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Regional Morphometrical and Histological Studies on the Thoracic Aorta of Buffalo *(Bubalus bubalis)*

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ABSTRACT

The study reports morphometrical and histological details at different regions of thoracic aorta in buffalos. Specimens of adult, apparently healthy buffalos were collected from local slaughter houses in and around Proddatur. A total of six specimens each were collected three regions *viz.,* immediately behind the origin of common brachiocephalic trunk, at the level of sixth thoracic vertebrae and at the level of hiatus aorticus. The average transverse diameter of the thoracic aorta measured 24.59 ± 0.24 mm, 18.86 ± 0.27 mm and 14.15 ± 0.29 mm, while the average longitudinal diameter of thoracic aorta measured 22.81 ± 0.16 mm, 17.90 ± 0.41 mm and 12.37 ± 0.63 mm in proximal, middle and distal segments respectively. The average transverse luminal diameter of thoracic aorta measured 18.70 ± 0.73 mm, 14.89 ± 0.21 mm and 12.49 ± 0.23 mm, while the average longitudinal diameter of its lumen measured 17.22 ± 0.26 mm, 15.59 ± 0.13 mm and 11.75 ± 0.16 mm in the proximal, middle and distal segments respectively. Average thickness of wall of thoracic aorta measured 5.48 ± 0.17mm, 3.83± 0.13mm and 1.73 ± 0.11mm in proximal, middle and distal segments, respectively. The general histological features of a large artery i.e,, Tunic intima,media and externa were appreciated. Variations were observed in endothelial cell morphology from being elongated to flattened proximally to being rounded in distal segments. Meshwork of connective tissue elements which included branched elastic fibres, collagen fibres and reticular fibres in the subendothelium. An indistinct Internal Elastic Lamina (IEL) observed in the proximal segments of the aorta which became distinct in the distal segment with prominent foldings. Tunica media which constituted the major portion of the thoracic aortic wall was predominantly made up of smooth muscle fibres, elastic lamellae, collagen fibres and reticular fibres in all three segments. Proximal and middle segment of the tunica media revealed smooth muscle fibres which alternated with elastic lamellae in the inner region while the outer region exhibited condensation of smooth muscle fibres into muscle bundles with tapering ends attached to elastic fibres thus forming muscle islands. Indistinct External Elastic Lamina was observed in all the segments.Tunica adventitia was mainly comprised of collagen fibres with fewer elastic and reticular fibres. The predominance of collagen fibres supports the role of the adventitia in providing tensile strength and structural support to withstand hemodynamic forces.The adventitia in all three segments was well supplied with vasa vasorum and nerve fibres.

Key words: Thoracic aorta, Diameter, Wall thickness

INTRODUCTION

The thoracic aorta plays a central role in hemodynamic regulation due to its large diameter, elastic architecture, and strategic anatomical location. Its ability to buffer pressure fluctuations and maintain flow continuity is vital for cardiovascular stability (Nichols *et al.,* 2011). In human practice, development and testing of intraaortic devices depend heavily on suitable animal models that simulate human cardiovascular anatomy and physiology. However, selection of appropriate species is vital for surgical feasibility, compatibility of the device and translational relevance. Calves around 4–6 months of age are generally preferred due to anatomical similarities and manageable size (70–100 kg) with humans for device compatibility studies in cardiovascular interventions (Chee *et al., 2*004). However, during long-term studies they can undergo considerable growth. Therefore, this study was conducted on adult animals to provide histological and morphometrical data on different regions of the thoracic aorta of buffalo.

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MATERIALS AND METHODS

Specimens of adult, apparently healthy buffalos were collected from local slaughter houses in and around Proddatur. A total of six specimens each were collected from three regions of the aorta *viz.*, immediately behind the origin of common brachiocephalic trunk, at the level of sixth thoracic vertebrae and at the level of hiatus aorticus. The thoracic aortae were measured immediately after collection to assess thickness of the aortic wall, along with longitudinal and transverse diameters of its lumen by using vernier calipers. The data collected was analysed statistically using one way ANOVA (Snedecor and Cochran, 1994) and the means were tested for significance by Tukey's HSD test (Tukey, 1949) using SPSS (2009) Version 20.0. Histological studies were conducted on the tissue samples collected from the three regions after routine processing.

RESULTS AND DISCUSSION

In buffalo, the average transverse diameter of the thoracic aorta recorded values of 24.59 ± 0.24 mm, 18.86 ± 0.27 mm and 14.15 ± 0.29 mm, while the average longitudinal diameter of thoracic aorta measured 22.81 ± 0.16 mm, 17.90 ± 0.41 mm and 12.37 ± 0.63 mm in proximal, middle and distal segments, respectively. The average transverse luminal diameter of thoracic aorta measured 18.70 ± 0.73 mm, 14.89 ± 0.21 mm and 12.49 ± 0.23 mm, while the average longitudinal diameter of its lumen measured 17.22 ± 0.26 mm, 15.59 ± 0.13 mm and 11.75 ± 0.16 mm in the proximal, middle and distal segments, respectively. Average thickness of wall of thoracic aorta measured 5.48 ± 0.17mm, 3.83± 0.13mm and 1.73 ± 0.11mm in proximal, middle and distal segments, respectively (Table 1 and Graph 1).

This study revealed a clear and progressive reduction in the longitudinal and transverse diameter of thoracic aorta along with its lumen from the proximal to distal segments in buffalo. Similar reports were given in pig by Sokolis *et al.* (2002) in pigs using image-based techniques which revealed that the aortic diameter showed a gradual and significant reduction from the proximal ascending region to the distal abdominal segment. The pattern of gradual reduction noted in the current study is also supported by the findings of Dabanoglu (2007) in German shepherd dogs wherein transverse diameter of the thoracic aorta in the cranial thoracic region (20.50 ± 0.81 mm) decreased to (12.75 ± 0.41 mm) in the caudal thoracic region. The gradual tapering observed in the descending thoracic aorta from tracheal bifurcation to fifth rib by Siefert *et al.* (2016) in minipigs also strongly support our finding. Weisskopf *et al.* (2021) in sheep reported higher diameters by using CT and angiographic techniques. Similarly, Bhasin *et al.* (2020), reported that the diameter of the descending aorta was higher in male buffaloes (2.62 ± 0.06 cm) than in female buffaloes (2.44 ± 0.09 cm). However, variation among the species may also be attributed to differences in the body size, growth pattern and their hemodynamic requirements. Average thickness of the aortic wall decreased significantly ($p<0.05$) from proximal end to distal end (5.48 ± 0.17 mm to 1.73 ± 0.11 mm) (Table 1 and Graph 1). There is little data available on the wall thickness in different segments within the species to support our findings.

Thus, the present study clearly establishes decrease in the thickness as well as the diameters of both thoracic aorta and its lumen from proximal end to its distal end. These findings indicate that the anatomical tapering and specific variations of the thoracic aorta may contribute for maintaining efficient vascular function.

Histological study revealed that the lumen of thoracic aorta in all three segments was lined by tunica intima which was composed of an endothelial lining, subendothelial connective tissue, and an internal elastic membrane (Fig.1). This general arrangement is in accordance with earlier descriptions by Al-Asadi (2017) in dogs, who reported that the intima was composed of simple squamous endothelium supported by a connective tissue layer and bounded externally by the internal elastic lamina.

However, variations were observed in endothelial cell morphology from being elongated to flattened proximally (Fig.1) to being rounded in distal segments (Fig.2). Meshwork of connective tissue elements which included branched elastic fibres, collagen fibres and reticular fibres were observed in the subendothelium which is in accordance with studies of Awal *et al.* (1999) on the of large arteries in black bengal goat and Sharanagouda *et al.* (2016) in Deccani sheep and Bidri goat. An indistinct Internal Elastic Lamina (IEL) observed (Fig.1) which is in agreement with the reports of Copenhaver and Johnson (1958) and Cormack (1987) in humans and Bhasin *et al.* (2020) in buffalo who stated that in large elastic arteries like the aorta, the IEL was often indistinct due to fragmentation and fusion with adjacent elastic lamellae of the tunica media. However the lamina appeared distinct in the distal segments (Fig.2) which is in line with observations of Ogeng'o *et al.* (2010) in goat who noticed thick and prominent folding of IEL towards the abdominal aorta.

Tunica media which constituted the major portion of the thoracic aortic wall was predominantly made up of smooth muscle fibres, elastic lamellae, collagen fibres and reticular fibres in all three segments. Our findings are in concurrence with reports of Greep (1954) in humans, Awal *et al.* (1999) in black Bengal goat, and Sharanagouda *et al.* (2016) in Deccani sheep and Bidri goat who reported that tunica media was composed of elastic lamellae with smooth muscle cells and collagen fibres arranged in a cohesive manner. Structurally, proximal and middle segment of the tunica media revealed smooth muscle fibres which alternated with elastic lamellae in the inner region (Fig.3) while the outer region exhibited condensation of smooth muscle fibres into muscle bundles with tapering ends attached to elastic fibres thus forming muscle islands (Fig.4). This structure corresponds closely with observations of Knieriem (1967) in bovine aorta and Csibi *et al.* (2017) in lambs, Ogeng'o *et al.* (2010) who described musculoelastic zones in the thoracic aorta of goats. According to them these islands consisted of smooth muscle cells arranged in multiple orientations and disrupted the continuity of elastic lamellae. However the posterior segment showed general reduction in smooth muscle islands (Fig.5) which may be due to diminished hemodynamic forces acting on the vessel wall which correlates with the reports of Ogeng'o *et al.* (2010). Reduction in vascular elements (vasa vasorum) in the posterior segments is reinforced by Olabu *et al.* (2011) in goats, who noticed a progressive decrease in vasa vasorum towards the caudal regions of the aorta. The reduction in vascular supply of the distal segment proposes decreased metabolic demands. Indistinct External Elastic Lamina was observed in all the segments which is in coherence with reports of Eurell and Frappier (2013) in domestic animals, Divya (2015) and Rachel *et al.* (2025) in pig.

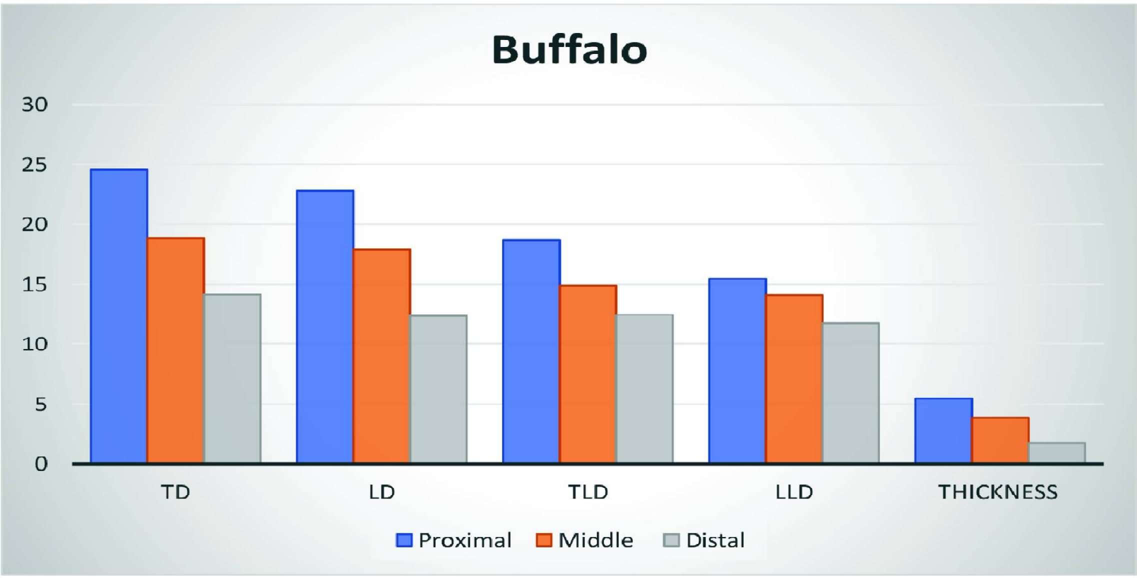
Tunica adventitia was mainly comprised of collagen fibres with fewer elastic (Fig 6) and reticular fibres. The predominance of collagen fibres supports the role of the adventitia in providing tensile strength and structural support to withstand hemodynamic forces, in agreement with Rao *et al.* (2016) in ruminants and humans and Sharanagouda *et al.* (2016) in Deccani sheep and Bidri goat. The adventitia in all three segments was well supplied with vasa vasorum (Fig.7) and nerve fibres, corroborating the observations of Awal *et al.* (1999) in goat, Divya (2015) in pig, Ogeng'o *et al.* (2015) in goat, Sharanagouda *et al.* (2016) in Deccani sheep and Bidri goat, and Bhasin *et al.* (2020) in buffalo. The gradual increase in adventitial thickness from the cranial to caudal segments (Fig 6 & Fig 8) suggests a functional transition from supporting the elastic proximal aorta to providing greater structural anchorage distally.

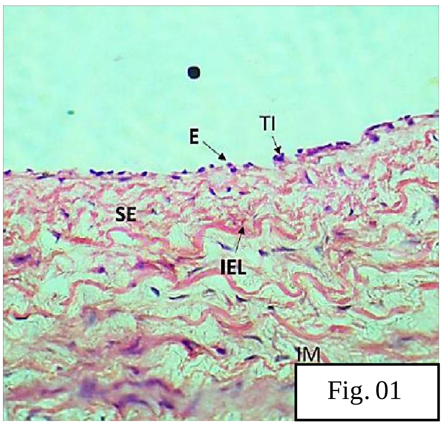
Table 1: Morphometrical Measurements (Mean ± S.E) of the Thoracic Aorta in Buffalo at Different Regions.

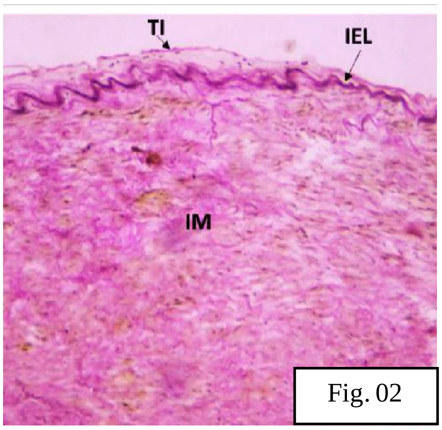
	TD (mm)	LD (mm)	TLD (mm)	LLD (mm)	Thickness (mm)
Proximal	24.59 ± 0.24^{a}	22.81 ± 0.16^{a}	18.70 ± 0.73^{a}	17.22 ± 0.26^{a}	5.48 ± 0.17^{a}
Middle	18.86 ± 0.27^{b}	17.90 ± 0.41^{b}	14.89 ± 0.21^{b}	15.59 ± 0.13^{b}	3.83 ± 0.13^{b}
Distal	14.15 ± 0.29^{c}	12.37 ± 0.63^{c}	12.49 ± 0.23^{c}	11.75 ± 0.16^{c}	1.73 ± 0.11^{c}

^{a,b,c} values with different superscripts in a column differ significantly ($p<0.05$)

Plate 1: Morphometrical data (Mean ± S.E) of the Thoracic Aorta in Buffalo at Different Regions.







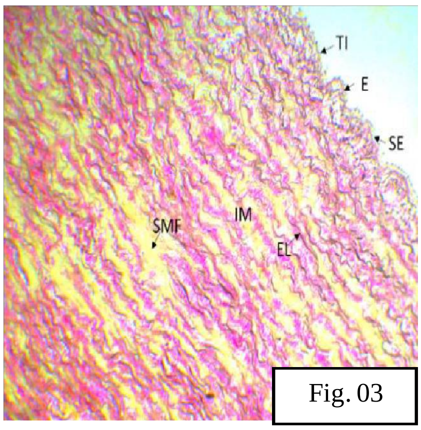
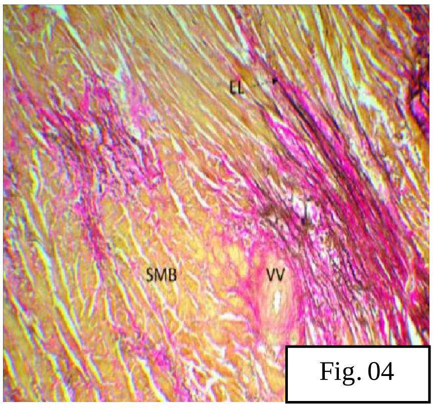
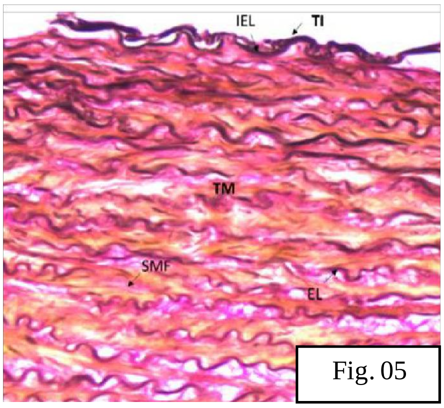


Fig 1: Photomicrograph of proximal segment of thoracic aorta in buffalo showing tunica intima (TI), endothelium (E), subendothelium (SE), internal elastic lamina (IEL) and inner media (IM**). Hematoxylin and Eosin method x 400; Fig 2:** Photomicrograph of distal segment of thoracic aorta in buffalo showing tunica intima (TI), internal elastic lamina (IEL) and inner media (IM). Verhoff's method x 100; **Fig 3:** Photomicrograph of proximal segment of thoracic aorta in buffalo showing tunica intima (TI) endothelium (E), subendothelium (SE), inner media (IM), elastic lamellae (E) and smooth muscle fibre (SMF). Verhoff's method x 100.





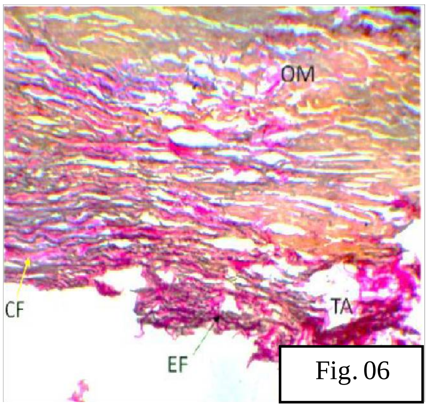
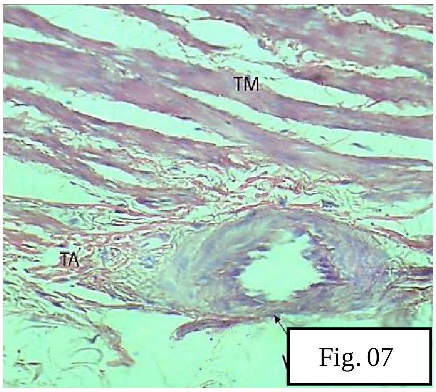


Fig 4: Photomicrograph of proximal segment of thoracic aorta in buffalo showing elastic lamina (EL) and smooth muscle bundle (SMB) in tunica media. Verhoff's method x 100; **Fig 5:** Photomicrograph of distal segment of thoracic aorta in buffalo showing tunica intima (TI), internal elastic lamina (IEL), tunica media (TM), elastic lamellae (EL) and smooth muscle fibre (SMF). Verhoff's method x 400; **Fig 6:** Photomicrograph of proximal segment of thoracic aorta in buffalo showing outer media (OM), elastic fibres (EF) collagen fibres (CF) and tunica adventitia (TA).Verhoff's method x 400



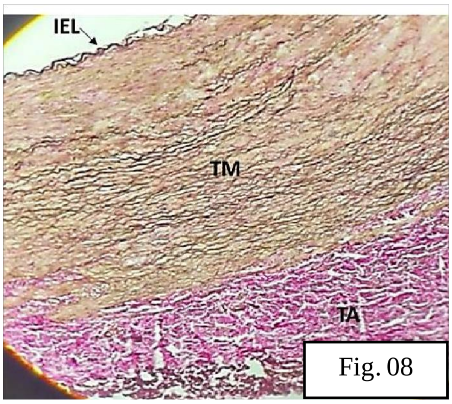


Fig 7: Photomicrograph of proximal segment of thoracic aorta in buffalo showing tunica media (TM), tunica adventitia (TA) and vasa vasorum (VV). Hematoxylin and Eosin method x 400; **Fig 8:** Photomicrograph of distal segment of thoracic aorta in buffalo showing internal elastic lamina (IEL), tunica media (TM) and tunica adventitia (TA). Verhoff's method x 100.

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