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# The Prevalence of the Tortuous Upper Limb Arteries and Its Effects on the Histological Structure of the Arterial Walls

## Prevalencia de las Arterias Tortuosas de los Miembros Superiores y sus Efectos en la Estructura Histológica de las Paredes Arteriales

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**SUMMARY**: Change in the direction of the flow of blood in the tortuous vessel could affect the histological structure of the vessel and so causing atherosclerotic plaque. In particular, the tortuous cause of the radial artery can cause difficulty in access during transradial catheterisation. Tortuosity could hinder the passage of the catheter and hence cause complications in the success of the arterial catheterisation. Therefore, these variant arterial patterns have an impact on planning and success of surgical procedures. However, the prevalence and effect of tortuosity has not been sufficiently recorded in literature. The aim of this study is to record the prevalence of tortuosity of upper limb arteries and its effect on the histological structure of the vessels. Arteries from 180 upper limbs of 90 cadavers were dissected in the Department of Anatomy at Sefako Makgatho Health Sciences University (ethics number: SMUREC/M/193/2022: PG). Proximal, tortuous, and distal segments of the arteries were harvested and processed for histological analyses of wall thickness and connective tissue changes. Tortuous arteries were recorded in 42/180 cases. 15/180 tortuous arteries were the brachial arteries, while 27/180 were radial arteries. The tunica intima was significantly thicker in the tortuous segment compared to the proximal segment ($p = 0.007$). The connective tissue area fraction of the tunica media was significantly higher in the distal segment of the tortuous artery ($p = 0.027$). Tortuosity was more prevalent in the radial artery, whereby it caused significant thickening of the tunica intima, potentially increasing the risk of arteriosclerotic plaques.

**KEY WORDS: Tortuosity; Radial artery; Tortuous arteries.**

## INTRODUCTION

Tortuous arteries and veins are increasingly becoming a common observation throughout the human body (Mishra & Mishra, 2017). A previous study demonstrated a strong association between the tortuosity of the vessel and mechanical factors, such as blood pressure, blood flow, axial tension and structural changes in the arterial walls of the vessel (Han, 2012).

The mechanical stability of arteries depends on the wall stiffness (Han, 2012). Elastin is an important extracellular matrix component for arterial elasticity, stiffness demonstrated by the fact that elastin degradation weakens the arterial wall (Dobrin & Canfield, 1984). Degradation of elastin in the arterial walls are said to cause the weakening of the arteries leading to tortuosity even though the detailed mechanism of vascular tortuosity is unclear (Han, 2012). Fragmentation of elastin has also been reported in the walls of tortuous arteries and has been considered the cause of vessel lengthening leading to tortuosity (Leeson & Leeson, 1981).

Clinical observations have linked ageing, atherosclerosis, hypertension, genetic defects, diabetes mellitus and reduced axial tension or elongation of the arteries to some of the factors thought to cause tortuosity (Han, 2012). Certain levels of axial tension are essential in maintaining the stability of arteries and preventing tortuosity (Nichols *et al*., 2022). Tortuous arteries are favoured sites of atherosclerosis (Singh *et al*., 2020). Change in the direction of the flow of blood in the tortuous vessel could affect the histological structure of the vessel wall and so causing atherosclerotic plaques (Sharma *et al*., 2015). The increase in subendothelial cell population could lead to the thickening of the innermost layer of the arterial wall which may contribute to the tortuosity of the artery (Claassen *et al*., 2008).

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A previous study noted sclerotic changes in the tortuous arteries in the tunica media (Sharma *et al*., 2015). The above echoes the fact that tunica media is often affected by atherosclerosis due to infiltration with inflammatory cells, leading to thickening of the arterial walls as well as fibrosis, with subsequent narrowing of the arterial lumen and atherosclerosis (Sharma *et al*., 2015). Tortuosity also increases the resistance in blood flow and in severe cases, obstruction or even occlusion of blood flow in the vessels can happen (Hutchins *et al*., 1978).

Tortuosity could hinder the passage of the catheter and hence cause complications in the success of the arterial catheterisation which is commonly done in the radial artery (Valsecchi *et al*., 2006). The radial artery is commonly used in vascular, plastic and reconstructive surgery and is routinely used for puncture and cannulation (Haladaj *et al*., 2018). In case of an anomaly in the radial artery, like tortuosity, the ulnar artery is used as an alternative in coronary, cerebral angiography and ulnar-cephalic arteriovenous fistula when access to the radial artery fails (Casal *et al*., 2012).

In addition, trans-radial access may be hindered by the presence of an unusual origin or tortuosity of the radial artery (Zheng *et al*., 2014). Tortuosity may also lead to misinterpretation of angiographic images, or severe disturbance of hand irrigation during surgical procedures on the arm (Deligonul *et al*., 1988). The aim of the study was to record the prevalence of tortuosity of upper limb arteries and its effect on the histological structure of the vessels.

## MATERIAL AND METHOD

This study comprised dissection of 180 upper limb arteries of 90 cadavers from the Department of Human Anatomy and Histology at Sefako Makgatho Health Sciences University. The radial arteries were exposed via gross anatomical dissection using a method described by Tank (2013). The tortuous arteries were harvested from the cadavers and the blocks from the proximal (before tortuosity), tortuous (middle), and distal (after tortuosity) segments of the tortuous arteries were prepared for histological analyses. Blocks of each segment were processed using an automatic tissue processor, followed by paraffin embedding. The hematoxylin and eosin stains were used for tissue architecture and thickness of tunica intima and media. Masson's trichrome stain was used for the area fraction of the collagen fiber bundles in tunica media.

Photomicrographs of the stained sections were acquired using Leica software (Version 3.0) connected to a Leica ICC50 HD camera linked to a Leica microscope DM500 (At 10X, 40X, and 100X). The thickness of the layers was measured using the line tool of Image J software in photomicrographs of 10 serial sections (10X) of each segment of the artery. Additionally, the area fraction of collagen fiber bundles was calculated in 18 sections using a grid method of image J by employing a formula, $A = ap \times \sum p$ and $AF = A/ap \times 100$. In the above formula, area, [$A = ap \times \sum p$, where ap is the area per point and $\sum p$ is the sum of the points falling on the connective tissue within a camera field (25 600 $mm^2$) of each intimal section of the artery and Area fraction (AF) = $A \div 25\ 600\ mm^2 \times 100$]. A total of 20 camera fields were used for each segment.

The data was analysed using SPSS v. 24 software. Frequency distribution of the tortuosity of the upper limb arteries was recorded in the studied population from the left and right upper limbs and compared using the Chi-square statistical test. A p-value $\leq 0.05$ was considered statistically significant. Thickness of layers and connective tissue area fraction was also compared between studied segments of the tortuous arteries.

## RESULTS

Tortuosity of the brachial artery was recorded in 20/180 (11.11%) cases (Fig. 1). It was bilateral in 18/20 (90.0 %) of cadavers, and unilaterally in 2/20 (10.0 %) of cadavers. The sex distribution of the above twenty cases of tortuous radial artery showed that 15/20 (75.0%) cases were in males and 5/20 (25.0 %) were in female cadavers. Considering race distribution of the above 20 cases, 13/20 (65.0 %) cases were recorded in Caucasians whereas 7/20 (35.0 %) were recorded in Africans.

Tortuosity of the radial artery was observed in 31/180 (17.22 %) cases (Fig. 2). It was bilateral in 24/31 (77.42 %) cadavers and unilateral in 7/31 (22.58 %) cadavers. Analyses of sex distribution of tortuous radial artery showed that 17/31 (54.84 %) cases were in male cadavers, while 14/31 (45.16%) cases were in female cadavers. Considering the race distribution, 23/31 (74.19 %) cases were in Caucasians, while 8/31 (25.81 %) cases were in Africans.

The Chi-square test showed a significantly high frequency of tortuosity of arteries in the Caucasian cadavers compared to the African cadavers ($p<0.001$). The comparison of tortuosity in the side ($p=0.230$) and sex ($p=0.230$) did not show statistical significant differences.

**Changes in the thickness of the tunica intima of tortuous arteries.** The ANOVA test showed that there were significant differences in the thickness of the tunica intima when comparing the proximal, tortuous, and distal segments of the tortuous arteries ($p=0.0001$; Fig. 3). The Bonferroni's

Post Hoc test showed that there was a significant increase in thickness of the tunica intima in the tortuous segment of the artery when compared to the proximal segment (p=0.001). There were no significant differences in the thickness of the tunica intima when comparing the proximal (p=0.414) and distal (p=0.011) segments of the tortuous artery.

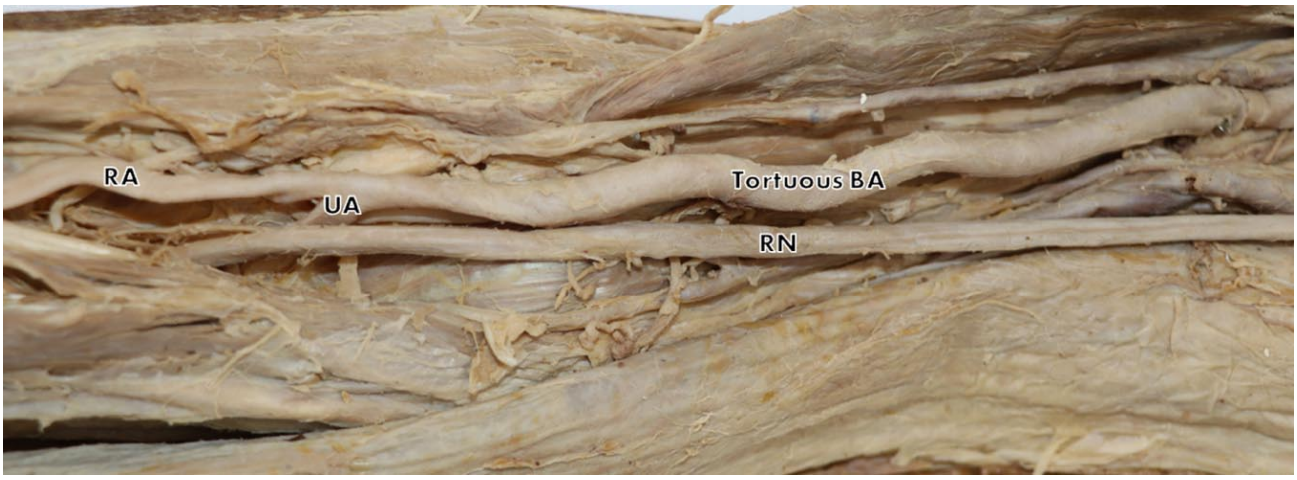


Fig. 1. The anterior view of the arm showing the tortuous brachial artery.


Fig. 2. The anterior view of the forearm showing the tortuous radial artery.

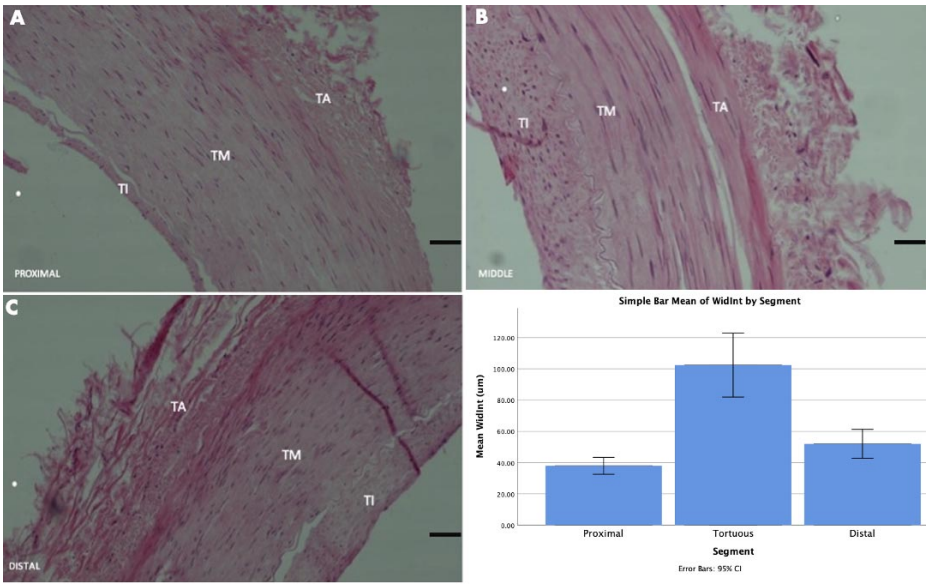


Fig. 3. a-c: Micrographs representing the changes in the thickness of the tunica intima of the proximal (a), tortuous (b), and distal (c) segments of the arteries. The bar graph of measurements of intimal thicknesses shows that the tunica intima was significantly thick in the tortuous segment of the arteries (P=0.001). Error bars indicate the standard error of the mean. **: Represent significant changes - Sacle bar = 10 µm. Key: TA, Tunica Adventitia; TM, Tunica Media; TI, Tunica Intima.

**Changes in the thickness of the tunica media.** The ANOVA test showed that there were no significant changes in the thickness of the tunica media when comparing the proximal, tortuous, and distal segments of the tortuous artery (p = 0,269) (Fig. 4).

**Changes in the connective tissue area fraction (CTAF) in the tunica media of tortuous arteries.** The ANOVA test showed that there were significant changes in the CTAF when comparing the proximal, tortuous, and distal segments of the tortuous arteries (p=0.020) (Fig. 5). The Bonferroni's Post Hoc test showed that there was a significant increase in the CTAF in the distal segment of the tortuous arteries compared to proximal segment (p=0.027). There were no significant differences in the CTAF when comparing the proximal and tortuous segments of the tortuous arteries (p = 0.105).

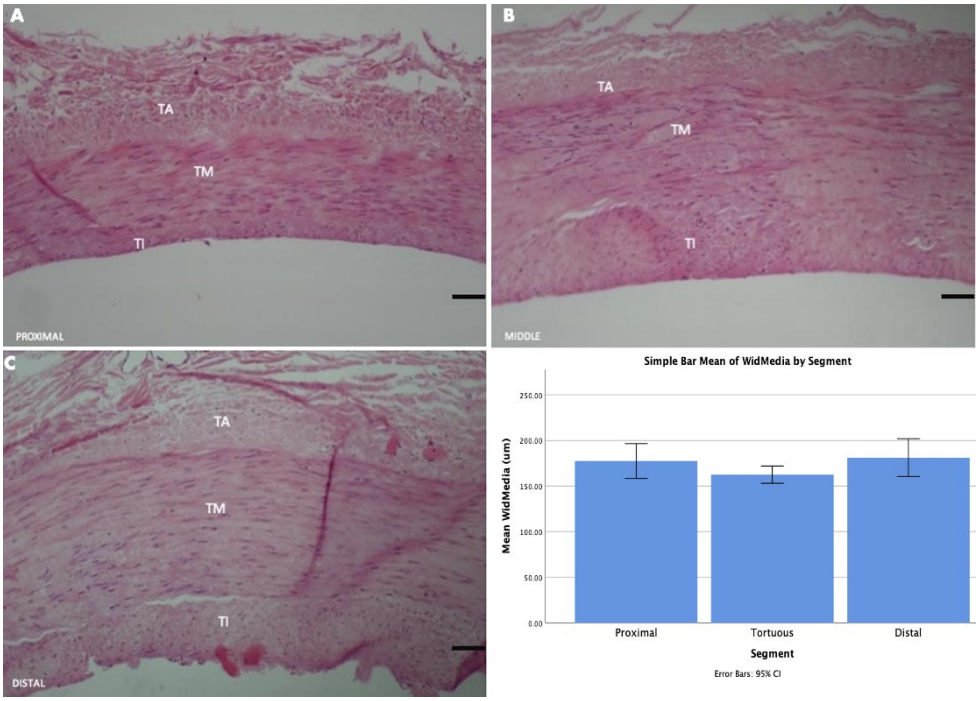


Fig. 4. a-c: Micrographs representing the changes in the thickness of the tunica media of the proximal (a), tortuous (b), and distal (c) segments of the arteries. The bar graph of measurements of medial thicknesses shows that the tunica media was not significantly thick in the tortuous segment of the arteries (P=0.269). Error bars indicate the standard error of the mean. Scale bar = 10 µm. Key: TA, Tunica Adventitia; TM, Tunica Media; TI, Tunica Intima.

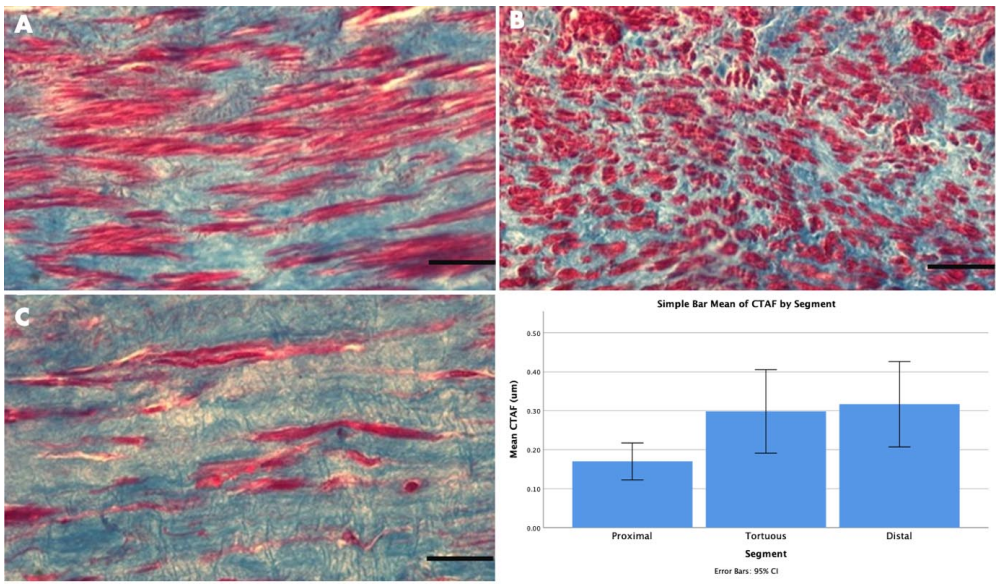


Fig. 5. a-c: Micrographs representing the changes in the connective tissue area fraction of the proximal (a), tortuous (b), and distal (c) segments of the arteries. The bar graph of measurements of connective tissue area fraction shows that the connective tissue area fraction was significantly abundant in the tortuous segment of the tunica media (P=0.027). Error bars indicate the standard error of the mean. Scale bar = 20 µm **: Represent significant changes.

## DISCUSSION

The tortuous brachial artery was reported in 11.11% of cases in the current study. Tortuosity of the brachial artery is a rare occurrence and is mostly recorded in case reports (Mahajan *et al*., 2015; Mishra & Mishra, 2017; Carter *et al*., 2022). The reported incidence of 11.11% cases of the current study points to the high incidence of tortuosity in the South African population.

The tortuous radial artery was reported in 17.22% of cases in the current study. Tortuosity of the radial artery has been reported to range from 3.6% to 23% of cases in the previous studies (Mahajan *et al*., 2015; Mishra & Mishra, 2017; Carter *et al*., 2022) which is in agreement with the results of the current study. The presence of tortuous arteries can lead to difficulty during catheterization and may result in iatrogenic injuries. Considering the race distribution, the tortuous radial artery was observed in 12.78% of the Caucasian cadavers and 4.44% recorded in the African cadavers. Similar to the tortuous brachial artery, these results suggest high prevalence of tortuosity of the upper limb arteries in the Caucasian South African Population than in the African - South African Population. It has previously been suggested that tortuosity of the arteries is related to diabetes and hypertension (Han, 2012). In this current study, the above is supported by the evidence that diabetes and hypertension is more prevalent in the Caucasian South African Population than in the African South African Population (Kandala *et al*., 2021). The tortuosity of the upper limb arteries was also high (28.33%) compared to previous studies (1.25-5.91%) (Mishra & Mishra, 2017; Carter *et al*., 2022).

Histological analyses showed that tortuosity caused a significant increase in intimal thickness. The above could be due to the fact that when an artery is tortuous, there is an infiltration of inflammatory cells leading to fibrosis of the tunica intima, increasing its thickness which narrows the lumen of the arteries and lead to atherosclerosis (Ross & Pawlina, 2011).

## CONCLUSION

The current study recorded a high incidence of tortuosity of the upper limb arteries in the South African population, with Caucasians recording a higher incidence than Africans. Histological analyses confirmed that tortuosity causes an increase in intimal thickness in the tortuous segment of the arteries. Interestingly, fibrosis was significant in a segment of arteries distal to tortuosity, a phenomenon that could not be explained.

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**RESUMEN:** Un cambio en la dirección del flujo sanguíneo en un vaso tortuoso podría afectar su estructura histológica y causar placa aterosclerótica. En particular, la tortuosidad de la arteria radial puede dificultar el acceso durante la cateterización transradial. La tortuosidad podría dificultar el paso del catéter y, por consiguiente, causar complicaciones en el éxito de la cateterización arterial. Por lo tanto, estos patrones arteriales variables influyen en la planificación y el éxito de los procedimientos quirúrgicos. Sin embargo, la prevalencia y el efecto de la tortuosidad no se han documentado adecuadamente en la literatura. El objetivo de este estudio fue registrar la prevalencia de la tortuosidad en las arterias de los miembros superiores y su efecto en la estructura histológica de dichos vasos. Se diseccionaron arterias de 180 miembros superiores de 90 cadáveres en el Departamento de Anatomía de la Universidad de Ciencias de la Salud Sefako Makgatho (número de ética: SMUREC/M/193/2022: PG). Se extrajeron y procesaron los segmentos proximal, tortuoso y distal de las arterias para análisis histológicos del grosor de la pared y los cambios en el tejido conectivo. Se registraron arterias tortuosas en 42/180 casos. 15/180 arterias tortuosas correspondían a arterias braquiales, mientras que 27/180 eran arterias radiales. La túnica íntima fue significativamente más gruesa en el segmento tortuoso que en el proximal ($p = 0,007$). La fracción de área de tejido conectivo de la túnica media fue significativamente mayor en el segmento distal de la arteria tortuosa ($p = 0,027$). La tortuosidad era más frecuente en la arteria radial, lo que provocó un engrosamiento significativo de la túnica íntima, lo cual podría aumentar el riesgo de placas arterioscleróticas.

**PALABRAS CLAVE: Tortuosidad; Arteria radial; Arterias tortuosas.**

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