



## OPEN Feasibility to obtain vessel occlusion using vessel loop

Albert Pons-Riverola<sup>1✉</sup>, Agustí Martí<sup>2</sup>, Laia Nogué-Navarro<sup>3</sup>, Joan Leal-Blanquet<sup>1</sup> & Josep Maria Muñoz-Vives<sup>1</sup>

This ex-vivo study evaluated the tensile strength required for vascular occlusion using vessel loops on human femoral arteries and porcine aortic arteries. Temporary vascular occlusion is critical in many interventions, yet research on the tensile strength needed for effective occlusion with vessel loops is limited. Using an electronic-mechanical instrument, tensile strength in grams was measured across various sizes of Dormolop vessel loops. The study compared the Potts loop and Rummel tourniquet techniques, revealing significant differences in the tensile strength required for occlusion. The Potts loop technique required a mean tensile strength of 305.75 g ( $\pm$  106.07), while the Rummel tourniquet technique required 564.50 g ( $\pm$  139.81), with a statistically significant difference ( $p = 0.027$ ). All experiments achieved flow occlusion, demonstrating that the Potts loop technique requires less tensile strength, potentially resulting in less trauma during occlusion. These findings suggest that the choice of occlusion technique can impact the tensile force needed, with clinical implications that warrant further investigation, including studies with larger sample sizes and microscopic analyses to assess tissue trauma.

**Keywords** Temporary vascular occlusion, Vessel loop, Surgical instrument, Potts loop, Rummel tourniquet

Temporary vascular occlusion represents a fundamental element in vascular interventions. The necessity for blood flow control has driven the development of numerous systems and techniques that have been evolving continuously since the 1960s. Various types of clamps have been introduced over time, and despite their intended atraumatic nature, microscopic studies have demonstrated that none are entirely atraumatic<sup>1–5</sup>. Vessel loops have emerged as one of the less traumatic systems<sup>6</sup>.

To the best of our knowledge, there are no experimental studies that have examined the force required for vascular occlusion and the resilience of these vessel loops. We chose to compare two commonly used vessel loop techniques—Potts loop and Rummel tourniquet—due to their widespread use in surgical practice and the lack of data quantifying the tensile strength required for each. Understanding this parameter is clinically relevant, as excessive force may increase the risk of vascular trauma. Despite a thorough review of the recent literature, we found no studies since 2014 that address this topic, highlighting a significant gap in current knowledge. Our study aims to provide preliminary mechanical data that may inform future investigations and clinical decisions.

**Objective:** The primary objective of this study was to assess the feasibility of vessel loops for achieving vascular occlusion and quantifying the tensile strength needed to occlude arteries in both human and porcine models. An ex-vivo setup was designed to replicate the conditions encountered during surgical procedures. The tests were performed using various loop sizes and two distinct occlusion techniques: Potts loop and Rummel tourniquet.

### Materials and methods

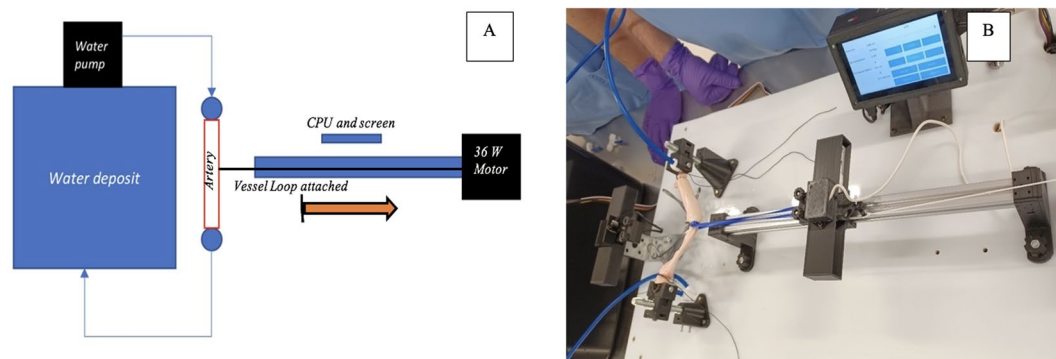
#### Apparatus

For the investigation of the tensile strength required to achieve vascular occlusion in both human and animal vessels, an electronic-mechanical instrument was employed. This apparatus consisted of a force sensor, a pressure pump, a pressure sensor, and a 36 W step-motor (Fig. 1). Each sensor or actuator was controlled by a dedicated microcontroller, and all microcontrollers were interconnected to a CPU equipped with a touch screen interface for instrument operation and result visualization.

The motor was programmed for moving and stopping on demand. Motor speed was set to ensure a precision of 2 g in the tensile strength measurements.

The instrument measured pressure in millimeters of mercury (mmHg) and tensile strength in grams. The touch screen enabled the investigator to set the water pressure applied to the vessel and regulate the tensile strength required for occlusion.

<sup>1</sup>Department of Orthopedic Surgery and Traumatology, Althaia Xarxa Assistencial Universitària de Manresa, Carrer Dr Joan Soler, 1-3, 08243 Manresa, Spain. <sup>2</sup>Greenhouse Data Science, S.L., Barcelona, Spain. <sup>3</sup>IRIS-CC & MoD Lab Research Group, Faculty of Medicine, UVic-UCC, Vic, Spain. ✉email: albertpons96@gmail.com



**Fig. 1.** Overview of the custom electronic-mechanical apparatus used to measure the tensile force required for vascular occlusion. **(A)** Schematic diagram of the apparatus, showing the main components (force sensor, pressure pump, pressure sensor and motor). **(B)** Photograph of the actual device used in the experiments.

Size	Width (mm)	Height (mm)	Section (mm <sup>2</sup> )	Tensile strength (g)
Micro	0.7	0.5	0.275	210
Mini	1.25	0.95	0.933	713
Maxi	2.5	1.4	2.755	2102
Super maxi	5.3	1.5	6.244	4775

**Table 1.** Theoretical maximal tensile strength for different vessel loop sizes, as reported by the manufacturer based on loop dimensions.

### Vessel loops characteristics

The vessel loops utilized in this experiment were DORMO LOOP manufactured by TELIC, S.A.U., and provided by ARN Healthcare (Josep Pla, 163, 3<sup>a</sup>2<sup>a</sup>, 08020 Barcelona, Spain). Telic provided a report where the theoretical maximal tensile strength of each vessel loop was calculated based on width, height, and section (Table 1).

### Biological materials

The ex-vivo porcine aortic artery was donated by Patel Sau slaughterhouse. The ex-vivo human artery is on loan from the anatomy laboratory of the Faculty of Medicine of the UVic-UCC (Vic, Spain).

The vessels utilized in the ex-vivo experiments were a porcine aortic artery, used to test the experimental setup, and a human femoral artery, representing surgical conditions. The diameters of the vessels were 20 mm and 6.5 mm, respectively. In the case of the human artery, a recently extracted cadaverous femoral artery from an 87-year-old woman was used.

The flow for the experiment was anterograde. The tube through which pressurized water entered was placed at the proximal part of the vessel, and the exit was at the distal end of the vessel. All branches were ligated with silk sutures or clamped, and these seals were tested to 300 mmHg to ensure there were no leaks.

### Test procedure

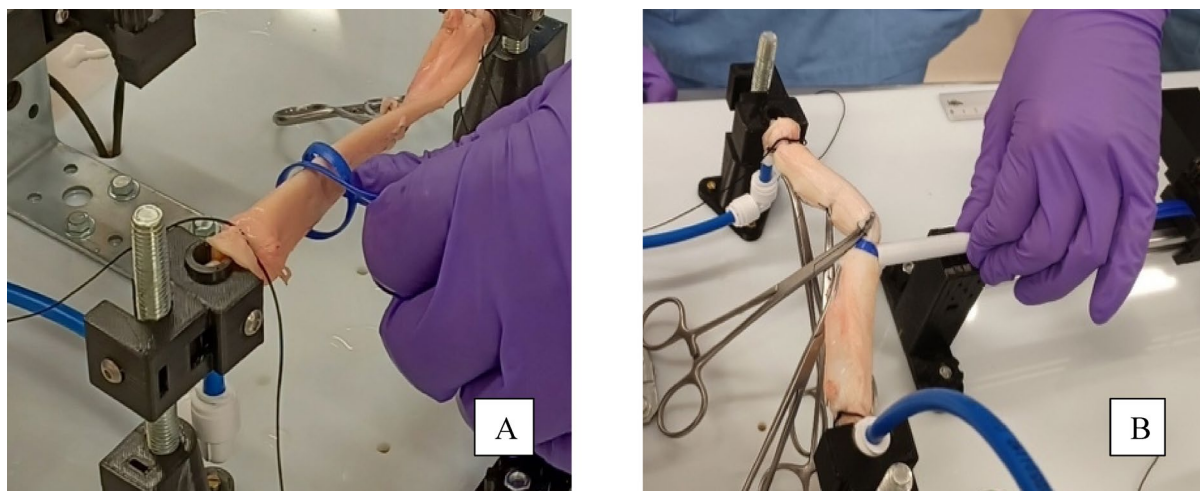
Once the vessels were secured to the water tubes, seven tests were conducted on the animal aortic artery and six tests on the human femoral artery, following these steps.

1. An initial water flow to achieve 80mmHg was applied to the vessel.
2. Placement of the vessel loop around the vessel in either a Potts loop or a Rummel tourniquet configuration (Fig. 2).
3. The motor initiated pulling the vessel loop until flow occlusion was achieved.
4. At this point, the motor was detained, and the tensile strength was recorded.
5. The water pump pressure was increased to a maximum of 300 mmHg.
6. If occlusion was maintained, the tensile strength was decreased until leakage occurred.

### Statistical analysis

Statistical analysis was performed using SPSS (version 24; IBM Corp, Armonk, NY, USA). This study posited several causal hypotheses: specifically, that three different independent variables (vessel type, vessel loop size, and occlusion technique) influence one dependent variable, namely, the strength required to occlude the vessel.

Descriptive statistics for all recorded variables in the study were obtained and tabulated using means and standard deviations for continuous numerical variables, and frequencies and proportions (%) for nominal or dichotomous variables.



**Fig. 2.** Examples of the two vascular occlusion techniques evaluated in this study. (A) Potts loop occlusion. (B) Rummel tourniquet occlusion.

Vessel type	Occlusion technique	Loop size	Tensile strength to initiate occlusion (g)	n = 12
Human femoral artery	Potts loop	Micro	370	1
		Mini	326	1
		Maxi	280	1
		Supermaxi	180	1
	Rummel tourniquet	Micro	-	0
		Mini	-	0
		Maxi	690	1
		Supermaxi	460	1
Porcine aortic artery	Potts loop	Micro	220	1
		Mini	340	1
		Maxi	390	1
		Supermaxi	340	1
	Rummel tourniquet	Micro	-	0
		Mini	680	1
		Maxi	-	0
		Supermaxi	428	1

**Table 2.** General descriptive results for all tests, showing vessel type, occlusion technique, loop size, tensile strength to initiate occlusion and sample size (n).

To assess the influence of factors on the dependent variables, T-Test and General Linear Model (GLM) tests were applied. Particularly, inter-subject effects tests with GLM were conducted to investigate the effects of the factors on tensile strength to initiate occlusion (grams). A statistical significance level of  $p < 0.05$  was applied in all tests.

## Results

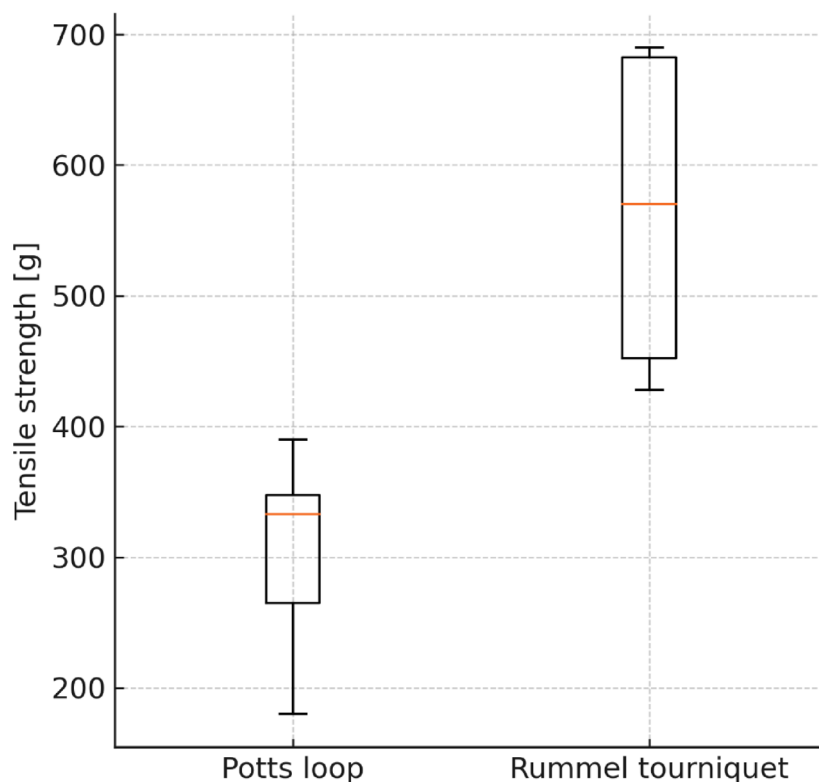
### General descriptive results

A total of 12 tests were conducted (Table 2), employing four different sizes of vessel loops (micro, mini, maxi, and super-maxi), two distinct occlusion techniques (Potts loop or Rummel tourniquet), and two types of vessels (human femoral artery or porcine aorta). In each test the tensile strength required to initiate occlusion was measured, additionally, tensile strength needed to maintain occlusion was measured in 5 tests.

All tests achieved flow occlusion, regardless of vessel type or loop type or method of occlusion. The average tensile strength required to initiate occlusion was  $392.0 \pm 158.1$  g. In contrast, the tensile strength required to maintain occlusion was  $166.6 \pm 73.5$  g, representing  $38.7\% \pm 12.7\%$  of the tensile strength needed for occlusion.

### Occlusion technique

A total of 8 tests were conducted using the Potts loop technique, while 4 were performed using the Rummel tourniquet (Fig. 3). With the Potts loop an average tensile strength of  $305.75$  (SD  $\pm 73.50$ ) grams was required



**Fig. 3.** Comparison of the tensile strength required to initiate vascular occlusion between the Potts loop and Rummel tourniquet techniques. Values are expressed as mean  $\pm$  standard deviation.  $n = 8$  for Potts loop,  $n = 4$  for Rummel tourniquet. Statistically significant difference ( $p = 0.027$ ).

Loop size	Micro	Mini	Maxi	Supermaxi	Total
n	2	3	3	4	12
Tensile strength to initiate occlusion (g)	295 $\pm$ 106.07	448.67 $\pm$ 200.46	453.33 $\pm$ 212.21	352 $\pm$ 125.39	$p = 0.670$

**Table 3.** Mean tensile strength required for occlusion for different vessel loop sizes, expressed as mean  $\pm$  standard deviation, with sample size (n), and p-value from ANOVA.

to initiate occlusion. Conversely, in the Rummel tourniquet group an average tensile strength of 564.50 ( $\pm$  139.8) grams was needed.

The results of the T-test indicate a significant difference between the two groups ( $p = 0.027$ ).

### Vessel loop size

Among the 12 tests, 2 were conducted using the Micro size, 3 with the Mini size, 3 with the Maxi size, and finally, 4 with the Super-Maxi size (Table 3). The mean tensile strength required for occlusion was 295.00 g ( $\pm$  106.07), 448.67 g ( $\pm$  200.46), 453.33 g ( $\pm$  212.21), and 352.00 g ( $\pm$  125.39), respectively.

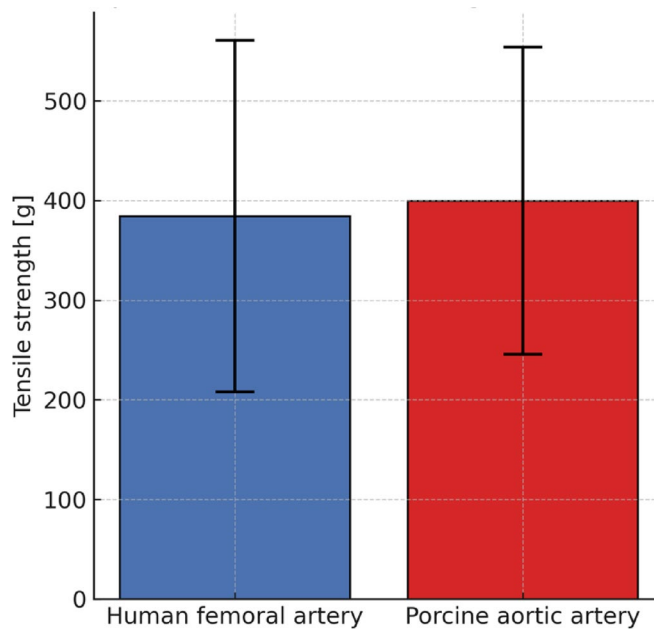
The ANOVA results indicate that there is no significant relationship between occlusion strength and loop size ( $p = 0.670$ ). Additionally, the measures of association, R-squared ( $R^2 = 0.168$ ), equivalent to Eta-squared ( $\eta^2 = 0.168$ ) in one-way ANOVA, suggest a very weak relationship between occlusion strength and loop size, reinforcing the conclusion of no significant effect.

### Vessel type

A total of 6 tests were conducted using a human femoral artery, while 6 were performed using the porcine aorta (Fig. 4). It was observed that the mean tension required to initiate occlusion was not significantly different in the human femoral artery (384.33 g) compared to the porcine aortic artery (399.67 g) ( $p = 0.876$ ).

### Discussion

Temporary vessel occlusion is a critical aspect of vascular interventions, and the choice of occlusion method plays a crucial role in minimizing trauma to the vasculature<sup>1-5</sup>. No occlusion method can claim to be entirely atraumatic. It has been established for over three decades that endothelial and vascular damage correlates with the occlusion force applied by clamps or vascular loops<sup>7-9</sup>, however, other factors, such as occlusion duration,



**Fig. 4.** Comparison of the tensile strength required to initiate vascular occlusion in human femoral artery and porcine aortic artery. Values are expressed as mean  $\pm$  standard deviation.  $n = 6$  for human artery,  $n = 6$  for porcine artery. Difference was not statistically significant ( $p = 0.876$ ).

contribute to endothelial damage. It is widely accepted that vessel loops<sup>6</sup> are among the less traumatic options, likely due to their lower force requirements for achieving occlusion compared to other systems.

To our knowledge, no prior studies have examined the differences in tensile strength required for occlusion between different types of knots in vessel loops. Our ex-vivo study has revealed a significant difference in the tensile strength required for occlusion between the Rummel tourniquet and the Potts loop. These results are particularly valuable for surgeons who routinely use the Rummel tourniquet technique, as it may be associated with a higher level of trauma compared to the Potts loop. These results align with the findings of San Norberto<sup>11</sup> whose microscopic in-vivo study demonstrated that damage caused by vessel loops was greater when the Rummel tourniquet technique was employed instead of the classical Potts loop (although lesser caliber vessels were employed).

In our study, we also observed that different loop sizes required surprisingly similar forces to achieve flow occlusion. However, we must consider that the tensile strength might induce a greater damage when the smaller vessel loops are employed, since this force would be distributed over a reduced surface area. Nevertheless, this assumption should be confirmed through a different type of study with microscopic analysis.

The observed difference in tensile strength between the Potts loop and the Rummel tourniquet may have implications in terms of vascular trauma. From a biomechanical perspective, when the same or greater tensile force is applied over a smaller contact area—as could occur with certain vessel loop configurations—local transmural pressure increases, which may lead to greater endothelial damage. Moore et al.<sup>10</sup> demonstrated a clear correlation between the magnitude of transmural force applied by occlusive devices and the extent of intimal injury observed via electron microscopy, identifying a threshold beyond which endothelial disruption becomes significant.

Additionally, San Norberto et al.<sup>11</sup> reported that circumferential occlusion techniques, including vessel loops, resulted in more histological damage than tangential occlusion methods like vascular clamps. Together, these findings suggest that both the tensile force and the way it is distributed around the vessel wall are critical factors in determining vascular trauma.

In our study, although different loop sizes required comparable forces to achieve occlusion, smaller loops may concentrate the applied tension over narrower areas, potentially increasing local stress and tissue injury. Further studies incorporating histological evaluation are needed to confirm this hypothesis.

It is important to note that our study's results differ from those reported in Pabst's study<sup>12</sup> where the tensile strength required for occlusion was over four times lower than what we observed. This difference may be attributed to the different sizes of vessels used; Pabst used smaller canine vessels in an in-vivo setting.

Finally, it is crucial to acknowledge some limitations of our experiment. We conducted a total of 12 tests, employing different loop types, occlusion techniques, and vessels. Additional tests would be necessary to validate our findings. With a larger sample size, multivariate analysis could have been performed, providing further insights.

Another limitation is that our study solely focused on the tensile strength required to occlude flow, without assessing the actual damage inflicted by the loops. Future in vivo studies and histological evaluations are needed to assess the true damage and clinical impact of different occlusion techniques.

Lastly, our study was conducted in an ex-vivo setting. While our vessels were obtained from fresh cadavers, they may have slight differences compared to real surgical scenarios.

## Conclusions

This experimental investigation has demonstrated that the tensile strength required to break a vessel loop significantly exceeds the force necessary to achieve flow occlusion in human arteries, whether using the Potts loop or Rummel tourniquet occlusion techniques, even under extreme systemic pressures.

Furthermore, our study has revealed that the tensile strength required to achieve flow occlusion is notably higher when employing the Rummel tourniquet technique compared to the Potts loop technique, this higher force may induce more injury to the vessel wall. However, further research is essential to corroborate this hypothesis.

## Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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## References

1. Rutherford, R. B. Basic vascular surgical techniques. In *Vascular Surgery*, 5th edn (ed Rutherford, R. B.) 476–486 (WB Saunders, 2000).
2. Haimovici, H. Vascular sutures and anastomoses. In *Haimovici's Vascular Surgery*, 4th edn (eds Haimovici, H., Ascer, E., Hollier, L. H., Srandness, D. E. & Towne, J. B.) 239–249 (Blackwell Science, 1996).
3. Margovsky, A. I., Chambers, A. J. & Lord, R. S. The effect of increasing clamping forces on endothelial and arterial wall damage: An experimental study in the sheep. *Cardiovasc. Surg.* **7**, 457–463 (1999).
4. Hsi, C. et al. Experimental coronary artery occlusion: Relevance to off-pump cardiac surgery. *Asian Cardiovasc. Thorac. Ann.* **10**, 293–297 (2002).
5. Darçin, O. T., Cengiz, M., Özardağ, I. & Andaç, M. H. Pressure-controlled vascular clamp: A novel device for atraumatic vessel occlusion. *Ann. Vasc. Surg.* **18**(2), 254–256 (2004).
6. Moore, W. M., Manship, L. L. & Bunt, T. J. Differential endothelial injury caused by vascular clamps and vessel loops. I. Normal vessels. *Am. Surg.* **51**, 392–400 (1985).
7. Dobrin, P. B., McGurrin, J. F. & McNulty, J. A. Chronic histologic changes after vascular clamping are not associated with altered vascular mechanics. *Ann. Vasc. Surg.* **6**, 153–159 (1992).
8. Dujovny, M. et al. Reduced vascular trauma after temporary occlusion with modified Biemer and Yasargil clips. *J. Microsurg.* **2**, 195–201 (1981).
9. Harvey, J. G. & Gough, M. H. A comparison of the traumatic effects of vascular clamps. *Br. J. Surg.* **68**, 267–272 (1981).
10. Moore, W. M., Bunt, T. J., Hermann, G. F. & Fogarty, T. J. Assessment of transmural force during application of vascular occlusive devices. *J. Vasc. Surg.* **8**(4), 422–427 (1988).
11. San Norberto, E. M., Álvarez-Barcia, A. J., Taylor, J. H., García-Saiz, I. & Vaquero, C. Valoración de La lesión vascular Tras La Aplicación de Métodos extraluminales de oclusión Temporal. *Angiología* **66**(6), 293–299 (2014).
12. Pabst, T., Sr, Flanigan, D. P. & Buchbinder, D. Reduced intimal injury to canine arteries with controlled application of vessel loops. *J. Surg. Res.* **47**, 235–241 (1989).

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## Author contributions

A.P.-R.: Conception and Design, Analysis and interpretation, Data Collection, Writing the Manuscript and Statistical Analysis. A.M.: Conception and Design, Analysis and interpretation, Data Collection, Critical Revision, Statistical Analysis and Funding. L.N.: Supply of biological material and Critical Revision. J.L.-B.: Analysis and interpretation and Critical Revision. J.M.M.-V.: Conception and Design, Analysis and interpretation, Data Collection, Critical Revision and Statistical Analysis. All authors have approved the final version of the manuscript and agree to be accountable for all aspects of the work, ensuring that any questions related to the accuracy or integrity of any part of the study are appropriately investigated and resolved.

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## Declarations

## Ethical approval

All procedures involving human and animal biological material in this study complied with ethical and legal standards. The human femoral artery was obtained through the Body Donation Program of the Faculty of Medicine at the University of Vic—Central University of Catalonia (UVic-UCC). Donors had provided informed written consent for the use of their bodies in educational and research activities, including the publication of scientific images, with full anonymity. No additional ethical approval was required, as the

material was used post-mortem within the institution's regulated donation framework.

### **Additional information**

**Correspondence** and requests for materials should be addressed to A.P.-R.

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