Chapter 2. What to Evaluate before Surgery

Preoperative diagnostic imaging plays an important role in IA chemotherapy, mainly for staging and understanding vascular anatomy. Interventional radiologists performing catheterization procedures should prepare by analyzing the preoperative images independently from the diagnostic imaging specialists and head and neck surgeons. It is not an overstatement to say that the success or failure of the treatment depends on the amount of effort outside the catheterization laboratory (cath lab). IA chemotherapy aims at a cure, not reducing the size of the cancer. Therefore, a microcatheter must be guided into all the feeding arteries involved in the cancer to infuse an anticancer drug. This is a complicated procedure and requires a considerable amount of time. By performing careful preoperative imaging, the procedures can be done more efficiently and quickly. The main items to be evaluated by imaging are staging and vascular anatomy. Evaluation of the direction of tumor progression via staging helps to determine the priority of arteries to be treated, increasing the efficacy of procedure. Knowing the vascular anatomy in advance allows for safe and rapid microcatheter guidance through the tumor's feeding arteries. With these preoperative evaluations reducing the time of procedure, the frequency of catheter-related adverse events is decreased, and treatment completion rates are improved by reducing mental and physical stress on the patient. The additional operation time resources allow the clinician to make more accurate intraoperative judgements.

Staging

Staging is aimed at determining the indication for treatment and estimating feeding arteries by assessing their extent of progression, and contrast-enhanced MRI, contrast-enhanced dynamic CT, and ^{18}F-FDG PET-CT are used as modalities. Indication for treatment is determined by exclusion of distant metastases and evaluation of lymph node metastases. IA chemotherapy is a local treatment and is not indicated for patients with distant metastases. Lymph node metastases are treatable if they areLevel I-V. While lateral posterior pharyngeal lymph node (Rouvière lymph node) is often treated as equivalent to distant metastasis, the area can be an indication for IA infusion (although careful procedure is required). CT, and ^{18}F-FDG PET-CT are used for these evaluations, and ultrasonography is used for the lymph node metastasis. For primary tumors, a combination of bone window CT and MRI of each sequence is used to evaluate the range of extension and internal nature of the lesion. To evaluate the range of extension, it requires not only the usual depth invasion diagnosis based on the T-factor but also readings from the aspect of vascular territories which enables forming a strategy as to which arteries to treat. Evaluating the internal nature of the lesion, particularly central necrosis, or non-neoplastic effusion (e.g., obstructive sinusitis), and distinguishing between the tumor's solid components play an important role in determining the perfusion area of each artery using IA-CT.

CT

CT scans can evaluate lymph node and systemic metastases, and bone window images can evaluate bone destruction and reactive osteosclerosis. CT does not provide as much information as MRI in the evaluation of the primary lesion, but rather is often used to evaluate the vasculature by CT-angiography (CTA) which is discussed later. However, in facilities where frequent MRI is not available or in cases where MRI cannot be performed due to metal in the body, CT scans can be used as baseline images for future follow up.

In maxillary sinus cancer, the presence or absence of invasion into the orbital apex, pterygoid base, or greater wing of sphenoid bone often determines staging. Subtraction CT or Iodine mapping using Dual Energy CT should be used when necessary. Both are capable of depicting contrast enhancement effects within the bone, whereas the former is superior in bone removal, and the latter is less affected by body motion.

MRI

MRI is used to assess the extent of primary tumor in detail. Non-contrast T1-weighted image (T1WI), fat-suppressed T2-weighted image (FsT2WI), gadolinium-enhanced fat-suppressed image (FsGd), and diffusion-weighted images (DWI) are useful. FsT2WI and FsGd are not very different in their ability to detect tumor boundaries, and share a tendency to slightly overestimate the range of extension through edema and venous congestion in the surrounding tissues. On this point, the reliability can be increased by carefully evaluating signals of fat tissues around the tumor using T1W1. The apparent diffusion coefficient (ADC) map produced by diffusion-weighted imaging is useful for identifying viable malignant tumors, despite its poor spatial resolution, and should be taken in combination with MRI.

FsT2WI is superior in differentiation between tumor and mucosa, and from obstructive sinusitis, while FsGd is better for evaluation of necrosis in the tumor. In general, MRI is readable only on axial section images, but coronal and sagittal section images may be added if necessary.

Evaluation of Tumor Using Preoperational Imaging

- Bone window CT/ Contrast enhanced CT: evaluation of invasion depth and lymph nodes
- Non-contrast T1-weighted image (T1WI): evaluation of tumor boundaries using surrounding fatty tissue.
- Fat-suppressed T2-weighted image (FsT2WI): evaluation of tumor boundaries, and obstructive sinusitis
- Fat-suppressed contrast enhanced image: evaluation of tumor boundaries, and intra-tumor necrosis
- The apparent diffusion coefficient (ADC) map: identification of viable tumors

Diagnosis of Tumor Extent

The purpose of preoperative evaluation of the extent of tumor invasion is to pick out preliminarily the feeding arteries to be treated. The most reliable way to determine whether an artery is feeding a tumor is intra-arterial contrast enhanced CT (IA-CT), in which a microcatheter is placed in the artery and a contrast agent is infused while CT imaging is performed. It is widely accepted that this technique is the gold standard for identifying feeding arteries. However, the time available in the cath lab is limited, and it is impractical to examine every artery that may be involved in the tumor using IA-CT. Therefore, during preoperative imaging, we estimate the involved arteries and their order of priority based on anatomical knowledge, depending on which region the tumor is spreading to. This estimation is mainly made using MRI, which is more precise when combined with the findings of 3D-CTA, which will be discussed later, and finally verified by intra-operative IA-CT.

The following are generally descriptive of the directions of maxillary sinus carcinoma, which is roughly divided into the anterior wall extension, orbital ethmoid extension, alveolar extension, posterior wall extension, and medial wall extension. The names of the arteries that may be involved are discussed in detail in later chapters. You may refer to them as you read.

Anterior wall extension

When maxillary sinus carcinoma extends anteriorly by destroying the anterior wall of the maxillary sinus, the feeding arteries are often the internal maxillary artery, especially the infraorbital artery, and the angular branch of the facial artery and the transverse facial artery may also be involved. Tumors that destroy the anterior wall of the maxillary sinus often form a convex lens-shaped mass under the anterior buccal skin. On the cephalic side, it reaches the orbital ethmoid bone extension, and on the caudal side, it continues to the alveolar extension.

A tumor with anterior wall extension first contacts the anterior superior alveolar artery. The artery runs inside the bone of the anterior wall of the maxillary sinus (anterior alveolar canal) and is distributed along the bone wall of the anterior half of the maxillary sinus. In the case of squamous cell carcinoma with strong destructive changes, the artery is often quickly engulfed and collapses.

The tumor next contacts the periosteal branch of the infraorbital artery. This artery often becomes the most important feeding artery for tumors in the maxillary region. With a large tumor, arteries may narrow or collapse, but blood often recanalizes as the tumor shrinks.

Finally, the tumor contacts the angular artery (the terminal branch of the facial artery) and transverse facial artery, which run subcutaneously in the buccal region. These arteries run in the shallower layer (closer to the epidermis) than the periosteal branch of the infraorbital artery and provide less blood supply than the infraorbital artery when tumors extended subcutaneously from the maxillary sinus through the bone. However, when the infraorbital artery is stenoseddue to a tumor, or in the regions of the lower anterior wall and lateral anterior wall where the infraorbital artery is distant and perfusion pressure is low, blood supply from the facial artery system is relatively dominant. Although rare, the contralateral facial artery may “go over a mountain” to the angular region on the affected side (Cross reference: angular artery).

In cases where such anterior wall extension was observed, three branches of the internal maxillary artery (infraorbital artery), facial artery (angular artery), and transverse facial artery are unconditionally targeted for treatment. Then 3D-CTA is used to confirm stenosis or development in the infraorbital artery and superselective treatment should be planned. In the actual treatment, how much thefacial and transverse facial arteries are related to the tumor is evaluated using IA-CT, and the final decision of the treatability is made.

In cases where such anterior wall extension was observed, three branches of the internal maxillary artery, facial artery, and transverse facial artery are unconditionally targeted for treatment. Then, 3D-CTA is performed to check for stenosis of the infraorbital artery, which is the terminal branch of the maxillary artery and often the most important feeder for maxillary cancer, to determine if RADPLAT itself is effective. In the actual treatment, how much the the facial and transverse facial arteries are related to the tumor is evaluated using IA-CT, and the final decision of the treatability is made.

Orbital ethmoid extension

In cancers with a origin in the upper anterior wall of the maxillary sinus (infraorbital rim) or in large advanced maxillary sinus carcinomas, infraorbital extension is observed, the tumor often also extends into the ethmoid cells. Tumors in this region may receive blood supply from the internal carotid artery system, where it is difficult to perform an IA procedure, and are located at the margins of the irradiation field. Tumors in the area are more likely to persist and require attention. While many have learned that these are supposed to be nourished by the anterior and posterior ethmoidal arteries derived from the ophthalmic artery, a branch of the internal carotid artery. In fact, blood is often supplied from the sphenopalatine and infraorbital arteries, terminal branches of internal maxillary artery, and the ratio varies depending on each case. Since it is very difficult to identify which of these arteries actually provide blood supply to the tumor by preoperative diagnostic imaging, it is necessary to determine the perfusion area using internal carotid arteriography during treatment and IA-CT for the internal maxillary artery.

In cases of extension of the area, it is often complicated with obstructive sinusitis in the anterior ethmoid and frontal sinuses on the tumor affected side. Depending on the nature of fluid retention, the imaging appearance can be similar to that of a tumor component. These inflammatory lesions are not enhanced by IA-CT, which may lead to misinterpretation during treatment. It is advisable to differentiate the tumor component from obstructive sinusitis by preoperative imaging.

Alveolus extension

The maxillary alveolar extension is mainly categorized into anterior and posterior regions. The former is often associated with an anterior wall extension and the latter with a posterior wall extension.

Tumors extending into the anterior alveolus are fed from the cranial side by the anterior superior alveolar artery and the periosteal branch of the infraorbital artery, and from the caudal side by the facial artery (superior labial branch of the facial artery). Since this is the most peripheral region of all arteries, and the infusion pressure of anticancer drug tends to be low due to the difficulty of the superselective catheterization, tumors tend to remain after treatment. Nevertheless, unlike an orbital extension, this is an easy site for salvage surgery.

The tumor in the posterior alveolar region is fed by the posterior superior alveolar artery from the cranial side and by the facial artery (the buccal branch of the facial artery) from the caudal side. The basic principles are the same as for the anterior alveolar region. However, if the tumor extends further posteriorly and invades the retromolar area, the feeding arteries become more complex and the difficulty of the treatment increases. The buccal branch, diverging proximally from the facial artery, flows in from the caudal side, while the buccal and pterygoid branches, originating distally from internal maxillary artery, supply blood from the cranial side. When the tumor extends through the alveolus or directly to the hard palate, the descending palatine artery provides blood supply to the tumor.

In the case of alveolar extension, in principle the internal maxillary artery should be examined with the anterior and posterior superior alveolar arteries in mind, and the facial artery should also be examined considering caudal blood supply. If there is a tumor extension to the retromolar area, more arteries should be investigated.

Posterior wall extension

Maxillary sinus cancer extending posteriorly often destroys the bone of the posterior wall. However, there are some cases in which the cancer extends posteriorly outside of the sinus as if infiltrating without obvious bone destruction. The tumor of the posterior portion compresses the pterygopalatine fossa and narrows the proximal part of the third portion of internal maxillary artery and each terminal branch running in the same area. If the tumor extends further posteriorly than pterygopalatine fossa, it invades the base of the pterygoid muscles.

When the tumor extending posteriorly advances inward, the root of pterygoid process, or greater palatine canal, is located in that direction. Since the bones in the area are relatively thick and are able to withstand tumor invasion for a considerable period of time, it is rare for the descending palatine artery running within the greater palatine canal to be involved in the tumor. If a posterior extension of the tumor spreads laterally, it may invade the temporal muscle. Caudal extention, i.e., to the posterior alveolus, is often observed, in which case the presence or absence of the aforementioned retromolar extension is important.

Tumors extending posteriorly through the posterior wall of the maxillary sinus are subject to relatively sequential vascular control, which is similar to anterior wall extensions. That is, the tumor first contacts the posterior superior alveolar artery, which runs inside the bone of the posterior wall (in the posterior alveolar canal). Unlike the anterior superior alveolar artery, which is only a branch of the infraorbital artery, this is one of the major terminal branches of the internal maxillary artery and is very well developed. The posterior superior alveolar artery is the most dominant feeding artery in the posterior wall extension of maxillary sinus cancer.

The tumor next contacts the maxillary tuberosity branch of the infraorbital artery. It is a branch of the infraorbital artery arising just before it enters the orbit through the inferior orbital fissure from the pterygopalatine fossa, and it descends on the periosteal surface of the lateral posterior wall of the maxillary sinus. This is equivalent to the periosteal branch in the anterior buccal region. It provides some blood supply to the tumor, but it is a narrow branch and often becomes obstructed.

Here the tumor leaves the bone and begins to invadethe fatty tissue of the infratemporal fossa. The buccal artery descending from the internal maxillary artery and the buccal branch ascending from the proximal facial artery in the retromolar area pass through this gap in a cephalocaudal direction. These two branches anastomose with each other and provide blood to the tumor. This is a space with a high degree of flexibility, and even if the posterior wall extension of the tumor is quite massive, the arcade between buccal artery and branch is often deviated dorsally and not obstructed.

As mentioned earlier, the base of the pterygoid muscles is involved in the tumor in the slightly medial posterior extension. In this case, the pterygoid branch of the internal maxillary artery becomes a feeding branch. If the dorsal side of muscle is affected, the accessory meningeal artery becomes a feeding artery, and if the nasopharyngeal mucosa is affected medially, the ascending palatine artery becomes a feeding artery.

When the temporal muscle is affected by lateral posterior extension, the anterior deep temporal artery becomes a feeding artery first. Although rare, the middle deep temporal artery may also be involved.

Therefore, in case of normal posterior wall extension, imaging and examination should be performed distally from the internal maxillary artery with the posterior superior alveolar artery and the maxillary tuberosity branch (of the infraorbital artery) in mind. If there is extension to the retromolar areas, temporal muscle, or pterygoid muscles, further examination of each portion should be given.

Medial wall extension

As maxillary sinus cancer progresses medially, it pushes or destroys the natural foramen and protrudes into the nasal cavity, and approaches the nasal septum destroying the nasal dorsum. Most of the feeding arteries are sphenopalatine arteries, and there is no additional artery that should be examined closely for extension in this direction. However, in rare cases, blood may be delivered to the tumor via the septal branch of the contralateral sphenopalatine artery, which should be kept in mind as a possibility.

Evaluation of Blood Vessels

Evaluation of Major Vessels

Evaluation of the major vessels, especially the aortic arch, is performed using contrast-enhanced CT for the purpose of predicting procedural difficulty and safety. Since IA chemotherapy is administered mainly to the external carotid artery system, the risk of cerebral thromboembolism is greater during the time the catheter passes from the aortic arch through the common carotid artery to the external carotid artery. The risk increases if the procedure takes a long time as thrombus formation from the catheter occurs over time. If the carotid artery is highly tortuous due to atherosclerotic changes, it may require a longer time for catheter placement into the (relatively) safe external carotid artery. However, if the route of the carotid artery is known in advance, the time of the procedure can be shortened by selecting a catheter of suitable shape and by using techniques that are useful for specific vascular anatomy. Furthermore, plaques and intramural thrombus may be present in the major vessels and carotid arteries, and unintentional scraping of these may result in cerebral embolism. If the location of hazardous obstructions including plaques is identified beforehand, the risk can be reduced by avoiding them.

In addition to the safety issues, tortuosity of aorta due to atherosclerotic changes also affects the effective length required for the catheter device. If the aortic tortuosity is too strong to allow the catheter tip to reach the external carotid artery, a longer catheter should be prepared in advance. Evaluation of major vessels for this purpose is sufficiently feasible utilizing chest CT images taken for staging.

If possible, an oblique coronal section image of the aortic arch should be made to confirm the angles of origin of the brachiocephalic trunk and the left common carotid artery. When sclerotic changes are strong and the starting angle of the carotid artery is steep, the use of a triple coaxial system including 6F-4F or 5F-3F should be considered.

Evaluation of Carotid Bifurcation

Prior to the insertion of a catheter into the carotid bifurcation, it is essential to evaluate for the presence or absence of carotid plaque and its characteristics in order to perform the procedure safely. Carotid artery plaques frequently appear as a symptom of atherosclerosis in the internal carotid artery, particularly in the posterior wall of its origin. Unstable plaques can break down with mechanical irritation from inadvertent catheter manipulation and cause distal embolization (cerebral infarction). Therefore, preoperative diagnosis of the presence and nature of plaque is necessary. The diagnosis of the presence of plaques is for determining where extra attention is required when a catheter or guidewire passes through the carotid artery. The plaque characterization is for evaluating the instability of the plaque through plaque morphology including ulceration, and presence or absence of bleeding and of calcification to predict the risk of breakdown.

While plaques can be identified by contrast-enhanced CT, carotid ultrasonography can simultaneously diagnose the presence and nature of plaques, and is less invasive and easier, thus is preferred wherever possible. Highly calcified lesions may have poor ultrasound visibility.

In such cases, MRI (black-blood image) can be used to evaluate instability. Performing these tests in advance is expected to reduce the risk of catheter manipulation at the carotid bifurcation.

Evaluation of External Carotid Artery Branches

Prior anatomic analysis of each branch of external carotid arteries is crucial to successful treatment. Head and neck cancers usually receive blood supply from multiple branches of an external carotid artery. In IA chemotherapy, to distribute the anticancer drugs to all regions of the tumor, a physician must locate every artery involved in the tumor from the many branches of the external carotid artery and place a microcatheter in each one. However, the external carotid artery system is rich in anatomical variations and is prone to vasospasm. Without prior anatomical knowledge of the external carotid artery system, the arteries to be examined may be misidentified, including not knowing from which position and in which direction they originate, leading to repeated blind manipulations. It unnecessarily prolongs examination time, often inducing vasospasm, and increases the risk of thromboembolism. It also causes mental and physical distress to the patient, sometimes reducing the completion rate of treatment. In addition, it limits the number of branches that can be examined and treated in a realistic amount of time for the physician to maintain his/her concentration. Preoperative examinations should be performed to identify anatomical variations, to determine the starting angles and optimal working angles of the branches expected to be difficult for catheter placement, and to prioritize the arteries considered to be feeding branches of tumor. Then it will significantly shorten the time required for the initial examination, allow necessary and sufficient treatment of the branches, and reduce the risk of overlooking unexpected feeding branches that may result in incomplete treatment. The most appropriate examination for preoperative evaluation of external carotid artery branches is 3D-CT angiography (3D-CTA). Since this test greatly affects the success or failure of IA chemotherapy, it should be performed to a high standard in both imaging and reading.

Tips for 3D-CTA Imaging

The preoperative 3D-CTA should be able to depict all arteries of at least 1mm in diameter where a microcatheter can be placed. Therefore, it is necessary to obtain images with higher spatial resolution by imaging with several points in mind. Important subbranches including the pterygoid branch and accessory meningeal artery are only depictable in a carefully optimized imaging environment. The keys to obtaining good images are: to increase the peak concentration of the iodine contrast agent; to keep the tube voltage low (100kV); to use a small-focus X-ray tube; and to minimize effects caused by metal artifacts or body motion. Contrast agents are more effective when injection conditions are improved rather than using high-concentration agents or increasing the dose blindly. For instance, administration of 100mL of a high concentration (370mlg/mL) at 2.5mL/sec to a patient weighing 60 kg may sometimes result in poor imaging of the tertiary branch of the external carotid artery. However, even when only 60 mL of a 300 mgl/mL formulation is administered, a trapezoidal cross-injection of 30 mL saline boost at 3.5 mL/sec will enable the thinnest and most important branches to be depicted. When a hyperosmotic contrast agent is injected at high speed, patients may feel a strong sensation of heat, which may lead to involuntary body movements, particularly swallowing. A collar may be useful to prevent this. Suppression of body motion also contributes to improve image quality in subtraction CT, which will be discussed later.

Preventing Metal Artifacts

When evaluating alveolar extension of maxillary sinus cancer or oropharyngeal cancer, metal artifacts caused by metal dental crowns are the greatest obstacle to imaging. If it is an upper tooth, it can be avoided to some extent by using the mouth open position, which should be discussed with the radiologist. It is also useful to position the occlusal plane oblique to the imaging plane. The use of metal artifact reduction technologies such as Single Energy Metal Artifact Reduction (SEMAR), Orthopedic-Metal Artifact Reduction (O-MAR), or dual-energy CT contributes greatly to the accuracy of reading arteries in the oral region, especially facial arteries.

Subtraction CT

It is difficult to depict blood vessels closely adjacent to bone structures with a regular 3D-CTA. These include the maxillary tuberosity branch of the infraorbital artery, the posterior alveolar artery running in the posterior alveolar canal, and the zygomatic branch of the middle and deep temporal artery. The trouble is that each of these arteries often has a significant involvement in a tumor. A subtraction CTA can sometimes solve this problem. While suppressing body motion sufficiently, subtraction CTA combined with non-rigid registration or metal artifact reduction can also provide good imaging of arteries which are adjacent to the bones or running in the bones.

3D-CTA Reading

As a general rule, Multiplanar Reconstruction (MPR) images are used when reading 3D-CTA. Volume Rendering (VR) images are still insufficient in terms of spatial resolution and should be considered only as a supplementary image to get an overview of the major arteries and to intuitively understand the spatial position of the branches. The thickness of the axial section slices should be 0.6-1 mm. with a few exceptions, almost all of the vessels in which a 1.6F microcatheter can be placed can be identified in the image. If reconstruction to sagittal or coronal images is to be considered, the slice gap should be set even thinner than the slice thickness, 0.3-0.5 mm (anisotropic voxel). In this way, the quality of the reconstructed images is further improved. The items to be evaluated in advance in the 3D-CTA are as follows:

Sclerotic Changes in Carotid Arteries

The angle at which the common carotid arteries begin from the aortic arch and degree of tortuosity of the common carotid artery are evaluated, and the presence or absence of stenosis, wall irregularity, calcification, or plaque formation in the arteries is also examined. In particular, “shaggy aorta” with severe atherosclerosis in the aorta and unstable plaque at the origin of internal carotid artery should not be overlooked. The guiding catheter should be inserted as far away from the lesions as possible.

Anatomy of External Carotid Artery Branches

The analysis of arterial anatomy is intended to enable efficient and quick placement of microcatheters in the numerous branches of the external carotid artery, and should identify anatomical variations and the height and direction of branching origin. The anatomical variations include hyperplasia, hypoplasia, aplasia, duplication, aberrant origin, common trunk formation, direct origin from the main artery, and combinations of these. Specifically, for examples in the case of maxillary sinus cancer, the starting position of the facial artery (normal, higher, or common trunk formation), the complementary relationship between the facial and transverse facial arteries, and the abnormal starting position of ascending palatine artery are included. It is also important to confirm the directions in which each branch originates so that the C-arm can be rotated to the optimal angle during microcatheter guidance. When evaluating, branches that may not be related to the primary tumor should also be understood comprehensively. In addition to the anatomical information, the modification of the findings by the tumor should also be confirmed. For example, the presence or absence of stenosis or occlusion of the infraorbital artery due to the lesion, the presence or absence of stenosis of the third portion of internal maxillary artery in the pterygopalatine fossa, and the bilateral difference in the diameter of the ophthalmic artery.

Footnote: especially when there is an obvious dilation of the ophthalmic artery on the affected side and the tumor extends into the infraorbital or ethmoid sinus, eradication may be difficult and should be discussed with a head and neck surgeon as soon as possible.

Feeding Arteries

Since it is not possible to perform a comprehensive examination of every branch of the external carotid artery during the catheter placement procedure due to time constraints, it is necessary to list the arteries passively involved in the tumor and prioritize them for the procedure by preoperational examinations. The arteries reaching each tumor site can be identified by 3D-CTA, and the degree of involvement is predicted based on the length of the distance the artery contacts the tumor and the diameter of the artery. The same process should be performed for lymph node metastases. Arteries in which involvement was not clear from the preoperative images should also be recorded.

Dangerous Anastomosis

Examine for anastomoses of the internal maxillary artery, anterior deep temporal artery, and middle meningeal artery to the ophthalmic artery, abnormal development of the arteries of foramen rotundum and pterygoid canal, and anastomoses of the branches of occipital artery with vertebral artery.

Limitations of 3D-CTA

3D-CTA has some limitations. First, subbranches at the level where microcatheters cannot be placed will not be sufficiently depicted by 3D-CTA. These include the separation of the pharyngeal and auricular branches of the accessory meningeal artery, the pterygoid branch originating from the internal maxillary artery, the undilated inferior alveolar artery, and the posterior branch of the infraorbital artery. Although they do not require a selective placement, the information on the origin influences the decision of where to place the catheter in the parent vessel. Next, evaluation of areas overlapping with veins are difficult in 3D-CTA. Specifically, it may not be possible to accurately evaluate the subbranches of the internal maxillary artery that originate where it travels through the pterygoid plexus, or the gathering part of the superior laryngeal artery and vein. This can be overcome to some degree by strictly timing the arterial phases using the test injection method or the carefully configured bolus tracking method. Last, 3D-CTA is susceptible to interference from metal artifacts including dental crowns. This is often a serious obstacle when evaluating alveolar extension of maxillary sinus cancer and often prevents the evaluation of the terminal branches of the facial artery. This situation is being improved by metal artifact reduction techniques including SEMAR, but has not yet been completely resolved.