitudinally and its endothelium was stripped off. The tunica media was separated layer by layer and each layer was flat spread on a slide and silver stained. Then the specimen was examined with optical microscopy. It was found that there were changes of the morphology and arrangement of SMCs after different pressure loadings were exerted on the aortic wall. When high (27～40 kPa) or superhigh (93～107 kPa) pressures were applied，the average spiral angle between muscular fibers was reduced from the control value of 11 degrees to 1 degree and the muscular fibers were gradually changed into circular direction to increase the strength of circular contraction of the aortic wall.

It is believed that pressure overloading results in the structural and architectural changes of the tunica media of the aorta and its architectural changes are to be compliant with increased loading in the vessel.

Key words aorta/AH；muscle，smooth，vascular；rats

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