AORTIC WALL THICKNESS - RADIUS RATIO IN LIVING DOGS

A.E. Marble, M.Eng
Ph.D. Candidate
Department of Electrical Engineering
Nova Scotia Technical College
Halifax, Nova Scotia

A.S. MacDonald, M.D.
Department of Surgery
Dalhousie University
Halifax, Nova Scotia

J.G. Holland, M.D.
Department of Medicine
Victoria General Hospital
Halifax, Nova Scotia

W. Hilliard, D.V.M.
Animal Care Centre
Dalhousie University
Halifax, Nova Scotia

C.H. Miller, Ph.D.
Department of Mechanical Engineering
Nova Scotia Technical College
Halifax, Nova Scotia

D.A. Winter, Ph.D.
Department of Surgery
University of Manitoba
Winnipeg, Manitoba

ABSTRACT

Wall thickness-radius ratio measurements on the descending thoracic aorta of living dogs have been made using angiographic techniques. Results from preliminary experiments designed to prove the feasibility of the technique indicate that this ratio is in the vicinity of 0.125, whereas previous in vitro measurements have indicated a ratio of 0.10. Simultaneous pressure recordings have indicated that the change in wall thickness with pressure over the normal physiological range is negligible. The implication of these results on the theoretical relationships used in modelling are discussed briefly and it is concluded that the descending thoracic aorta can be considered as a thin-walled vessel.

INTRODUCTION

It is apparent from the literature that in vivo measurements of wall thickness of blood vessels have not been accomplished. The measurements reported to date have been conducted by such researchers as: Evans[1], Peterson[2], Noordergraaf[3], Wolinsky[4], Attinger[5], and Patel[6]. Most of these authors have concluded that the wall thickness-radius ratio for the descending thoracic aorta of both dogs and humans is in the vicinity of 0.10. Peterson[2], however, has obtained a ratio of 0.17 and 0.22. His measurements were made on only two dogs, a puppy and an old dog. McDonald[7], measuring excised arteries on eight dogs, obtained a ratio of 0.16 for all arteries between the ascending aorta and the saphenous artery. All of the foregoing measurement methods relied on a direct thickness measurement using vernier calipers or on indirect calculations using radius, length, and volume information for the vessel segment.

METHOD

A series of preliminary experiments was carried out using angiographic techniques to determine the wall thickness and the variation of wall thickness over the cardiac cycle. Three experiments were performed on healthy mongrel dogs ranging in weight from 25 to 38 kg. One or two weeks prior to the measurements, the dogs were anesthetized (sodium pentobarbital,30 mg/kg body weight), and, using aseptic techniques, lead hemispheres, 2 mm in diameter, were sutured in position on the descending thoracic aorta. These hemispheres were centered approximately 3 and 9 cm proximal to the diaphragm. The thoracic cavity was then routinely sutured and the dogs were allowed at least a week for post-operative recovery prior to angiographic measurements. A General Electric DXS 350 X-ray unit with settings at 90 kv, 300 ma, and 1/120 second exposure time was used in the measurement technique. The dogs were anesthetized, and two catheterizations were performed. One Odman-Ledin* catheter was advanced to the arch of the aorta via the carotid artery in order to inject radiopaque contrast medium (Renovist)†. A second catheter was advanced to the thoracic aorta via the femoral artery for monitoring intravascular pressure. The latter catheter was a side-hole Odman-Ledin type with an outside diameter of 2 mm (No. 6F). This catheter was connected to a Sanborn 267B Pressure Transducer and a Hewlett Packard 7858B recorder. The overall frequency response of the pressure monitoring equipment was 3db down at 50 Hz. This pressure monitoring catheter was positioned within the descending thoracic aorta in the vicinity of the lead hemispheres using the viewing moritor on a Marconi Type OE-1280B X-ray unit. The dogs were then transferred to the G.E. X-ray unit so that radiographic studies could be conducted. A comparator circuit was utilized in order to activate the X-ray unit at any pre-set intravascular pressure desired. Renovist (40 cc) was injected using a Gidlund Injector and Roentgenograms and pressure measurements were obtained for approximately 6 dye injections per dog.

EXPERIMENTAL RESULTS

A typical Roentgenogram resulting from this measurement technique is shown in Fig. 1. It can be noted that the left lead hemisphere is sutured on the outside of the artery so that with the dog in this position, the base of the hemisphere appears as a straight line, indicating that the base is parallel to the X-ray beam. The lead hemisphere on the right is either rotated toward or away from the observer. A series of Roentgenograms at different pressures in the physiological range was obtained for each dog. The wall thickness and radius measurements were determined from the Roentgeno-

*Kifa, Sweden

†E.R. Squibb & Sons, Ltd.

gram using a Joyce Mark IIIC Automatic Recording Microdensitometer. The readout from this instrument for the Roentgenogram shown in Figure 1 is shown in Figure 2. Table 1 shows the results of the measurements of wall thickness, radius, and wall thickness-radius ratio for the 3 dogs. Over the cardiac cycle or pressures, (115-145 mm Hg), the thickness of the aortic wall remained constant to within measurement accuracy (±0.01 mm). Wolinsky[8], has made in vitro measurements on rabbit aortae and found no variation in wall thickness with pressure in the physiological range of 80 - 140 mm Hg. After the measurements were completed, dog No. 2 was sacrificed and a cross-section of the aorta containing the hemisphere was excised and examined. There appeared to be no appreciable alteration in the outer surface of the aorta itself due to the presence of the lead hemisphere.

CONCLUSIONS

It is apparent that the ratio of wall thickness to radius obtained in vivo is somewhat than that previously reported from in vitro experiments. Our measurements indicate that there is negligible variation in wall thickness with pressure in the normal physiological range, and thickness can be considered as a constant in modelling the aorta. The wall-thickness ratio reported here is less than the standard of 0.20 reported by Peterson[9] as the division between considering a blood vessel as being thin rather than thick. The Leplace equation can, therefore, be used to relate hoop stress to intravascular pressure in the descending thoracic aorta with apparently negligible error.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the invaluable assistance of Dr. C. Chan and Miss C. Falvey of the Clinical Research Center, and Mr. T. Gibson and staff at the Audio-Visual Center of Dalhousie University, Halifax, Nova Scotia.

BIBLIOGRAPHY

1. Evans, R.L., Pelley, J.W. and Quenemoen, L : A.M. J. Physiol. 199:1150, 1960.
2. Peterson, L.H., Jensen, R.E., and Parnell, J : Circulation Res., 8:622, 1960.
3. Noordergraaf, A., Verdouw, P.D., and Boom, H.B.K. : Prog. in Cardiovascular Diseases, 5:419, 1963.
4. Wolinsky, H., and Glagov, S. : Circulation Res., 14:400, 1964.
5. Attinger, E.O., Anne, A., Mikami, T., and Sugawara, H. : in Hemorheology, A.L. Copley, editor, New York, Pergamon Press, 1966.
6. Patel, D.J. Janicki, J.S., and Carew, T.E. : Circulation Res., 25:765, 1969.
7. McDonald, D.A.: Blood Flow in Arteries, Williams and Wilkins, Baltimore, 1960.
8. Wolinsky, H., and Glagov, S. : Circulation Res., 25:677, 1969.
9. Peterson, L.H. : Physiol. Rev., 42, Suppl. 5:309, 1962.

TABLE 1

WALL THICKNESS-RADIUS RATIO MEASUREMENTS FOR THE DESCENDING THORACIC AORTA OF DOGS

DOG	WEIGHT (kg)	PRESSURE (mmHg)	THICKNESS (mm)	RADIUS (mm)	RATIO
# 1	25	145	0.90	6.97	0.128
# 2	29	137	0.88	7.20	0.122
# 3	27	120	0.95	7.50	0.127

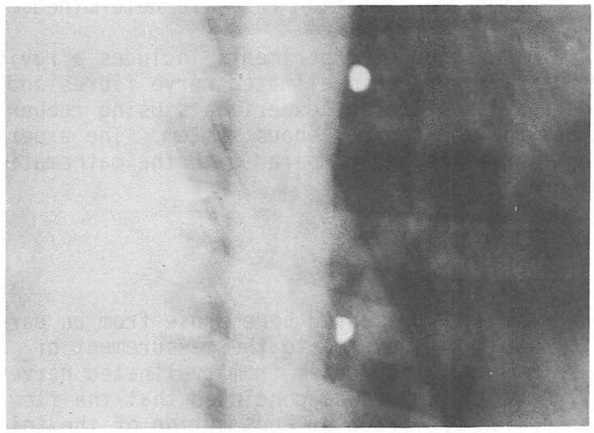

Fig. 1 - Roentgenogram print showing lead hemispheres on descending thoracic aorta.

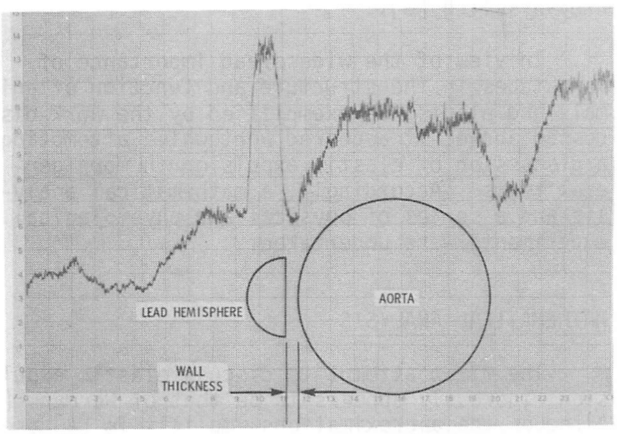

Fig. 2 - Microdensitometer Readout showing relative dimensions of wall thickness and aorta.