Chapter 5. Technical Notes

Prevention of Embolism

Catheter-related embolisms can be roughly classified into thrombus, air embolism, and plaque embolism, each of which requires different preventive measures.

Thrombosis

The keys to preventing thrombosis are to maintain continuous perfusion with heparinized saline, to control the level of the parent catheter, and to minimize the intervention time.

Management of Heparinized Saline Perfusion

Continuous perfusion with heparinized saline is performed through the parent catheter using a pressure bag to prevent blood from coagulating inside the catheter. Those who specialize in the body trunk may also have experience with perfusion when using IDC (Interlocking Detachable Coil).

The drop rate of heparinized saline changes significantly each time a microcatheter or guidewire is inserted or removed from the parent catheter, and the rate must be reset each time by manipulating a clamp. If the Y-connector outlet (hemostatic valve opener) is not tightened properly, heparinized saline will flow back out without perfusing through the parent catheter. These problems in managing perfusion can easily occur when concentrating on the procedure. The pressure from the pressure bag decreases with time, and even if it is maintained, perfusion stops when the heparinized saline in the bag is low. It sometimes happens that no one notices this situation until arterial blood flows back into the catheter. It is necessary to share enough information so that nurses can smoothly and spontaneously perform these observations, re-pressurizations, and bag changes.

> Drip chamber of the heparinized saline line
>
> When inserting the infusion set into the pressure bag, the fluid level in the drip chamber should be aligned so that it is not too high or too low, but just in the middle. Since the fluid level rises due to pressurization, if the initial fluid level is too high, it will reach the top of the drip chamber and the flow rate cannot be determined. If the fluid level is too low, air bubbles generated by the impact of the dripping may be sucked into the line, causing air embolisms.

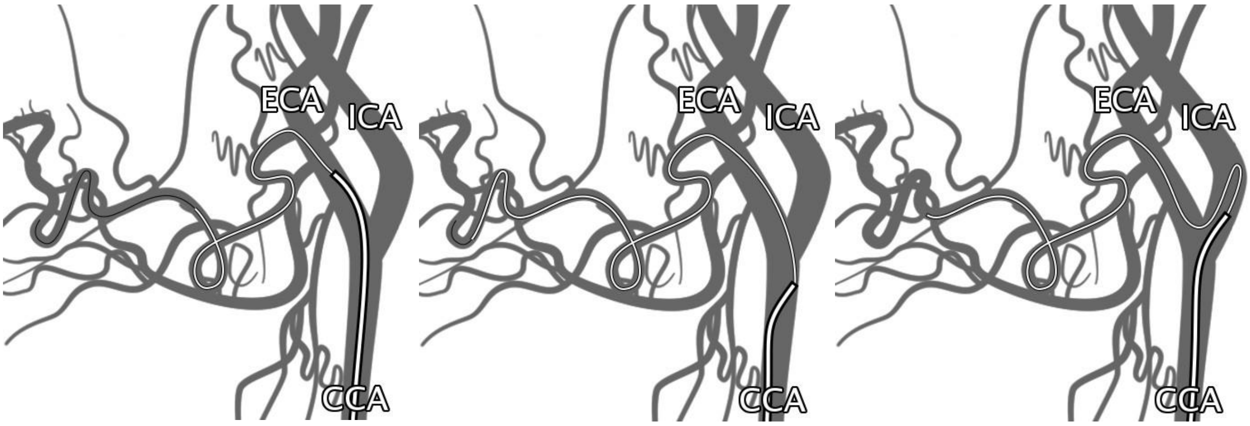

Figure 11. Linkage of vertical movement of guiding catheter and torque
Left: When a microcatheter is advanced using the over-the-wire technique, the guiding catheter is subjected to a downward reaction.
Middle: The downward movement corresponds to clockwise rotation of the torque, and the guiding catheter slowly rotates downward.
Right: Once the microguidewire is removed, the guiding catheter, which has less reaction, is raised quickly and sometimes slips into the internal carotid artery. This is a high-risk situation for intracranial thromboembolism, and there is also the risk that a microcatheter may be dislodged after it has been placed. When operating at the most distal end of the branch, the carotid bifurcation may be out of the range of fluoroscopy, and this situation may be unnoticed.

Management of the Level of the Parent Catheter

A parent catheter can be a very dangerous source of emboli the moment continuous perfusion with heparinized saline is not properly performed. That being said, even if such a situation should arise, as long as the tip of the parent catheter is in the external carotid artery, the thrombus will flow into the external carotid artery system, which should not be too dangerous (disregarding the intracranial anastomosis).

This means that it is important as a risk management measure to check the position of the parent catheter and whether it has fallen from the external carotid artery to the common carotid artery. When approaching a vessel with a low origin and strong peripheral tortuosity, such as the facial artery, be sure to keep a close eye on the parent catheter position.

Guiding catheters placed in the low external carotid artery often cause a kickback as the microcatheter is guided distally and often dislodge to the common carotid artery. In general, the main trunk of the carotid artery, which originates from the aortic arch, runs in a gentle spiral, so that the vertical movement of the catheter is linked to the rotating movement in the region (counterclockwise for ascending and clockwise for descending. The exception is the bovine aortic arch variant, in which the response is reversed). Because of this characteristic, a guiding catheter dropped from the external carotid artery into the common carotid artery may be subjected to 180° torque, and as a result, the dislodged catheter may re-enter the internal carotid artery on its own (with the microcatheter involved) (Figure 11??). Inadequate perfusion with heparinized saline can easily lead to cerebral thromboembolism, so the utmost caution is required.

Duration of Intervention

Even with the most careful use of continuous heparinized saline perfusion and catheter positioning, thrombus formation due to inevitable causes such as blood coagulation on the device surface is likely to occur at a certain rate. Therefore, minimizing the intervention time is a major contribution to the prevention of thrombosis.

However, it is important not to rush, or become careless with the procedures. If there is a limit to what can be done to speed up the process safely, then it is safer to perform systemic heparinization without hesitating.

Air Embolism

The causes of air embolism can be limited to a few. Unlike thrombosis, this is a complication that can always be prevented by taking individual precautions (so there should be no reason for this).

Air in hand-pressed syringes

Make sure that the syringes for contrast are connected properly using a technique that prevents air from entering the syringe. When suctioning a contrast agent or a saline solution from a cup, (i) suction a small amount first, (ii) push the entire amount under the water (to release the air), and (iii) suction the necessary amount again. When connecting a syringe to a catheter hub or T-shape stopcock, push out a small amount and flush the connecting part while connecting. Never use contrast agent with air bubbles remaining in the syringe.

Air in Heparinized Saline Line

When first preparing the heparinized saline line, the air can be released by flicking the line from the pressure bag side. During this process, air tends to be trapped in the joints between the line and the extension line, the line and the T-shape stopcock, and the T-shape stopcock and the Y-connector, and it is difficult to visually recognize them. Bubbles in a T-shape stopcock have a tendency to stay in place instead of flowing when the flow speed is fast.

Even after a heparinized saline line is complete, bubbles can be drawn into the line from the surface of the solution if the drip tube is slanted due to vibration. It tends to occur when the patient's table is moved, such as when performing intra-arterial CT. It is recommended that the infusion line be taped to such as an IV pole at a position close to the drip tube in advance.

If the heparinized saline in the pressure bag is used up after prolonged treatment, a nurse will replace the bag. Air is also likely to be introduced when the line is reinserted into a new bag.

Guidewire Removal

When the guidewire is pulled out of the catheter at high speed, this creates negative pressure in the lumen and draws in air. The smaller the diameter of the catheter and the closer the catheter tip is to the vessel wall, the more likely this is to occur. Remove the wire slowly. If air is likely to be drawn in, a syringe should be placed at the hub of the catheter to add contrast agent or saline while removing the catheter.

At any facility, there are many cases of air bubbles escaping from microcatheters that appear to be caused by the wire removal.

Plaque Embolism

Atheromatous plaques may be deposited on the wall of the common carotid artery and of the aortic arch, as well as on the posterior wall of the internal carotid artery at the origin. Especially in the aortic arch, the presence of complex atheroma lesions may be problematic. If the endothelium is thinned, it can be ruptured by abrasion with a sharp edge of a parent catheter or by puncture with a guidewire, causing the contents to be dispersed and leading to embolism. This secondarily induces thrombus formation, which cannot be prevented by anticoagulant or antithrombotic drugs since the dispersed atheroma itself is not a thrombus.

Use of Guidewire

A guidewire is stiffer than a catheter, so it tends to travel the shortest possible distance in a bending vessel. When a catheter is used alone, it will always be rubbing the greater curvature side of the vessel as it advances, but when it follows a guidewire, it passes closer to the center of the vessel lumen. This is especially important when avoiding the posterior wall of the internal carotid artery at the origin, which is a frequent site of plaque formation.

Orientation of Catheter Tip

The tip of the catheter is bent, and the shaft of the catheter runs dorsally in the aorta due to gravity. Therefore, it is logical to move the catheter tip toward the ventral side in the aorta to minimize friction of the tip.

The aortic arch runs obliquely from right ventral to left dorsal. The catheter tip should be oriented along this direction for safety (right anterior slightly downward). When examining the main arteries of the neck (brachiocephalic artery, left common carotid artery, and left subclavian artery), some textbooks instruct that the catheter tip to move back and forth in the aortic arch with the catheter tip facing up. Basically, it is better to move the catheter with the catheter tip pointing downward, and then turn the catheter 180° at the position where you think the carotid artery is originating, to minimize abrasion of the upper wall of the aortic arch.

Vasospasm

The external carotid artery system is very prone to vasospasm. In some cases, the main trunk of the external carotid artery may already be spasming even after a guiding catheter has been raised carefully to the external carotid artery using a 0.032" guidewire. The branches of the external carotid artery are more prone to spasm, especially the transverse facial artery and the lingual artery which can be easily triggered by unintentional manipulation. It is impossible to completely prevent vasospasm in the external carotid artery region, but it can be prevented to some extent.

Prevention of Vasospasm

There are two main ways of prevention: manipulation of catheters and devices, and administration of drugs.

Position of Catheter Placement

When a parent catheter is placed in an artery, the catheter tip can cause a spasm if it continuously stimulates the vessel wall due to pulsation. The height and orientation of the tip can be adjusted so that it will be less likely to cause a spasm. For example, in the external carotid artery, the bend of the catheter tip matches the bend of the genu part, which gently turns outward after ascending, making it suitable for placement.

Roadmap

Always use a roadmap that allows the contrast record to be superimposed on fluoroscopy, or an overlay that allows previously taken digital subtraction angiography (DSA) to be matched to fluoroscopy. Roadmaps cannot be used for the body trunk because of the respiratory movement of organs. Therefore, it is common practice to manipulate catheters and guidewires under live fluoroscopy while referring to DSA images. This is not the case in the head and neck region, and a roadmap should always be used. The frequency of vasospasm changes significantly without it.

Those in specialized fields who do not usually use this method are inclined to search for branches under the fluoroscopy without using a roadmap, and should make a conscious effort to use it.

Tip Formation

The tips of microcatheters and microguidewires should be molded at 90°. Never perform IA infusion in the head and neck with a straight tip.

When approaching each branch, avoid blindly rotating the microguidewire, while monitoring the fluoroscopy screen, using probability theory to insert the microguidewire into the branch (so called “kuru-kuru” method of inserting the catheter by rotating it). This method causes vasospasm in a matter of seconds.

Following the roadmap, the tip of the microcatheter should be directed toward the origin of the target branch, and then the microguidewire should be carefully advanced so that it will be inserted possibly in one go. This requires that the tips of the microcatheter and guidewire be bent.

Working Angle

Since the kuru-kuru method is not recommended, the starting direction of the branch must be accurately understood and imaged at a clear angle in order to advance the micro-guidewire to the desired branch. The key to smooth catheter insertion without vasospasm is to calculate the optimal working angle using preoperative 3D-CTA. This is especially important in facilities with single-plane equipment.

Non-guidewire Technique

In vessels prone to spasm, it is often easier to proceed with a soft-tipped microcatheter while the microguidewire is retracted, instead of using the over-the-wire technique. This method is particularly effective in the transverse facial artery and the proximal area of the facial artery.

Premedication

Hydroxyzine (Atarax P) and warm compresses have been reported to be effective in preventing spasm.

Vasodilators

Prophylactic IA infusion of calcium channel blockers and/or nitrite preparations, especially the latter, can prevent spasm. It is best to administer from the parent vessel at the point of targeting a subbranch that is likely to be difficult to place.

Management of Vasospasm

If a spasm develops, administer a vasodilator and wait for a while, or proceed to treatment of another branch and wait for it to spontaneously subside. It is possible to ameliorate the spasm considerably by administering a calcium channel blocker (e.g., Perdipine 2 mg/2 mL) in a 10-fold dilution, 1/10 of the dose at a time. If immediate release is necessary, administer arterial infusion of nitroglycerin (Myristolol) 100 µg at a time.

Occlusion of Feeding Arteries

Narrowed arteries due to encasement by the tumor may regain normal diameter as the tumor shrinks during treatment, or they may remain narrowed (despite tumor shrinkage) and eventually become occluded. This is an unavoidable natural process, but the feeding artery sometimes becomes occluded at a site before entering the tumor. This is mostly caused by procedures. Typical causes include the following.

Forcing the Procedure under Vasospasm

When it is difficult to identify the branch with a microguidewire, and it is necessary to repeat procedures, vasospasm may occur. It is a usual procedure to infuse vasodilators or to treat another site first and allow some time. However, if you are not aware that a spasm is occurring, you may continue the procedure, further increasing the extent of the spasm, and the artery may eventually become occluded. There are many cases of occlusion of the entire superficial temporal artery due to difficulty in identifying the transverse facial artery, or occlusion of its origin due to manipulation to the superior thyroid artery.

This is most likely to occur when the operation is performed using only fluoroscopy, without using a roadmap or overlay. This is because it is hard to notice a mismatch between the normal vessel diameter and the movement of the microguidewire tip.

Mismatch of microguidewires

0.016" diameter Meisters and GTs are widely used in regions of the body trunk, but these are "thick" wires in the external carotid region. If these tips are J-shaped and vigorously advanced into the feeding branch, arterial dissection may occur.

This is often due to a gap in the sense of scale caused by differences in areas of expertise. Even the external carotid artery, which is the parent artery for placement of the guiding catheter, is slightly smaller than the proper hepatic artery. The first segment of the internal maxillary artery is about as thick as the secondary branch of the left hepatic artery.

Remaining Tumor Components from Unknown Source of Blood Supply

There are cases in which, despite IA infusion CT from every artery imaginable, there are areas of the tumor that are not contrast-enhanced, yet are stained on conventional contrast-enhanced CT and necrosis can be ruled out. It is especially common in massive maxillary sinus cancer.

There are two possibilities. One is when the actual feeding artery is not recognized, which may be an overlooked subbranch, a contralateral vessel, or a vessel of the internal carotid artery system, such as the ophthalmic artery. After the procedure is completed, it should be reviewed carefully with 3D-CTA or IA infusion CT from the external carotid artery.

The other possibility is that the area is a divide receiving perfusion from multiple feeding arteries, and tumor staining is often visible only when the microcatheter is placed more distally and IA infusion CT is performed. In DSA, to-and-fro* of the feeding arteries may be seen in the divide area (e.g., the periosteal branch of the infraorbital artery and the peripheral angular artery). In this case, measures such as two-stage IA infusion and blood flow control with coil embolization are necessary, but there is still a possibility of residual tumor.

If the blood source cannot be identified until the end, do not hesitate to share the information with team physicians including the radiation oncologists and head and neck surgeons, and start planning for post-treatment follow-up early on. Recently, it has been reported that salvage surgery for maxillary sinus cancer can be safely performed even after full-dose IA infusion chemotherapy and radiotherapy. Therefore, it is important to be aware of which tumor sites the head and neck surgeon would most want eradicated by IA infusion chemotherapy, and conversely, which sites are most amenable to salvage surgery if they remain. It is also important to consult with each other to treat the patient.

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* If there is retrograde blood flow via anastomosis from another artery distally, in addition to the antegrade blood flow, the contrast agent may not flow unidirectionally, but may flow bidirectionally "to and fro" in response to pulsation in the peripheral region.