

DISTRIBUTION OF ELASTIC FIBRES IN THE HUMAN ABDOMINAL LINEA ALBA

AN Pulei, PO Odula, AK Abdel-Malek, JA Ogeng'o

Corresponding author: Pulei Anne Naipanoi Department of Human Anatomy School of Medicine University of Nairobi P.O. Box 30197 00100 Nairobi, Kenya. anmunkush@yahoo.com.

ABSTRACT

The linea alba (LA) supports biomechanical stress generated by intra-abdominal pressure. It is believed to contain connective tissue fibres, which provide tensile strength and pliancy. Previous studies have dwelt on collagen fibres with scarce reports on elastic fibres. Biomechanical studies have shown that the LA has elastic properties, which display regional variation. This study describes the pattern of distribution of elastic fibres in the LA in 18 young adults. Five millimetre transverse sections were taken from the supraumbilical, umbilical and infraumbilical regions of the LA. These sections were processed for paraffin embedding, sectioned, then stained with Weigert's resorcin and fuchsin and counter-stained with Van Gieson in order to visualize elastic and collagen fibres. Under light microscopy, a substantial amount of elastic fibres is present in the LA with higher amounts in the anterior, caudal and lateral parts. The elastic fibres are longitudinally and obliquely disposed in the entire length of the LA. These elastic fibres are more abundant in the anterior lamina, in the lateral and caudal parts of the LA. The elastic fibres demonstrated probably confer reversible pliability to the LA. The regional variations in their distribution may reflect differences in function of the parts of the LA: namely an upper respiratory and a lower visceral support.

Key Words: Linea alba, collagen fibres, elastic fibres, regional variation, anterior abdominal wall

INTRODUCTION

The LA is believed to support the biomechanical stress generated by intra-abdominal pressure in conjunction with the other structures in the anterior abdominal wall (Trostle et al, 1994). It has been reported to contain collagen fibers (Askar 1977, Axer et al 2001a, b), which are thought to confer tensile strength (Young and Heath 2000). Less attention however, has been paid to elastic fibres, which permit long-range deformability and pressure recoil without energy input in tissues in which they exist. (Kielty et al, 2002). Biomechanical

studies have shown that the LA has elastic properties (Kirker-Head et al., 1989, Rath et al., 1999). These observations suggest that it contains elastic fibers which are known to be major constituents of tissues with elastomeric properties conferring to them long-range deformability and pressure recoil without energy input (Kielty et al., 2002). There is evidence that the mechanical elasticity of the LA varies topographically such that the infraumbilical part exhibits a higher elastic coefficient (Rath et al., 1999).

Knowledge of the organization and distribution of elastic fibres in the LA may be of surgical importance as when disordered, they may result in hernia development (Odzogan et al., 2006).

Further, their distribution in the LA may help in explaining hernia patterns. The aim of the present study is to describe the regional distribution of elastic fibres within the LA.

MATERIALS AND METHODS

Eighteen adult subjects were used in the present study. The LA specimens were obtained as autopsies were being carried out at the Chiromo and Nairobi City Mortuaries after ethical approval and consent of the relatives. The LA was exposed via a midline skin incision and lateral reflection of the two skin flaps followed by removal of the superficial fascia. Subjects with wounds, scars, tumors, congenital abnormalities or any other deformations of the anterior abdominal wall were excluded from the study.

Five millimetre transverse sections of the supraumbilical, umbilical and

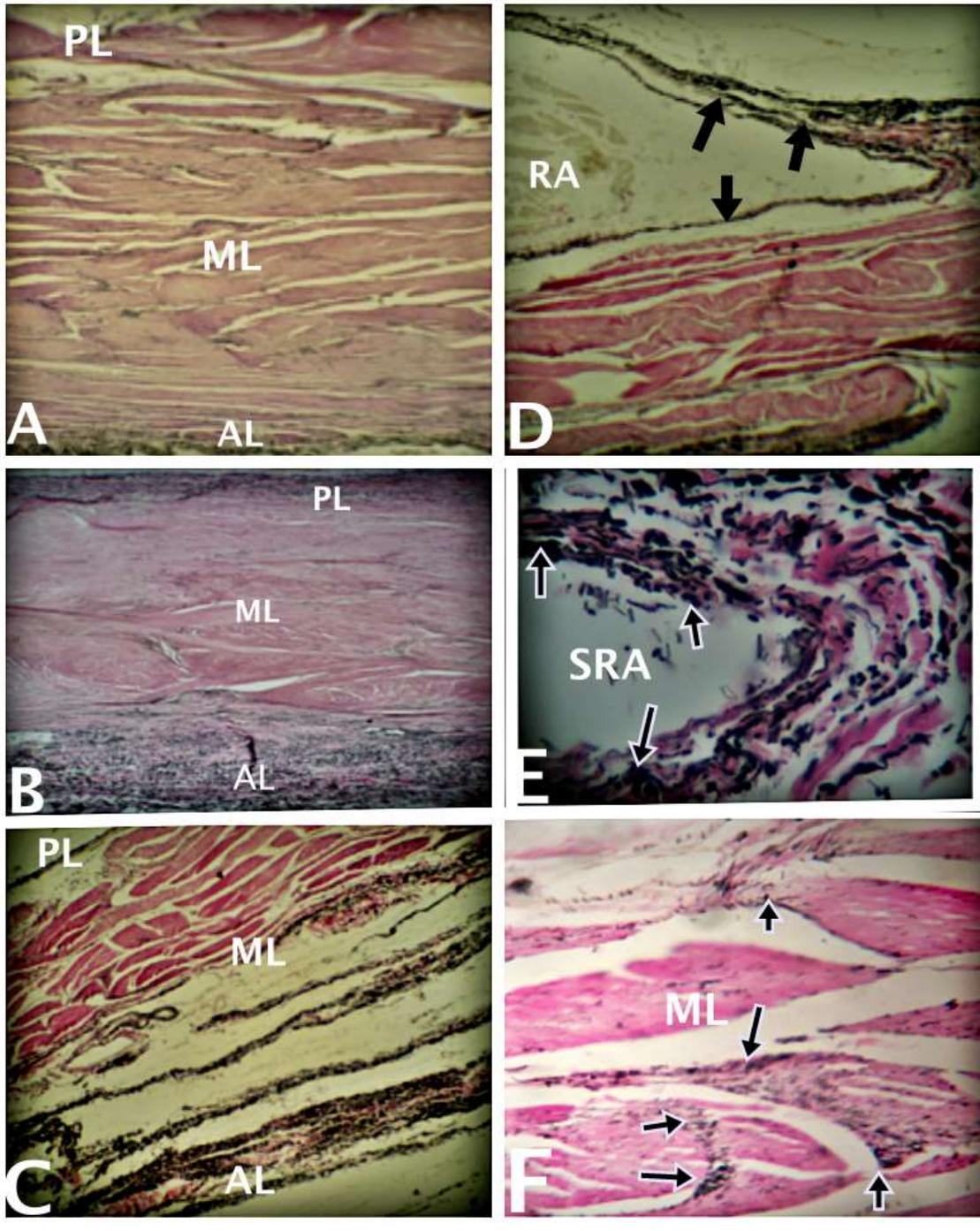
infraumbilical LAe were obtained from each subject, processed for paraffin embedding and sectioned.

Weigert Resorcin and Fuchsin stains with Van Gieson counter-staining were used for demonstration of collagen and elastic fibers as described by Drury et al (1967). A light microscope (Leica Model BME) was used to examine the 7 μ m thick specimens at magnifications x35, x100 and x400. Photomicrographs were taken using a digital camera (Sony Cybershot 7.2 Megapixel) that was fixed to a light microscope.

RESULTS

The LA contains both elastic and collagen fibres. According to the orientation of collagen fibres, the LA is organized into three laminae; anterior, middle and posterior. Substantial amounts of elastic fibres are in all the laminae at all levels of the LA. The elastic fibres are however more concentrated in the anterior lamina, followed by the posterior lamina, while the middle lamina contains the

least (Figs. 1a-c). The elastic fibres in the LA are longitudinally disposed and increase cranio-caudally such that the suprapubic part has the highest concentration (Figs 1a-c). The lateral parts of the LA contain more elastic fibres. A ring of elastic fibers is observed surrounding the rectus abdominis muscle (Fig 1d-e). These elastic fibers around the muscle also increase cranio-caudally.



Figs A-C: Photomicrographs of transverse sections of the supraumbilical (A), umbilical (1b), and infraumbilical (1c) linea alba. (The stain is Weigert elastic stain with Van Gieson, Mag. x35). Note that the concentration of elastic fibers is increasing progressively downwards along the linea alba. **Figs. D-E:** Photomicrographs of the infraumbilical linea alba. (The stain is Weigert elastic stain with Van Gieson, Mag. x35 for D and x400 for E.). Note the ring of elastic fibers around the rectus abdominis (RA). SRA is the space around the rectus abdominis. **Fig. F:** Photomicrograph of middle lamina (ML) of a transverse section of the supraumbilical linea alba. (Weigert elastic stain with Van Gieson, Mag. x400). Note the transverse collagen fibers (staining pink) and the elastic fibers (arrow) in close association with them on their edges. The elastic fibers run longitudinally and obliquely

DISCUSSION

Observations of the present study have revealed that the LA contains elastic fibres in addition to collagen. These elastic fibers exhibit cranio-caudal, antero-posterior as well as medio-lateral asymmetry. The substantial amount of elastic fibres in the LA may constitute part of its adaptation to function. In conjunction with the other structures of the anterior abdominal wall, the LA is believed to support the biomechanical stress generated by intra-abdominal pressure (Trostle et al., 1994). Accordingly, it is suited to accommodate the rapid forces associated with strenuous activity, which might otherwise cause injury to the abdominal viscera (Kirker-Head et al., 1989). Pertinent to this suggestion is the observation that structures subjected to forces similar to those of the LA contain elastic fibres. Such include; the rectus sheath and fascia transversalis (Pans et al., 1999), thoracic diaphragm and the rectus abdominis (Rodriguez and Rodriguez junior 2000) and the endopelvic fascia (Barbic et al., 2003).

The higher concentration of elastic fibres in the caudal, anterior and lateral parts of the LA may be an adaptation to more forces in these areas as a consequent to trunkal erectness. In this regard, previous workers have suggested that there are two separate functional parts of the LA; a "parachute respiratory mechanism" in the upper abdomen and a belly support in the lower abdomen (Askar 1977). It has been suggested that with the assumption of upright posture, gravitational stress, including bearing the weight of the intra-abdominal organs is directed toward the lower abdomen (McArdle 1998), and the pelvis (Moraes et al 2003).

The regional variation described in the present study may also provide part of the anatomical basis for the findings of biomechanical studies (Rath et a. 1999 and Grassel et al., 2005). Rath et al, (1999) using a dynamometer and a "bursting strength tester" demonstrated, that the subumbilical (infraumbilical) region of the human LA exhibits a larger coefficient of biomechanical elasticity than the supraumbilical region. In addition, observations of the present study which have revealed a preponderance of longitudinal elastic fibers appear to support those of Grassel et al, (2005) who demonstrated that the compliance of the LA is more in the longitudinal than in the transverse direction. The higher concentration of elastic fibres in the anterior aspect and the parts adjacent to the rectus abdominis of the LA, probably enable them to uniformly distribute the forces, as suggested by Ushiki (2002), generated by the muscle. Indeed, the tendinous intersections of the rectus abdominis inseparably blend with the anterior lamina of the rectus sheath (Sinnatamy 2000).

In conclusion, the elastic fibres demonstrated probably confer reversible pliability to the LA. The regional variations in their distribution may reflect differences in function namely an upper respiratory and a lower part for visceral support in tandem with upright posture in man.

ACKNOWLEDGMENTS: I am grateful to all the lecturers and the histology technicians at the Department of Human Anatomy, University of Nairobi, for their paramount contribution to this work.

REFERENCES

1. Askar OM. 1977. Surgical Anatomy of the Aponeurotic Expansions of the Anterior Abdominal Wall . *Ann R Coll Surg Engl.* 59 (4): 313-321.
2. Axer H, Keyserlingk DG, Prescher A.2001a. Collagen Fibers in Linea Alba and Rectus Sheaths I: General Scheme and Morphological Aspects. *J Surg Res.* 96 (1): 127-134.
3. Axer H, Keyserlingk DG, Prescher A. 2001b. Collagen Fibers in Linea Alba and Rectus Sheaths II. Variability and Biomechanical Aspects. *J Surg Res.* 96(2): 239-245.
4. Barbic M, Kralj B, Cor A. 2003. Compliance of the Bladder Neck Supporting Structures; Importance of Activity Pattern of Levator Ani Muscle and Content of Elastic Fibers of Endopelvic Fascia. *Neurorol Urodyn* 22 (4): 269-276
5. Drury RAB, Wallington EA, Cameron R. 1967. Connective Tissue Fibers. *Carleton's Histological Techniques.*4th edition. Newyork. Oxford university press 166-181.
6. Grassel D, Prescher A, Fitzek S, Keyserlingk D.G, Axer H. 2005. Anisotropy Of The Human Linea Alba: A Biomechanical Study. *J Surg Res.* 124 (1): 118-125.
7. Kiely CM, Sherratt MJ, Shuttleworth CA. 2002. Elastic Fibers. *J Cell Sci.* 115: 2817-2828.
8. Kirker-Head CA, Kerwin PJ, Steckel RR, Rubin CT. 1989. The in Vivo Biodynamic Properties of the Intact Equine Linea Alba. *Equine Vet J Suppl.*; 7: 98-106.
9. McArdle G. 1998. Is Inguinal Hernia a Defect in Human Evolution and would this Insight Improve Concepts for Methods of Surgical Repair? *Clin Anat.*10 (1); 47-55.
10. Moraes SG, Pinheiro M de S, Yamada AT, Toledo OMS, Joazeiro PP. 2003. Differential Distribution of Elastic System Fibers in the Pubic symphysis of Mice during Pregnancy, Partum and Post-Partum. *Brazil J Morphol. Sci.* 20(2): 85-92.
11. Odzogan M, Yildiz F, Gurer A, Orhun S, Kulacoglu H, Aydin R. 2006. changes in collagen and elastic fiber contents of the skin, rectus sheath, transversalis fascia and peritoneum in primary inguinal hernia patients. *Bratisl Lek Listy.* 107(6-7): 2235-238.
12. Pans A, Pierard GE, Albert A. 1999. Immunohistochemical Study of the Rectus Sheath and Transversalis Fascia in Adult Groin Hernias. *Hernia.* 3 (2): 45-51.
13. Rath AM, Attali P, Dumas JL, Golddust D, Zhang J, Chevrel JP. 1999 The Abdominal Linea Alba: An Anatomico-Radiologic and Biomechanical Study. *Surg Radiol Anat.*; 18: 281-288.
14. Rodrigues CJ and Rodrigues Junior AJ. 2000. A Comparative Study of Aging of the Elastic Fiber System of the Diaphragm and the Rectus Abdominis in Rats. *Braz J Med Biol Res.*; 33 (12): 1449-1454.
15. Sinnatamby SC. 2000. Abdomen. In: Last's Anatomy. J. Urquhart, R. Crum (eds) 10th Edition. London, Churchill Livingstone. pp. 217-218.
16. Trostle SS, Wilson D.G, Stone WC, Markel MD. 1994. A Study of the Biomechanical Properties of the Adult Equine Linea Alba: Relationship of Tissue Bite Size and Suture Material to Breaking Strength. *Vet Surg.* 23 (6): 435-441.
17. Ushiki T. 2002. Collagen fibers, Reticular Fibers and Elastic Fibers. A Comprehensive Understanding for a Morphological View Point. *Arch Histol. Cytol.* 65(2): 109-126
18. Young B, Heath JW. 2000. Supporting/ Connective Tissue. *Wheater's Functional Histology.* Toronto. 4th Edition. Churchill Livingstone 66, 72.