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REGIONAL DIFFERENCES IN THE MURAL STRUCTURE OF THE HUMAN CORONARY SINUS

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ABSTRACT

Regional differences in the mural structure of the coronary sinus are important in understanding its physico-mechanical properties and the basis for extent of atrial fibrillation and ablation. These features are only scarcely reported. This study therefore aimed at describing regional differences in the mural structure of coronary sinus among black Kenyans. This was a descriptive cross-sectional study on coronary sinuses from fifteen hearts obtained during autopsy on adult black Kenyans at the Department of Human Anatomy, University of Nairobi. Five-millimeter-long specimens were taken from the proximal, middle and terminal segments of the coronary sinus and processed routinely for paraffin embedding and sectioning. Seven-micron thick sections were stained with Masson's Trichrome to demonstrate connective tissue and smooth muscle while Weigert's Resorcin Fuschin stain was used to demonstrate elastic fibres. The slides were examined with a light microscope and photomicrographs taken with a high resolution digital camera. The results are presented in micrographs. The wall comprised three layers namely internal, middle and external. Regional differences were observed in the middle layer. In the proximal segment, there were concentrically oriented smooth muscles scattered within connective tissue. The middle and terminal segments on the other hand comprised cardiac muscle oriented both concentrically and longitudinally. The muscle was separated by connective tissue rich in elastic fibres and abundant vasa vasora. The external layer comprised connective tissue.

In conclusion the middle layer of the wall of the coronary sinus displays regional differences. The smooth muscle at the proximal segment may confer contractility to enhance blood flow while the cardiac muscle in the other segments enables it to function in synchrony with the right atrium during atrial systole. The complex arrangement of circular and longitudinal muscle facilitates blood flow and may also constitute a sphincter mechanism.

Keywords: Coronary sinus, regional differences, smooth and cardiac muscle

INTRODUCTION

Coronary sinus (CS), the major venous drainage of the heart, is a large channel of blood lying in the left atrio-ventricular (AV) groove (Barcello et al., 2004). It is formed at the point of confluence of the oblique vein of Marshall and the great cardiac vein (GCV) and terminates at the postero-inferior aspect of the right atrium (Chauvin et al., 2000). Its mural structure is not well elucidated. Some workers describe it as a cardiac chamber with endocardium, myocardium and epicardium (Barcello et al., 2004) while others describe the mural structure as a typical vein with tunica intima, media and adventitia (Mintrofanova et al., 2005).

Details of the mural structure are important in understanding the basis for extent of atrial fibrillation and ablation (Chauvin et al., 2000). Studies addressing regional histomorphology are nonetheless scarce. This study therefore aimed at elucidating the regional differences in the mural structure of the sinus.

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MATERIALS AND METHODS

Coronary sinuses for this study were obtained from fifteen hearts of black adult Kenyans harvested during autopsy at the Department of Human Anatomy, University of Nairobi. Ethical approval was granted by the Kenyatta National Hospital-University of Nairobi- Ethics and Research Committee before commencement of the study. Hearts were obtained within 48 hours after death. The CS was divided into 3 equal segments; proximal, middle and distal (Fig 1). Five (5) mm long sections were obtained from the middle portion of each segment, fixed in 10% formaldehyde solution for a period of 72 hours and subsequently processed routinely for paraffin embedding and sectioning. Five micron thick sections were stained with Masson's trichrome stain to demonstrate the general organization of connective tissue and muscle while Weigert's recorsin fuschin with van Gieson counterstain was used to show elastic fibre content and distribution. The slides were examined using a photomicroscope, and photomicrographs taken using a high resolution digital camera at various magnifications. The type of connective tissue and muscle fibres were noted as well as their orientation. Results are presented on photomicrographs.

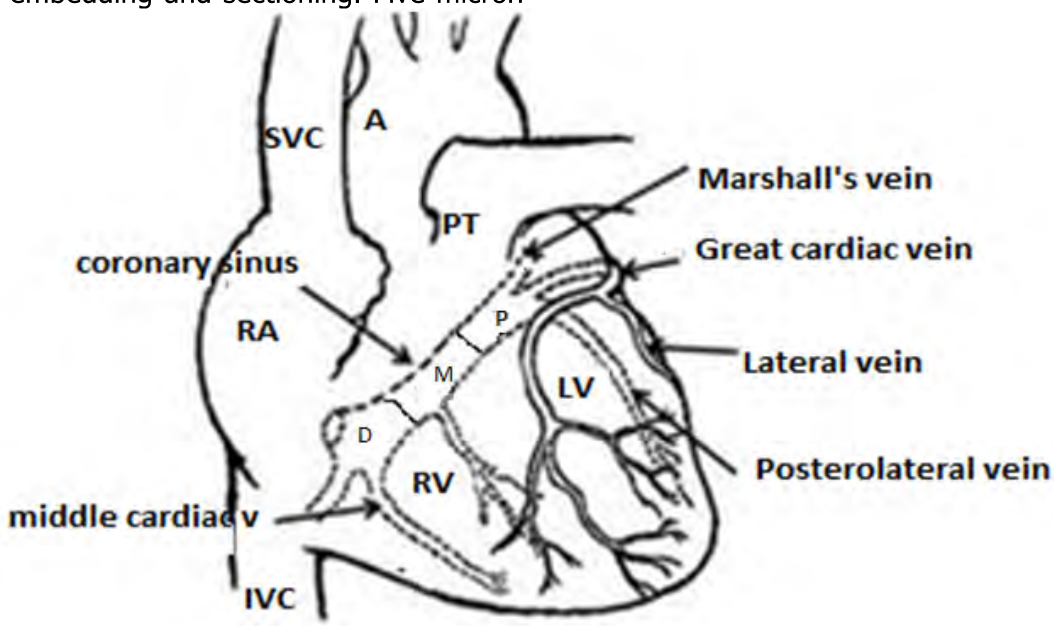
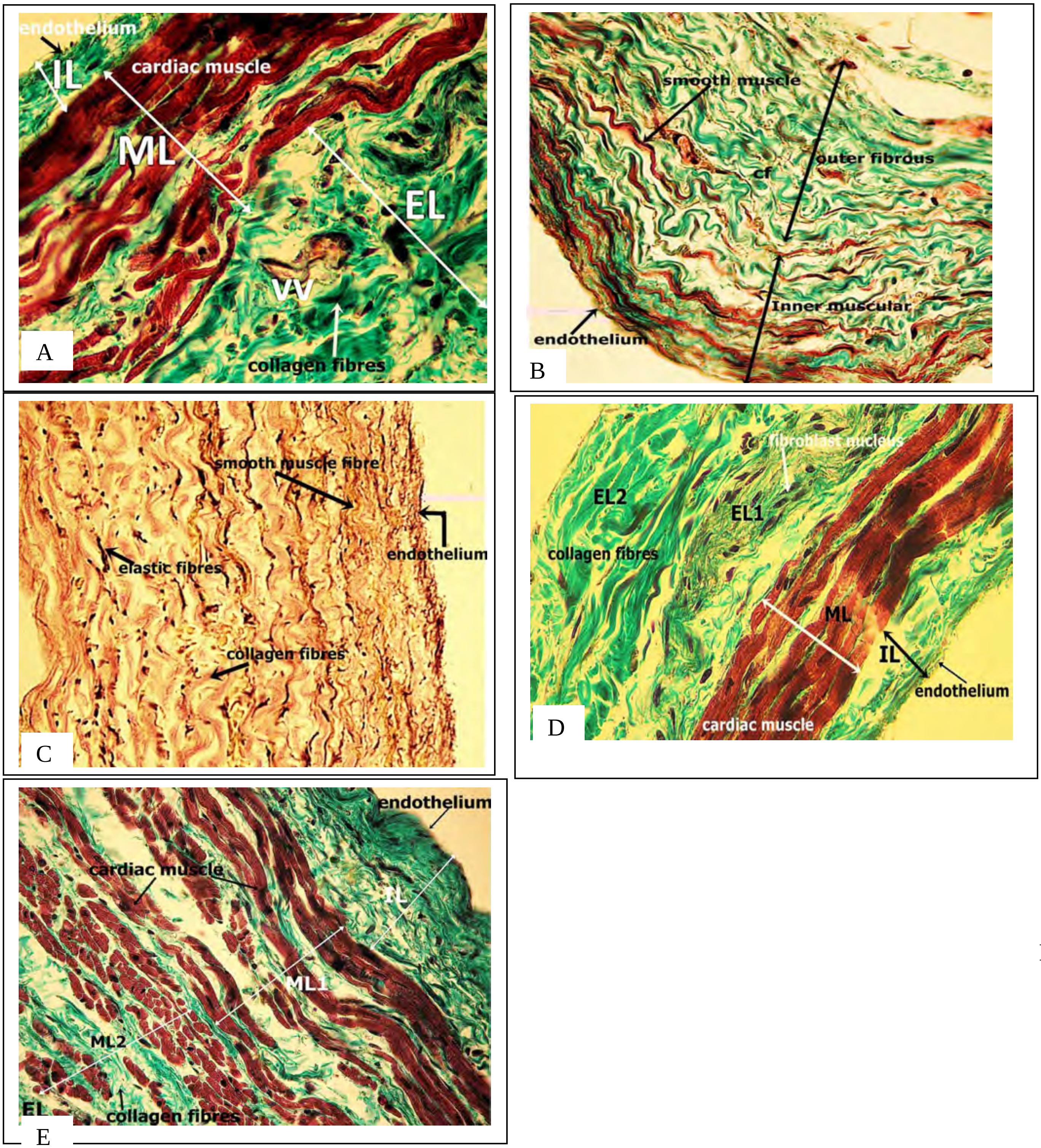


Figure 1: Drawing of the heart showing division of the coronary sinus into segments.
(P-proximal, M-middle and D- distal, A- aorta, SVC-superior vena cava, IVC-inferior vena cava, RA- right atrium, RV-right ventricle, PT- pulmonary trunk).

RESULTS

The CS wall comprised 3 layers namely; internal (IL), middle (ML) and external (EL) [Fig 2A]. Definite regional differences were observed in the middle layer. In the proximal segment, the wall was predominantly collagenous with some smooth muscle (Fig 2B) and elastic fibres (Fig 2C). There were no distinct layers at this segment. The luminal portion of the wall had more smooth muscle fibres compared to the outer portion (Fig 2B). Most of the muscle and connective tissue fibres were concentrically arranged with a few oriented longitudinally.

In the middle and distal segments on the other hand, there were concentrically arranged cardiac muscle fibres. Connective tissue fibres were interspersed between the muscle fibres. The EL comprised connective tissue fibres and vasa vasora. It had an inner cellular and an outer fibrous layer (Fig 2D). In the terminal segment, the ML had two layers of muscles; inner concentric and outer longitudinal. These layers were separated by connective tissue fibres. The longitudinally oriented muscle fibres were divided into an inner continuous layer and an outer layer of muscle fibres separated into bundles by connective tissue extensions from the EL (Fig 2E).



B

Figure 2A-E: Photomicrographs of transverse sections of various segments of the coronary sinus X400. A: Middle segment showing the three layers; internal (IL), middle (ML) and external (EL) layers. Note the presence of cardiac muscle in the ML and collagen fibers in the EL ***(Masson's Trichrome).*** B: Proximal segment showing no distinct layers. Note the smooth muscle cells (SMCs) interspersed within collagen fibres. The SMCs are more prominent near the lumen hence an inner muscular (IM) layer and an outer fibrous layer (OF). The muscle fibres are circumferentially arranged (***Masson's Trichrome).*** C: Proximal segment showing elastic fibres interspersed within muscle and collagen fibres. These fibres are circularly oriented towards the lumen and longitudinally oriented towards the epicardium **(*Weigert's resorcin-fuchsin with van Gieson counterstain).*** D: Middle segment showing collagenous sub-endothelial zone and the circumferentially oriented cardiac muscles in the middle layer. Note the external layer has an inner cellular zone (EL1) and an outer fibrous zone (EL2) [***Masson's Trichrome].*** E**:** Distal segment showing the internal and middle layers. Note the internal layer comprising endothelial cells and a highly collagenous sub-endothelial zone. The middle layer has an inner circular (ML1) and outer longitudinal (ML2) cardiac muscle layers. The outer longitudinal layer is divided into an inner continuous layer and an outer layer made up of longitudinal muscle fibre bundles separated by connective tissue fibre extensions from the sub-epicardial layer (***Masson's Trichrome].***

DISCUSSION

The CS wall had 3 layers namely internal layer (IL) made up of endothelium and sub-endothelial zone, middle (ML) and external layers (EL). This is concordant to the structure reported by Barcello et al (2004). According to these workers, these layers correspond to endocardium, myocardium and epicardium of the heart wall suggesting that the CS is a cardiac chamber. The composition of these layers however showed regional variation in some areas resembling tunica intima, tunica media and tunica adventitia of large veins. This is concordant with the findings of Mintrofanova et al (2005) who described it as a vein. The findings of the present study suggest that different parts of the sinus vary in structure.

The most distinctive regional variation in the CS is that the initial segment comprises smooth muscle cells mainly concentrated towards the luminal portion while the other segments have definite cardiac muscle in the middle layer. This is at variance with literature reports that its entire wall is made of cardiac muscle (Coakley and King, 1959; Barcelo et al., 2004). It is, nonetheless, consistent with the observation that in the transition areas of large veins entering the heart, cardiac and smooth muscles coexist (Gabella, 1999). This is important functionally. Considering the limited range of contraction of cardiac muscle, the presence of smooth muscle may be designed to increase the extent of vasoconstriction of CS as in the case of the pulmonary vein (Hosoyamada et al., 2010). In this way, the CS may be able to regulate blood flow through it.

The cardiac muscle cells are arranged in inner circular and outer longitudinal layers, similar to smooth muscle cells in the portal and spermatic veins (Ferraz et al., 1978; Tilki et al., 2007; Macchii et al., 2008). According to these workers, this relatively complex organization provides for a contractile mechanism for effective blood transport through the veins. A similar mechanism may operate in the CS. Contraction of circular muscles may cause narrowing of lumen leading to increase pressure hence facilitating flow (Salvucci et al., 2009). The longitudinal muscles contract leading to thickening of the wall and shortening of the sinus thus providing a forward push which propels blood.

The presence of circularly oriented cardiac muscle in the terminal portion is similar to that described for the cardiac ends of the pulmonary veins, superior and inferior vena cavae (Jacomo et al., 1993; Piffer et al., 1996; Hosoyamada et al., 2010). In these veins, the cardiac muscle diminishes peripherally eventually giving way to smooth muscle. The intra-pericardial portions of the vena cavae have been regarded histologically as extensions of the atrium, which probably contract together with it, constituting a functional unit that contributes to pumping action of the heart (Jacomo et al., 1993). The circular arrangement may enable this muscle to act as a sphincter that acts to control blood flow into the atrium as well as stopping back flow during atrial systole (Piffer et al., 1996). In the case of inferior vena cava, this sphincter action obliterates the cavo-atrial junction thus preventing venous reflux (Hashizume et al., 1995). It is probable that the presence of circular cardiac muscle at the termination of CS confers a sphincteric function to this segment, similar to that of the other large veins returning blood to the heart. Pertinent to this suggestion is the observation that the terminal part of the CS contains the thickest muscle layer of all segments.

Some of the cardiac muscle fibres were oriented longitudinally, similar to those reported in the pulmonary veins, in which they are thought to play a significant role in forward flow of blood (Hashizume, 1998). Similarly, this arrangement may constitute a mechanism of facilitating venous return in the CS. Indeed, thick longitudinal smooth muscle bundles in the tunica adventitia of large veins have been ascribed the function of facilitating venous return (Gabella, 1999).

The connective tissue of sub-epicardium at the terminal segment penetrates into the middle layer to divide the muscle into bundles eventually connecting with the sub-endothelial layer. This is similar to the organization of vena cavae and pulmonary veins in which elastic and collagenous connective tissue extends between the muscle bundles and in some instances appears to invest the muscle fibres (Carrow and Calhoun, 1964). A consistent feature in the present study where the connective tissue comprised collagen and elastic fibres was similar to that described in the great saphenous vein (Sansilvedtri – Morel et al., 2007). This elaborate system is probably designed to strengthen the wall of CS and enable it cope with the hemodynamic stress to which it is subjected during the cardiac cycle.

In conclusion, the middle layer of coronary sinus displays regional differences characterised by smooth muscle in the proximal, and cardiac muscle in middle and distal segments. The smooth muscle at the proximal segment probably confers contractility to enhance blood flow while the cardiac muscle in the other segments enables it to function in synchrony with the right atrium during atrial systole. The complex arrangement of circular and longitudinal muscle facilitates blood flow and may also constitute a sphincteric mechanism.

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CONFLICT OF INTEREST: There is no conflict of interest

REFERENCES

1. Barcelo A, De La Fuente L &Stertzer S. 2004. Anatomic and histologic review of the coronary sinus. *Int J Morphol.* 22:331-338.
2. Carrow R, Calhoun ML. 1964. The extent of cardiac muscle in the great veins of the dog. *Anat Rec*. 150:249-256.
3. Chauvin M, Shah CD,Haissaguerre M, Marcellin L, Brechenmacher. 2000. The anatomic basis of connections between the coronary sinus musculature and the left atria in humans. *Circulation.* 101:647-652.
4. Coakley JB and King TS. 1959. Cardiac muscle relations of the coronary sinus, the oblique vein of the left atrium and the left pre-caval vein in mammals. *J Anat*. 93: 30-35.
5. Ferraz de Cavalho CA and Rodrigues CJ. 1978. Functional anatomy of the portal vein and its main and segmental branches in the adult man. *Anato Anz*. 143:50-71.
6. Gabella G. Cardiovascular system. In: Gray's Anatomy.1999; 38th Edition. *Churchil Livingstone:*pg 1455-1470.

7. Hashizume H, Tango M, Ushike T. 1998. Three dimensional cytoarchitecture of rat pulmonary venous walls: a light and scanning electron microscopic study. *Anat Embryol (Berl)*. 198: 473-80.
8. Hashizume H, Ushiki T, Abe K. 1995. A histological study of the cardiac muscle of the human superior and inferior vena cavae. *Arch Histol Cytol*. 58:457-464
9. Hosoyamada Y, Ichimura K, Koizuri K, Sakai T. 2010. Structural organization of pulmonary veins in the rat lung, with special emphasis on the musculature consisting of cardiac and smooth muscle. *Anatomical Science International*. 85:152-159.
10. Jacomo AL, Rodrigues Junior AJ, Rodrigues CJ, Biazotto W. 1993. Morphologic study of the inferior cavo-atrial transition in man. Morpho-functional considerations. *Arq Bras Cardiol* 60:87-90.
11. Macchi V, Porzionato A, Iafrate M, Ebugheime E, Paoti A, Vigato E, Parenti A, Ficarra V, Artibani W, De Caro R. 2008. Morphological characteristics of the wall of pampiniform plexus veins and modifications in patients with varicocele. *Itali J Anat Embry.* 113: 1-8.
12. Mintrofanova L, Ivanov V, Platonov PG. 2005. Anatomy of the inferior interatrial route in humans. *Eur J Echocardiog*. 7:S49-S55.
13. Piffer CR, Piffer MI, Santi FP, Davoub MC. 1996. Structural characteristics of the superior vena cavae wall at the intra-pericardium segment in adult and aging individuals. *Okaji Folia Anat Jap.* 73:89-100
14. Salvucci FP, Bia D, Armentano RL, Barra JG, Craiem D, Zocalo Y, Fernandez JD, Baguear F, Atienza JM, Rojo FJ, Guinea GU. 2009. Association between mechanics and structure in arteries and veins. Theoretical approach to vascular graft confection. *31st Annual International Conference of the IEEE in Engineering in Medicine and Biology Society*. 4258-4261.
15. Sansilvestri-Morel P, Fioretti F, Rupin A, Senni K, Fabiani JN, Godeau G, Verbeuran TJ. 2007. Comparison of extracellular matrix in skin and saphenous veins from patients with varicose veins: does the skin reflect venous matrix changes? *Clin Sci*. 112: 229-239.
16. Tilki D, Kilick E, Steif CG, Tauber R, Ergun S. 2007. The complex structure of the smooth muscle layer of spermatic veins and its potential role in the development of varicocele testis. *Eur Urol* 51:1402-1409