Revolutionizing Neurovascular Interventions: Detachable Tip Microcatheters for Safer Embolization

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ABSTRACT

Detachable tip microcatheters represent a novel advancement in neurovascular interventions, enhancing embolization procedures through improved precision, particularly in complex anatomical regions. These devices are especially advantageous for treating arteriovenous malformations (AVMs) and arteriovenous fistulas (AVFs), where traditional approaches are associated with risks such as catheter entrapment or vessel injury. In this study, the clinical application of second-generation detachable tip microcatheters was evaluated in three cases involving AVMs and AVFs. Microcatheters of varying lengths were employed for embolization, with pre-procedure assessments conducted using CT, MRI, and angiography. Procedural steps included access site preparation, guide catheter insertion, microcatheter navigation, embolic agent delivery, and controlled tip detachment. Post-procedure imaging and clinical evaluations were performed to assess outcomes.

Successful embolization was achieved in all three cases, with significant lesion reduction, occlusion of feeding arteries, and resolution of fistulous components. Minimal complications were reported, and follow-up evaluations demonstrated symptom resolution, including reduced headaches and improved neurological function.

The sleeve plays a crucial role in controlling the detachable tip of the microcatheter. During the pull-out procedure, the applied force causes the tip to detach precisely at the target location, ensuring accurate delivery of embolic agents or other therapeutic materials.

In conclusion, detachable tip microcatheters were effective in achieving precise embolization with favorable outcomes. Further research is required to assess their long-term safety, efficacy, and cost-effectiveness and to facilitate their integration into standard neurovascular practices.

Keywords: *Detachable tip microcatheter; neurovascular interventions; embolization; AVM; hemangioblastoma; catheter detachment; tumor devascularization.*

INTRODUCTION

Detachable tip microcatheters represent a recent advancement in neurovascular interventions, developed to address the limitations and risks inherent in traditional embolization techniques. These microcatheters are primarily designed to deliver embolic agents for the occlusion of abnormal blood vessels, a common therapeutic approach for arteriovenous malformations (AVMs), highly vascularized tumors, and other complex vascular lesions. Traditional

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microcatheters, however, are associated with challenges such as catheter entrapment, vessel injury, and difficulties in controlled embolization, particularly in delicate regions of the brain. To mitigate these issues, detachable tip microcatheters were introduced. The design of these microcatheters allows for the controlled detachment of the catheter tip either during or after the injection of liquid embolic agents, thereby reducing the risk of vessel damage and catheter retention.

Among the most widely used second-generation detachable tip microcatheters is a model featuring a flexible and soft detachable tip, available in lengths of 15 mm, 30 mm, and 50 mm. This design allows for extended injection times, which facilitates more precise embolization with minimal risk of complications. Detachable tip microcatheters have gained widespread acceptance in neurointerventions due to their capacity to enhance procedural safety and improve clinical outcomes. They are especially valuable in challenging anatomical regions, such as the posterior fossa, or in scenarios where prolonged injection times and minimal catheter movement are essential for the success of the procedure.

Despite the growing use of this technology, it remains relatively new, and ongoing research is being conducted to fully explore its potential across a variety of clinical applications. This paper aims to discuss the design, application, and advantages of detachable tip microcatheters, focusing on their role in neurovascular interventions and highlighting key clinical cases and outcomes.

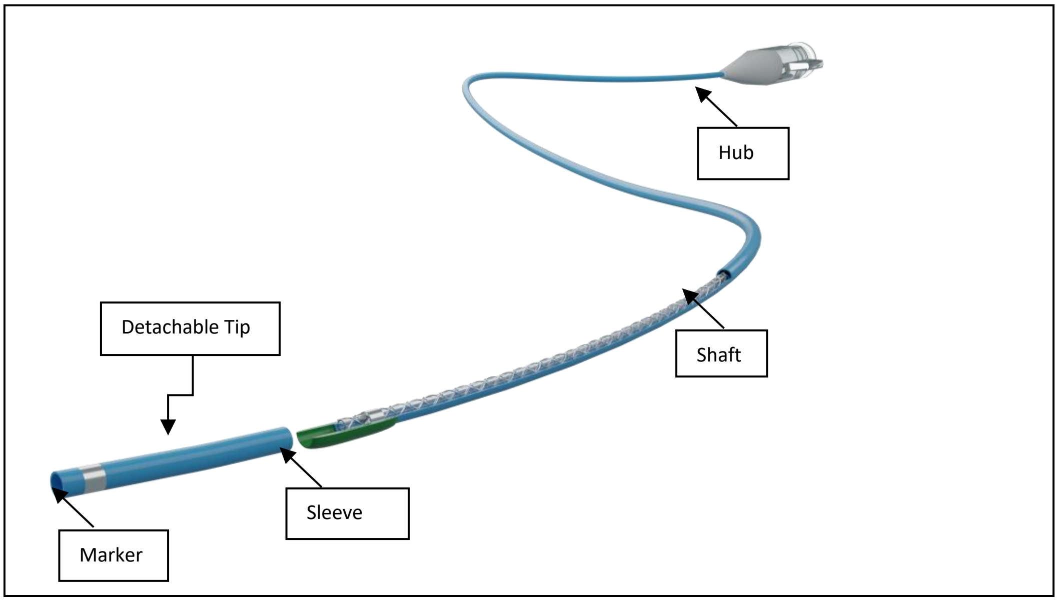

Figure.01 Rendering Image of Detachable Microcatheter

MATERIALS AND METHOD

Detachable Tip Microcatheters:

- **Device Model:** Second-generation detachable tip microcatheter with various tip lengths (15 mm, 30 mm, 50 mm).
- **Construction:** Soft, flexible detachable tips designed for precise embolization with minimal vessel injury.
- **Compatibility:** Designed for use with liquid embolic.

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Imaging Equipment:

- **Fluoroscopy System:** Used for real-time visualization and navigation of the microcatheter within the vascular system.
- **Diagnostic Imaging:** MRI, CT, or angiography for pre-procedure assessment of vascular anatomy and lesion characteristics.

Supportive Tools:

- **Guide Catheter** 6F or similar, used to navigate and stabilize the microcatheter.
- **Guidewire:** Compatible with the chosen microcatheter, used for precise navigation and positioning.

Preparation Materials:

Dimethyl Sulfoxide (DMSO): Used as a solvent.

- **Normal Saline:** Used for flushing the microcatheter and guide catheter.

Methods

Patient Preparation:

- Informed Consent obtains written informed consent from patients, outlining the risks and benefits of the procedure.
- Pre-Procedure Imaging performs MRI, CT, or angiography to evaluate the vascular anatomy, lesion size, and location.
- Pre-Procedure Medication Administer medications as needed, including anticoagulants (help prevent blood clots).

Procedural Setup:

- Access Site Preparation sterilize the access site usually the femoral or radial artery and administer local anesthesia (a medical procedure that prevents patients from feeling pain during surgery and other procedures)
- Vascular Sheath Insertion: Insert a vascular sheath (e.g., 6-French) into the access site to facilitate catheter introduction.
- Guide Catheter Insertion Insert the guide catheter into the target vessel using the access sheath and confirm positioning with fluoroscopy.

Microcatheter Preparation and Insertion:

- Microcatheter Assembly Attach the detachable tip microcatheter to the guide catheter.
- Priming Flush the microcatheter with normal saline and then with DMSO to remove air bubbles and ensure smooth delivery of the embolic agent.
- Guidewire Navigation Advance the guidewire through the microcatheter and navigate to the target vessel. Confirm placement under fluoroscopic guidance.

Embolization Procedure:

- Contrast Injection Inject contrast dye through the microcatheter to visualize blood flow and confirm the catheter's position.

- Embolic Agent Preparation Prepare the embolic agent according to the manufacturer's instructions. Load the embolic agent into the microcatheter.
- Embolic Agent Delivery Slowly injects the embolic agent while continuously monitoring the flow using fluoroscopy. Adjust the rate and volume of injection to ensure complete and precise filling of the targeted vascular structures.
- Tip Detachment After achieving the desired embolization, carefully withdraw the microcatheter. Disengage the detachable tip using controlled traction or the microcatheters detachment mechanism.

Post-Procedure Care:

- Post-Embolization Imaging Perform a final angiogram to confirm the completeness of the embolization and assess for any immediate complications.
- Catheter Removal of the guide catheter and other access devices. Close the access site and monitor the patient for any immediate complications.

Clinical Follow-Up:

- Monitoring regularly monitors patients for any adverse effects or complications post-procedure.
- Follow-Up Imaging Schedule follow-up imaging to evaluate the long-term outcomes of the embolization and assess for any residual or recurrent issues.

CLINICAL USE OF DETACHABLE MICROCATHETER: CASE REPORTS

Case 01: Following table 01 indicates the patient profile

Sr No	Field	Value
1	Age	57 Years
2	Sex	Female
3	Presenting symptoms	Headache and visual disturbances
4	Medical history	Diagnosed with a brain arteriovenous malformation (AVM) located in the parieto-occipital region of the right cerebral hemisphere.

Table 01: Patient-1 characteristics prior to the procedure

Initial Assessment A CT scan revealed intraparenchymal hemorrhage in the parieto-occipital region of the right brain. A cerebral angiogram identified a 3.2 × 1.3 cm AVM with feeders from the right middle and anterior cerebral arteries, a pre-nidal aneurysm, and arteriovenous fistulas. Venous outflow through the vein of Galen showed mild strictures. The AVM was classified as Spetzler-Martin grade III, indicating moderate complexity and treatment risk.

Diagnostic Procedure: The diagnostic procedure began with a CT scan, which revealed intraparenchymal hemorrhage in the right parieto-occipital region. A follow-up cerebral angiogram confirmed a 3.2 × 1.3 cm AVM with feeders from the right middle and anterior cerebral arteries, along with a pre-nidal aneurysm and fistulous components. Venous drainage through the vein of Galen showed mild strictures. The AVM was classified as Spetzler-Martin grade III.

Interventional Strategy: The interventional strategy utilized a detachable tip microcatheter to facilitate embolization of the AVM. Embolization was injected to occlude the major feeding arteries and arteriovenous fistulas. The procedure involved careful monitoring to manage reflux and ensure safe detachment of the microcatheter, optimizing embolization and minimizing procedural risks.

Procedure Details:

Preparation:

- **Patient Preparation**: Pre-procedure Imaging Review the patient's imaging studies (e.g., MRI, CT) to understand the lesion's anatomy and planning.
- **Equipment Preparation**: Microcatheter Selection Choose the appropriate detachable tip microcatheter based on the target anatomy and embolization requirements. Verify the microcatheter model and tip size. Embolic Agent Preparation Prepare the embolic agent according to the instructions. This may involve mixing with a solvent and ensuring the agent is at the correct temperature and consistency. Guidewire Preparation Select and prepare the guidewire compatible with the chosen microcatheter. Ensure it is free of kinks and properly lubricated if needed.
- **Access and Setup**: Access Site Preparation Clean and sterilize the access site, usually the femoral artery, and perform local anaesthesia. Vascular Sheath Insertion: Insert a vascular sheath (e.g., 6-French) into the access site to facilitate catheter introduction. Guide Catheter Insertion: Insert a guide catheter into the target vessel (e.g., vertebral artery) using the access sheath. Confirm correct positioning with fluoroscopy.
- **Microcatheter Setup**: Microcatheter Assembly: Attach the selected detachable tip microcatheter to the guide catheter. Priming Flush the microcatheter with normal saline and then with the appropriate solvent (e.g., DMSO) to remove air bubbles and ensure smooth flow of the embolic agent. Guidewire Navigation Advance the guidewire through the microcatheter and navigate to the target vessel. Confirm the microcatheter is in the desired location under fluoroscopic guidance.
- **Embolic Agent Preparation**: Embolic Agent Loading Load the embolic agent into the microcatheter. Ensure the agent is well-mixed and ready for controlled injection. Injection Setup Prepare the injection system, including syringes and any additional accessories required for controlled delivery of the embolic agent.
- **Final Checks**: Confirm Equipment Functionality: Verify that all equipment is functioning correctly and that the microcatheter and guidewire are properly positioned. Fluoroscopic Imaging Perform initial fluoroscopic imaging to confirm the microcatheter's position and to visualize the target vessel and lesion.

Advancement of the Guidewire: A guidewire was carefully navigated to the site of Ensure the guidewire is correctly positioned within the target vessel. The microcatheter should be advanced over the guidewire, maintaining the guidewire's stability throughout the procedure.

Microcatheter Advancement: The microcatheter into the target vessel or lesion. Ensure that the microcatheter is aligned with the vessel lumen and that it moves smoothly without resistance. Continuously monitor the microcatheter's position using fluoroscopy to avoid dislodging or damaging surrounding structures. Adjust the microcatheter's position as needed to ensure optimal placement. Fluoroscopic Imaging Perform real-time fluoroscopic imaging to confirm that the microcatheter tip is in the desired location. Check for proper placement within the target vessel or lesion. Position Verification, if necessary, use contrast injection to verify the microcatheter's placement and to ensure that it is positioned correctly relative to the embolization target.

Tip Detachment Preparation: Identify the planned detachment point, considering the anatomy and the need for controlled embolization. Ensure that the microcatheter is positioned proximal to any critical structures. A small volume of embolic agent to confirm the microcatheter's position and to ensure there is no unintended reflux or migration. The microcatheter position with fluoroscopy and contrast imaging, if needed. Ensure that it is securely in place before proceeding with the embolization. The microcatheter is correctly positioned for the detachment process and that all necessary equipment is ready for the final embolization and detachment steps.

Assessment of Lesion Modification: The initial angiogram showed a 3.2 × 1.3 cm AVM with major feeders from the right MCA and minor feeders from the right ACA. The lesion included a pre-nidal aneurysm and arteriovenous fistulous components.

Post-procedure imaging demonstrated significant reduction in the AVM's blood supply, with substantial occlusion of the feeding arteries and fistulous components. The pre-nidal aneurysm was no longer visible, indicating effective embolization and lesion modification.

Outcome and Follow-Up: The procedure successfully embolized the major feeders and fistulous components of the AVM, with significant reduction in the AVM's size and blood flow. The pre-nidal aneurysm was no longer visible. Follow-Up: The patient underwent surgical resection the following day, with minimal blood loss. Post-operative imaging showed effective removal of the AVM, and the detached catheter tip was confirmed to be safely embedded within the AVM cast. The patient was monitored for any post-surgical complications or residual symptoms.

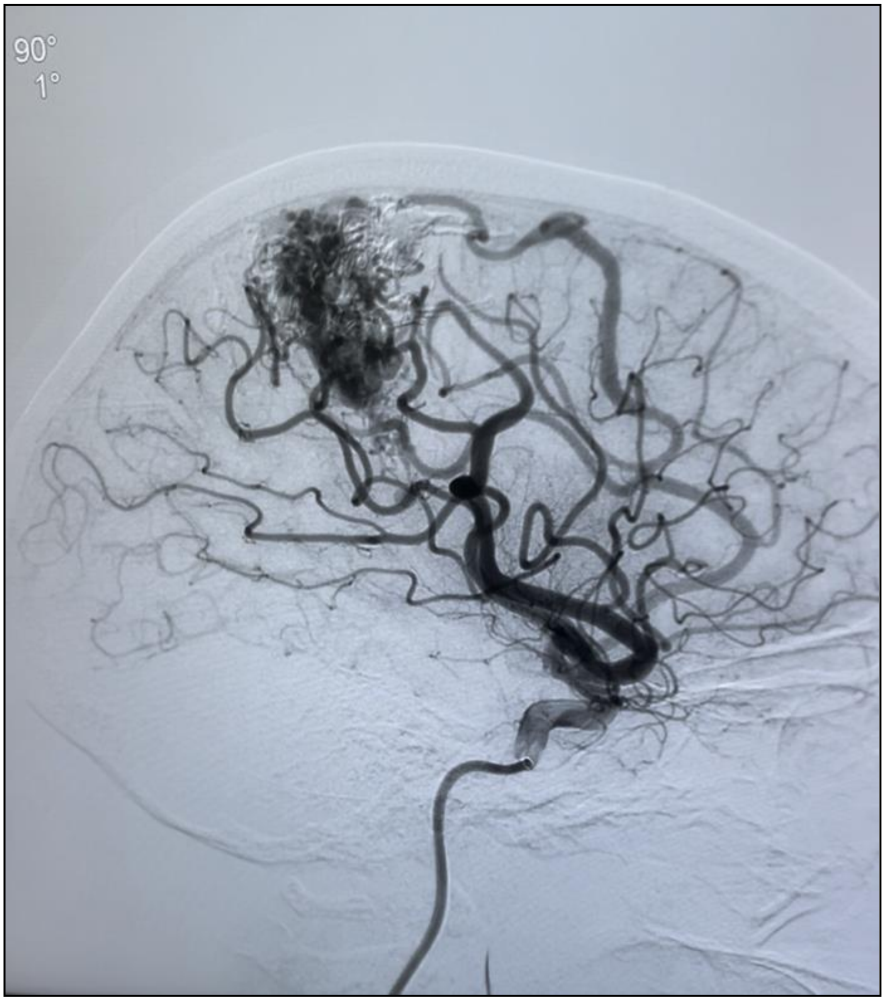

Figure 01: Illustrates the embolization during the detachable Microcatheter procedure.

Case 02: Following table 02 indicates the patient profile

Table 02: Patient-2 characteristics prior to the procedure

Sr No	Field	Value
1	Age	49 Years
2	Sex	Female
3	Presenting symptoms	Frequent headaches.
4	Medical history	(AVF) located near the transverse sigmoid sinus.

Initial Assessment: The patient is a 49-year-old female presenting with frequent headaches. She has a medical history of an arteriovenous fistula (AVF) located near the transverse sigmoid sinus.

Clinical Evaluation: Presenting Symptoms: The patient reports persistent and frequent headaches, which may be associated with the AVF. The location of the fistula near the transverse sigmoid sinus suggests the possibility of increased intracranial pressure or venous hypertension, which could contribute to the headache symptoms. A thorough neurological exam is crucial to rule out any signs of focal neurological deficits, such as visual disturbances, cranial nerve dysfunction, or motor/sensory abnormalities, which could suggest mass effect or ischemia related to the AVF.

Diagnosis: The headaches may be directly related to the AVF, potentially due to venous congestion, raised intracranial pressure, or altered cerebrovascular hemodynamics. Other differential diagnoses, such as migraine or tension-type headaches, should also be considered but are less likely given the patient's known AVF.

Outcome and Follow-Up: The patient underwent successful endovascular embolization of the AVF near the transverse sigmoid sinus. Post-procedure, her headache frequency and intensity significantly reduced, and there were no complications such as vessel injury or neurological deficits.

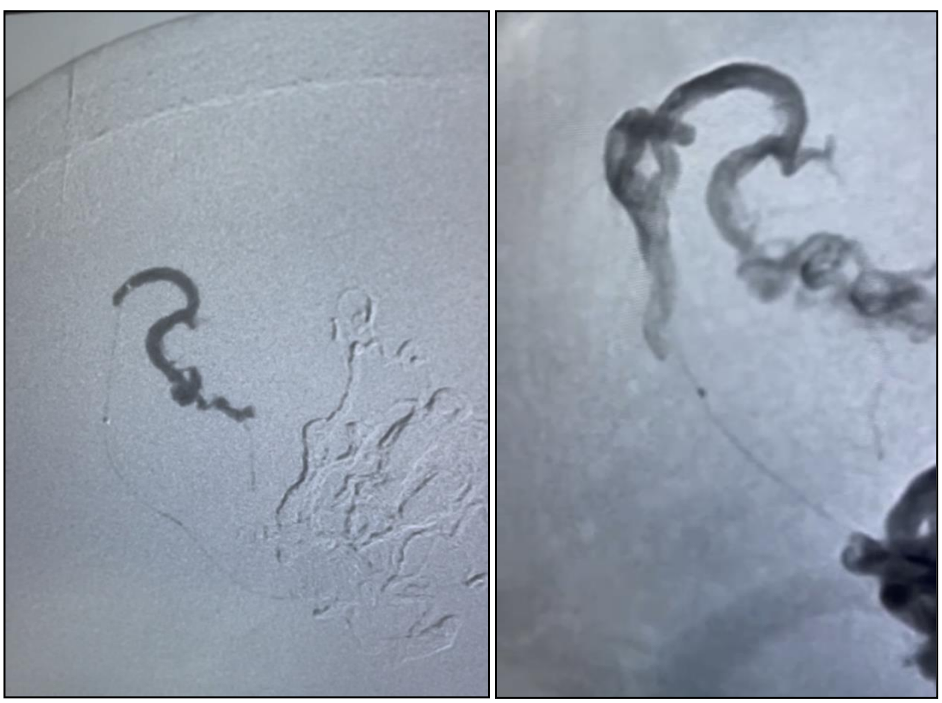

Figure 02: Illustrates the embolization during the detachable Microcatheter procedure.

Case 03 : Following table 03 indicates the patient profile

Sr No	Field	Value
1	Age	18 Years
2	Sex	Male
3	Presenting symptoms	Severe headaches and dizziness
4	Medical history	History of childhood migraines

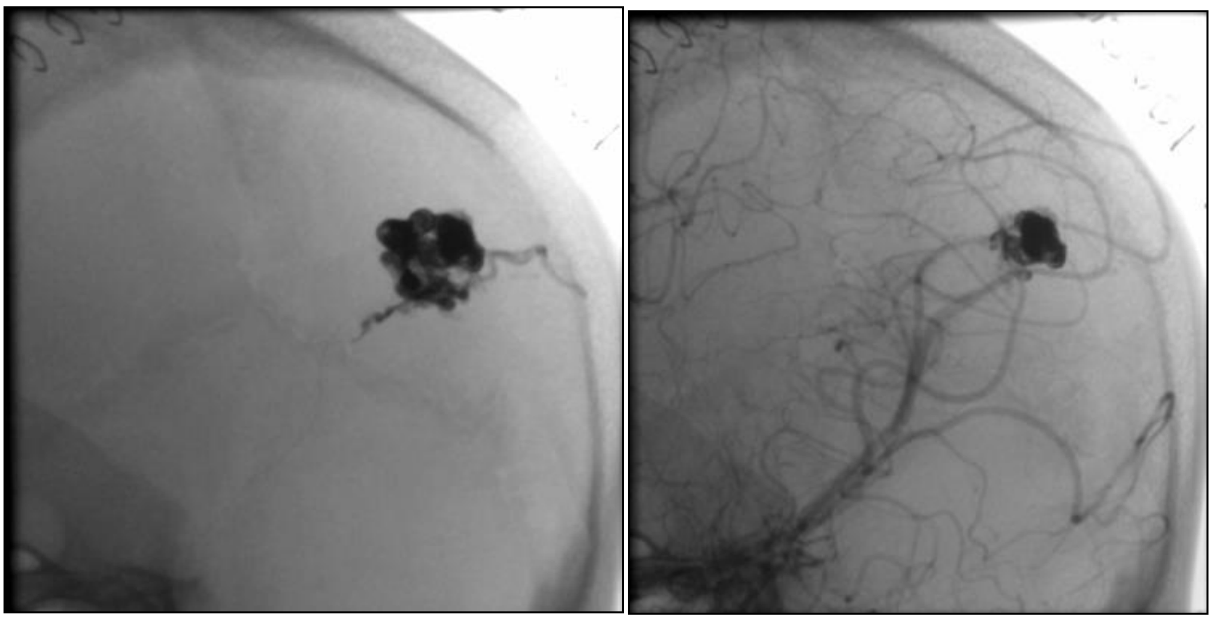

Figure 03: Illustrates the embolization during the detachable Microcatheter procedure.

Initial Assessment: The patient is an 18-year-old male presenting with frequent headaches. He has a medical history of an arteriovenous fistula (AVF) located near the transverse sigmoid sinus.

Clinical Evaluation: Presenting Symptoms: The patient is an 18-year-old male with a history of childhood migraines, resolved at age 14, now presenting with frequent, severe headaches, dizziness, and light sensitivity. MRI reveals a small arteriovenous malformation (AVM) near the occipital lobe, likely contributing to his current symptoms. Neurovascular Embolization using a detachable tip microcatheter is recommended to address the AVM and reduce the risk of complications.

Diagnosis: The diagnosis process began with the patient presenting with recurrent headaches, dizziness, and light sensitivity, which raised concerns beyond typical migraine recurrence, especially given the sudden onset of these symptoms after years of resolution. His clinical history of childhood migraines guided initial considerations, but the severity and new neurological symptoms suggested a need for further investigation. An MRI was performed, revealing a small arteriovenous malformation (AVM) near the occipital lobe, an area responsible for visual processing. This finding explained the patient's symptoms, as the AVM likely caused abnormal blood flow and pressure changes, leading to headaches and visual disturbances. The MRI confirmed the AVM as the most likely cause, guiding the treatment plan towards neurovascular intervention to prevent complications such as rupture or hemorrhage.

Assessment of Lesion Modification: Post-embolization, the assessment focuses on evaluating the effectiveness of the procedure. Digital subtraction angiography (DSA) is used to confirm that the AVM has been successfully occluded and to check for recurrent blood flow. The patient's symptom relief—including reduced headaches, dizziness, and light sensitivity—indicates that the lesion modification is likely effective. Comparing pre- and post-procedure images assesses any reduction in AVM size and confirms lesion stability. Long-term follow-up with regular imaging and clinical evaluations ensures continued success and monitors for potential complications or recurrence. Successful lesion modification is marked by significant reduction or complete occlusion of the AVM and improvement in the patient's symptoms.

Outcome and Follow-Up: The patient successfully underwent neurovascular embolization using a detachable tip microcatheter to treat the arteriovenous malformation (AVM) near the occipital lobe. The procedure was completed without complications, and post-operative imaging confirmed successful occlusion of the AVM, with no evidence of residual blood flow.

RESULTS

The use of detachable tip microcatheters in neurovascular interventions demonstrated successful embolization across all three cases, with minimal complications. Post-procedure imaging confirmed effective lesion modification, including significant reduction in AVM size and occlusion of feeding arteries and fistulous components, while preserving surrounding structures. Clinically, patients experienced symptom resolution, including reduced headache intensity and improved neurological function, with no adverse events reported during follow-up. These results highlight the effectiveness of the detachable tip microcatheter in achieving precise and targeted embolization

The integrity of the sleeve in a detachable microcatheter is critical for ensuring precise performance and reliability during medical procedures. The sleeve serves as the interface between the catheter shaft and the detachable tip, providing structural support and enabling controlled detachment. It is designed to withstand the mechanical forces exerted during navigation through complex vascular pathways while maintaining flexibility and durability.

DISCUSSION

The findings underscore the utility of detachable tip microcatheters in navigating complex and delicate neurovascular anatomies, offering both safety and precision. The detachable microcatheter is a critical advancement in interventional procedures, offering precise control and targeted delivery of therapeutic agents. The sleeve plays a vital role in maintaining the integrity and functionality of the system, ensuring that the tip detaches only at the intended location through a controlled pull-out mechanism. Preclinical studies have demonstrated the effectiveness of this design, leading to further research on optimizing catheter length for improved performance in various clinical applications. By refining the sleeve's structural integrity and detachment mechanism, we can enhance procedural safety, navigability, and overall treatment outcomes. Future developments will focus on expanding the adaptability of detachable microcatheters to meet the growing demands of complex medical interventions.

Compared to traditional methods, the detachable tip design appears to reduce the risk of complications and improve procedural outcomes, although its full potential in broader clinical applications remains to be explored.

CONCLUSION

In conclusion, the use of detachable tip microcatheters in neurovascular interventions has been demonstrated to be effective in achieving precise and targeted embolization. The results from the three cases indicate successful lesion modification, with a significant reduction in AVM size and occlusion of feeding arteries, while preserving surrounding structures. Clinically, symptom resolution, including reduced headache intensity and improved neurological function, was observed, and no adverse events were reported during follow-up. Although these microcatheters offer notable advantages in terms of safety and precision, based on preclinical studies, we will further explore and develop detachable microcatheters with varying lengths to optimize performance for different clinical applications. By evaluating the effectiveness and usability of different length configurations, we aim to enhance navigability, flexibility, and precision in complex vascular procedures. This ongoing research will help refine the design, ensuring improved patient outcomes and expanding the range of medical interventions where detachable microcatheters can be effectively utilized.

Further research, including long-term studies, is warranted to assess the sustained efficacy, safety, and cost-effectiveness of detachable tip microcatheters. The device's broader clinical applications and integration into standard neurovascular protocols should also be explored.

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