Intra-Aneurysmal Pressure

Intra-Aneurysmal Pressure refers to the blood pressure within an aneurysm sac, a critical factor in understanding the hemodynamics and stability of intracranial aneurysms. While the role of flow disruption in aneurysm treatment is well-studied, the impact of various endovascular interventions on intra-aneurysmal pressure remains less clear and is a subject of ongoing research.

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1. Understanding Intra-Aneurysmal Pressure

- **Baseline Pressure:**

1. Intra-aneurysmal pressure is generally thought to mirror the pressure in the adjacent parent artery, given the open communication between the two.
2. Variability in baseline pressure depends on systemic factors (e.g., blood pressure) and local vascular conditions.

- **Role in Aneurysm Rupture:**

1. High intra-aneurysmal pressure is often implicated in aneurysm rupture, though this relationship is not always direct.
2. Wall stress, influenced by both pressure and wall shear stress, is more closely tied to rupture risk than pressure alone.

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2. Effects of Endovascular Treatments on Pressure

Research findings, including the reviewed study, demonstrate the following effects of endovascular interventions on intra-aneurysmal pressure:

- **Coiling:**

1. Minimal changes (<5%) in intra-aneurysmal pressure during and after coiling, despite significant flow disruption.
2. The physical obstruction of coils dampens intra-aneurysmal flow but does not significantly alter the pressure transmitted from the parent artery.

- **Stent-Assisted Coiling:**

1. Similar to coiling, stent-assisted techniques reduce flow without major changes in pressure.
2. Stents redirect flow along the parent artery while maintaining communication between the aneurysm sac and the vessel.

- **Flow Diversion:**

1. Placement of flow diverters reduces intra-aneurysmal flow dramatically but has negligible impact on pressure.
2. Even near-complete flow interruption with multiple devices does not significantly alter intra-aneurysmal pressure, as the pressure equalizes with the parent artery.

- **Temporary Balloon Occlusion:**

1. Temporary occlusion of the parent artery causes more pronounced pressure changes:
   1. **Proximally:** Pressure increases due to flow obstruction.
   2. **Distally:** Pressure decreases as flow is reduced downstream.
   3. **Intra-aneurysmal pressure:** Aligns with the distal parent artery pressure, effectively reducing it during occlusion.

- **Positive Control (Healed Neck):**

1. Models with a sealed aneurysm neck eliminate intra-aneurysmal pressure, validating the hypothesis that neck closure is key to pressure management.

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3. Clinical Implications of Intra-Aneurysmal Pressure

- **Rupture Risk Assessment:**

1. Minimal pressure changes during endovascular treatment suggest that interventions primarily reduce flow-related forces, not pressure-driven rupture risks.
2. Wall integrity, influenced by hemodynamic stress and biological factors, remains the dominant determinant of rupture.

- **Treatment Decisions:**

1. Pressure modulation is not a primary objective of most endovascular treatments. Instead, interventions aim to reduce flow and promote thrombosis.
2. Temporary balloon occlusion may have unique applications in specific scenarios, such as intraoperative rupture management.

- **Adjunctive Therapies:**

1. Since intra-aneurysmal pressure remains largely unchanged, therapies targeting aneurysm wall strengthening or healing may complement endovascular interventions.

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4. Research Limitations and Future Directions

- **Short-Term vs. Long-Term Effects:**

1. Current studies focus on immediate pressure changes during treatment. Long-term adaptations in intra-aneurysmal pressure and wall stress require further exploration.

- **Complex Hemodynamics:**

1. The interaction between pressure, wall shear stress, and biological responses to flow disruption remains poorly understood.
2. Computational fluid dynamics (CFD) models could enhance our understanding of these complex relationships.

- **Patient-Specific Studies:**

1. Research should account for variability in aneurysm size, morphology, and location to better predict intra-aneurysmal pressure dynamics across patient populations.

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Conclusion

Endovascular treatments, including coiling, stent-assisted coiling, and flow diversion, have minimal direct effects on intra-aneurysmal pressure, despite significantly altering flow dynamics. This underscores the importance of focusing on flow disruption and wall remodeling as primary therapeutic targets. A better understanding of intra-aneurysmal pressure, combined with long-term studies and advanced modeling, could further optimize treatment strategies and improve outcomes for patients with intracranial aneurysms.

Experimental in vitro studies

Variability in long-term endovascular treatment outcomes for intracranial aneurysms has prompted questions regarding the effects of these treatments on aneurysm hemodynamics. Endovascular techniques disrupt aneurysmal blood flow and shear, but their influence on intra-aneurysmal pressure remains unclear. A better understanding of aneurysm pressure effects may aid in predicting outcomes and guiding treatment decisions.

Medium and large aneurysm models with intramural pressure taps on the dome and parent artery were designed and 3D-printed with vessel-like physical properties from UV-cured materials. The models were connected to a comprehensive flow system consisting of a pulsatile pump and a viscosity-matched blood analog. The system provided physiological pressure and flow control. Real-time pressures were recorded in the aneurysm dome and parent artery during initial placement of coils, stents, flow diverters, and temporary balloons under simulated surgical conditions. Coiling, stent-assisted coiling, and flow diverter placement were performed in both aneurysm sizes. Temporary balloon placement was performed in a large aneurysm model.

Coiling resulted in 24-30% packing density and diminished intra-aneurysmal flow. Flow diverter placement reduced intra-aneurysmal flow with near complete flow interruption after placement of three consecutive devices across the aneurysm neck. Compared to untreated controls, real-time pressure measurements during coiling and flow diversion showed minimal changes (< 5%) in intra-aneurysmal pressures. Temporary balloon occlusion blocked the parent artery, increasing the pressure proximal to the site of occlusion (by 9%), and reducing the pressure distally (by 14%). This maneuver also dampened intra-aneurysmal pressure to the average distal vessel pressure measurement. Positive control aneurysm models were 3D-printed with a sealed, “healed” neck. These controls verified a sealed neck eliminates intra-aneurysmal pressure.

Findings quantified minimal changes in intra-aneurysmal pressure during and immediately post-coiling and flow diversion. Intra-aneurysmal flow disruption alone has negligible impact on intra-aneurysmal pressures [1)].

This study makes a significant contribution by quantifying the minimal impact of endovascular techniques on intra-aneurysmal pressures. However, its findings must be interpreted within the context of its limitations. Future research should focus on integrating additional hemodynamic parameters, long-term outcomes, and in vivo studies to bridge the gap between experimental results and clinical application.

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Becker TA, Lewis KL, Berns HF, Robertson SE, Clark WE, Wells JC, Alnajrani MK, Rapoport C, Barhouse P, Ramirez-Velandia F, Filo J, Young M, Muram S, Granstein JH, Ogilvy CS. Aneurysm dome and vessel pressure measurements with coiling, stent assisted coiling and flow diversion. Acta Neurochir (Wien). 2025 Jan 9;167(1):8. doi: 10.1007/s00701-024-06392-5. PMID: 39789382.