ASK THE EXPERTS

How Do You Know When Not to Place Another Coil?

Experts discuss their techniques for determining adequate embolization and describe situations in which they would not place another coil.

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Coil embolization is one of the most effective, versatile, and helpful endovascular techniques available. Using modern microcatheters, microwires, and microcoils, every region in the human body can be reached to embolize acute bleeding, a tumor before surgery, or a visceral aneurysm.

Nevertheless, effective and safe coil embolization requires a lot of experience in different endovascular techniques and should only be performed by experienced interventional radiologists who are accustomed to working with microcatheters, wires, and microcoils.

For many years, I have almost exclusively worked with detachable coils because they are safer than pushable coils, and they are available in longer lengths so that fewer coils are needed to achieve a complete vessel/aneurysm occlusion. When I start coiling a vessel, I begin with a relatively short first coil to see and feel how the coil behaves in the vessel. If I am satisfied with the diameter and behavior of the first coil, I proceed with longer coils. I try to pack the coils as densely as possible to accomplish a complete and durable vessel occlusion—this is important in aneurysms as well as in straight vessels. To achieve a dense coil packing, soft coils are helpful.

It is crucial to know when not to place one more coil, especially when using a pushable coil, because it cannot be pulled back if there is not enough room for the whole coil. In most cases, you can predict how a coil will behave based on the behavior of the previous coil. Nevertheless, it could make sense to switch back to shorter coils when the embolization is almost complete. It is easy to remove or replace the last coil if it is not in the optimal place when using pushable coils. When using detachable coils, a snare loop is available to remove the misplaced coil, if necessary.

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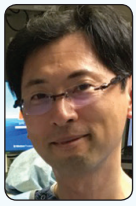
There are several factors that go into deciding whether or not to place another coil, but probably the first consideration is whether you have accomplished your goal. If you have effectively shut down the vessel or eliminated extravasation, then placing further coils may just risk nontarget embolization without increasing the therapeutic benefit.

When placing a series of coils in a single vessel, such as the gastroduodenal artery, the decision to not place another coil often depends on mechanical factors. Is there enough room to deploy the coil without having it extend back into the parent vessel? Is the catheter

stable enough to force the coil to form a tight nest without backing the catheter out? Often, you can sense the answer to these questions based on how the previous coil formed when it was deployed. If the previous coil was already close to prolapsing out into the parent artery, then it is unlikely that another coil can fit safely. However, when uncertain, this is a time to consider a detachable coil so that you can pull it back out if your assessment was incorrect.

With a multifocal bleeding source, you may be deploying coils in parallel in different vessels. In this situation, a prime determinant of when to stop is whether you think the end organ can tolerate further devascularization. An example of this would be colonic embolization for gastrointestinal bleeding. If you embolize too many vasa recta (usually more than three), the risk of ischemia or bowel infarction significantly increases.



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The goal of coil embolization is to achieve adequate blood flow reduction of the target vessels to meet the clinical demand. In the process of tubular vessel occlusion, tight cross-sectional occlusion is preferred to obtain long-term vessel occlusion. Several coils should be densely packed within the target vessel segment. However, we may wonder if the next coil can be safely deployed even though the blood flow remains without reaching the intended endpoint. In essence, the next coil would be dislodged into the nontarget vessel due to inappropriate coil size or catheter kickback. So, we should consider stopping the next coil delivery if the delivery catheter is already unstable and if only a short distance remains before the branch to preserve. Then, consider using a detachable coil or a plug if there is any concern about using a pushable coil next. N-butyl cyanoacrylate can also be an alternative, but reflux can occur due to a disturbed flow proximal to the deployed coils. Planning is very important to find suitable anatomy and secure adequate vessel length for safe coil deployment. The role of the delivery catheter is as important as appropriate coil selection, and the coaxial technique helps to control the coil delivery.

In the process of packing aneurysms, we previously revealed that coil compaction tends to occur at packing density < 24%.[1] We try to pack an aneurysm as tightly as possible with multiple coils, calculate the estimated packing density during the procedure as a reference for the procedure endpoint, and continue coil embolization until the estimated packing density exceeds 24%. Again, if there is any concern about catheter stability and coil dislocation to the parent artery even before reaching the endpoint, we consider stopping the procedure. Retrieval devices should always be available in your inventory to catch the migrated coil.

1. Yasumoto T, Osuga K, Yamamoto H, et al. Long-term outcomes of coil packing for visceral aneurysms: correlation between packing density and incidence of coil compaction or recanalization. J Vasc Interv Radiol. 2013;24:1798-1807.

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Coil embolization is performed in both the arterial and venous system, and deployment and the overall strategy may vary depending on the therapeutic goal. Coil embolization may be used to occlude mid- or large-size patent vessels, aneurysms, or arteriovenous fistulas or as a tool to induce flow reduction in the venous system. I know when not to place another coil when I am already satisfied with my previous planned therapeutic goal of embolization in a given clinical and angioarchitecture setting. This concept could be further examined in different settings, and I would probably not place another coil if:

- Fluoroscopic and/or angiographic confirmation of dense coil packing in the appropriate position is deemed unnecessary.
- Slow blood flow is visualized on angiography immediately after properly coiling a parent vessel. Just wait for a few minutes and check again, it is highly likely to be completely occluded.

- Distal flow is visualized despite a relatively well-positioned coiling to achieve hemostasis in a hemodynamic unstable patient. It is better to consider switching to another embolic material (glue) to achieve hemostasis. The coil vessel mechanism of occlusion needs to be activated by the autologous thrombotic system which could be impaired in patients with consumption coagulopathy secondary to severe hemorrhage.
- An artery has been coiled enough but has not occluded the lesion, and further proximal coils would occlude a branch supplying territory that has no adequate collateral circulation to ensure sufficient arterial supply. The knowledge of functional anatomy and evaluation of risk-benefit ratio is essential for decision making.
- There is a relatively high risk of proximal coil migration to a sensitive nontarget territory, which is especially true when dealing with an ostial vessel occlusion or an aneurysm with a relatively enlarged neck that is already almost filled up with coils. It's best to keep away from complications!
- Distal migration to the venous side has occurred when placing an assumed appropriate-size first coil in a high-flow arteriovenous fistula. Consider using a plug or any flow reduction system from the venous side to avoid complications.
- An appropriate distal sclerotherapy was performed for gonadal vein embolization and one or two coils were supplementarily deployed along the main gonadal vein to complement the embolization. In this case, there is no need to obtain a cross-sectional occlusion of the main vein with the previously deployed coils.

It is important to note that the aforementioned concepts can be adapted according to physician experience, risk-benefit ratio, and the possibility of utilizing other embolic material as well as many other factors related to proper patient management. The of decision whether to place another coil should be determined on a specific case analysis and may vary among physicians. When coiling and treating patients, it is wise to bear in mind Voltaire's aphorism, "The perfect is the enemy of the good."

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There are two main issues to consider when addressing this question: Is the embolization procedure complete, and is placement of one more coil potentially hazardous? The decision-making process for both of these issues is helped substantially by increased individual operator experience in coil embolization procedures.

Knowing when the embolization procedure is complete is more difficult for some procedures than others. For example, coil embolization of a hemorrhaging artery is performed until there is angiographic evidence of vessel occlusion and no further evidence of bleeding. In general, completion angiography should be performed from a proximal location rather than by injection through the catheter lodged at the site of embolization to avoid the spurious appearance of ongoing extravasation by a contrast medium "forced" through the nest of coils as a result of injecting contrast medium from the catheter tip adjacent to the coil nest. Deciding when coil embolization of a visceral artery aneurysm is complete may be more challenging if the aneurysm is being packed with coils. In general, it is safer to err on the side of caution and not deploy a coil if there is a risk of coil misplacement or migration out of the aneurysm. After all, it is almost always possible to come back another day if the embolization procedure turns out to be incomplete on follow-up imaging.

There are various situations when attempting to place another coil may lead to coil migration out of the vessel to be embolized. Alternatively, part of the coil may be successfully placed in the desired target vessel, and part of the coil may erroneously extend out of the target vessel into another vessel. In many situations, this is not problematic; migrated coils can typically be safely retrieved by snaring. Partial coil misplacement into a neighboring vessel may not be problematic and may be left in situ. However, for some anatomic locations, migration may be catastrophic. For example, coil embolization of common carotid or internal carotid artery lesions carries the risk of cranial migration. Similarly, for renal artery aneurysms or renal artery hemorrhage, misplacement of a coil or part of a coil into a neighboring branch artery may result in an increased territory of infarction than was originally desired.

In general, if the operator starts to be concerned about whether the next coil can be safely deployed after placing several coils, it is probably time to stop the procedure before "trying one more coil." It is usually this last coil that results in a complication that might have been avoided had the operator stopped the procedure before the final coil.

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Today's interventionist has many reasons for coil embolization. It can be used for life-saving control of active hemorrhage, radioembolization planning, and/or treatment of a varicocele. The indications keep expanding, and fortunately, our options are expanding as well. However, at time, the interventionist is left with the question of when enough coiling has been performed.

Knowing when to stop deploying an additional coil is a matter of experience. Still, even the most experienced interventionist may struggle with this decision, and this was a particular problem when detachable coils were not available. At academic centers, detachable coils help decrease trainee-related adverse outcomes and associated anxiety when repositioning is required. Despite these advantages, the difference between deploying pushable versus detachable coils does not have a significant impact in achieving complete stasis, other than the fact that more pushable coils may be required as compared to widely available large-volume detachable coils.

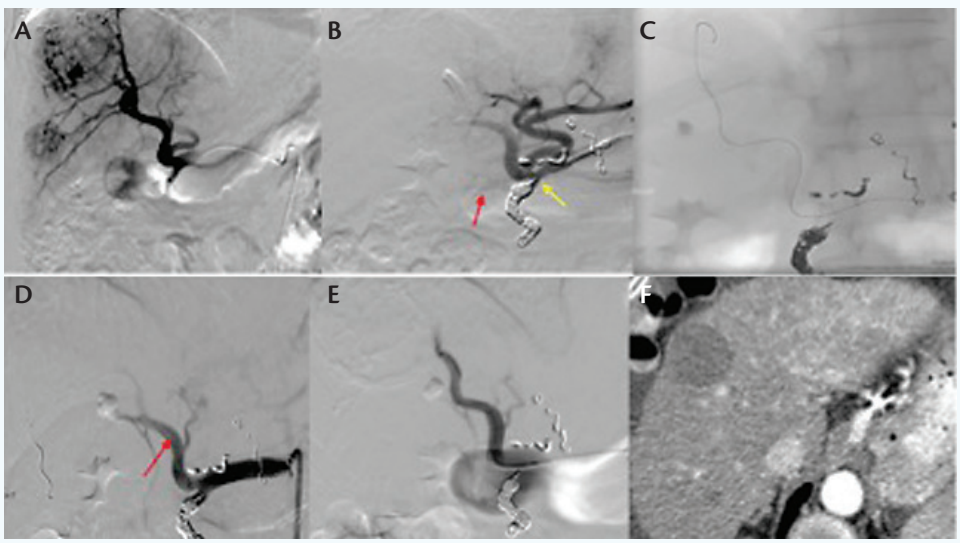

Figure 1. A 58-year-old man with bilateral hepatocellular carcinoma undergoing a mapping procedure for resin radioembolization. The initial digital subtraction angiogram showed large hypervascular hepatomas and hepatic arterial anatomy, with close proximity of the gastroduodenal artery (GDA) to right and left hepatic artery origins. Embolization of the GDA was warranted during mapping for resin-coated yttrium-90 spheres due to the higher risk of reflux (A). Embolization of the hepatic falciform artery and right gastric artery was also planned. Postembolization angiogram showed that despite < 1-cm segment of GDA left with flow after coiling (yellow arrow), small duedonal branches were noted coming off the GDA (red arrow) (B). A "final" detachable coil was advanced to GDA; however, it would not fit into the residual proximal GDA segment. The coil was pulled back, and a repeat angiogram showed that the coil detached within the microcatheter, and with contrast injection, the coil migrated to the right hepatic artery (C). After coil retrieval, dissection flap (red arrow) was noted in the proper hepatic artery, which did not resolve after balloon dilation (D). Poststenting digital subtraction angiogram showed restored laminar flow. However, not to lose the chance to treat the patient, bland microspheres were used to treat the right lobe lesions (E). Follow-up CT scan showed complete response of the treated lesions (F).

That being said, detachable coils will not always protect you from that "last coil syndrome"—when a coil is deployed and does not fit into the residual space within the intended artery and it refluxes and migrates to the distal nontarget artery. In some cases, this may be managed by just leaving the coil in place when no harm is expected; in other cases, it requires retrieval. Retrieval may be easy or difficult, and at times, difficult retrievals may lead to complications. Not deploying the last coil could have prevented those complications.

So then one should ask if com-

Figure 2. In this case, perhaps there should have been more concern for placing the last coil.

plete stasis is better reached by using a detachable coil versus a pushable coil. The authors recommend that a pushable coil not be deployed if the operator is already questioning its risk versus benefit. If using a detachable coil, the risk will be lower; however, it is not zero. Figure 1 demonstrates migration of a detachable coil and its consequences, and Figure 2 shows a case in which sometimes there is no limit to the number of coils used (the number of coils used was done so purposefully to show this). There are several factors that may prevent migration of the last coil if it is definitely required to achieve clinically desired embolization effect. Using a detachable coil instead of pushable coil, appropriate sizing (length and diameter) for the target segment, and secure positioning of the delivery catheter in the target vessel will minimize the risk.

Interventionists have many other tools than coils when performing embolization, including plugs, Gelfoam (Pfizer, Inc.), particles/microspheres, and liquid agents. However, most of us tend to reach for the nearest coil when managing an emergent case. It must be kept in mind that cessation of flow within a vessel is not always immediate when coils are used as the sole means for embolization. Depending on the size of the vessel and flow rates, it may take some time for the thrombotic effect of coils to occur.

The process of coil embolization is not a technique to be strictly followed as compared to other procedures such as the Seldinger or a Whipple technique. The interventionist has his or her own method of how often to administer contrast to determine satisfactory stasis, which may occur after a second or after the coil. Some use anatomical landmarks as the only final way to know when no additional coils should be used, such as when embolizing the GDA to its origin. This does not mean that complete stasis was achieved, but rather that physically no more coils should be used. One approach to minimize the need to embolize more proximally is to start embolization more distally. Packing of more coils for a few centimeters distally will achieve complete stasis sooner and more easily. ■