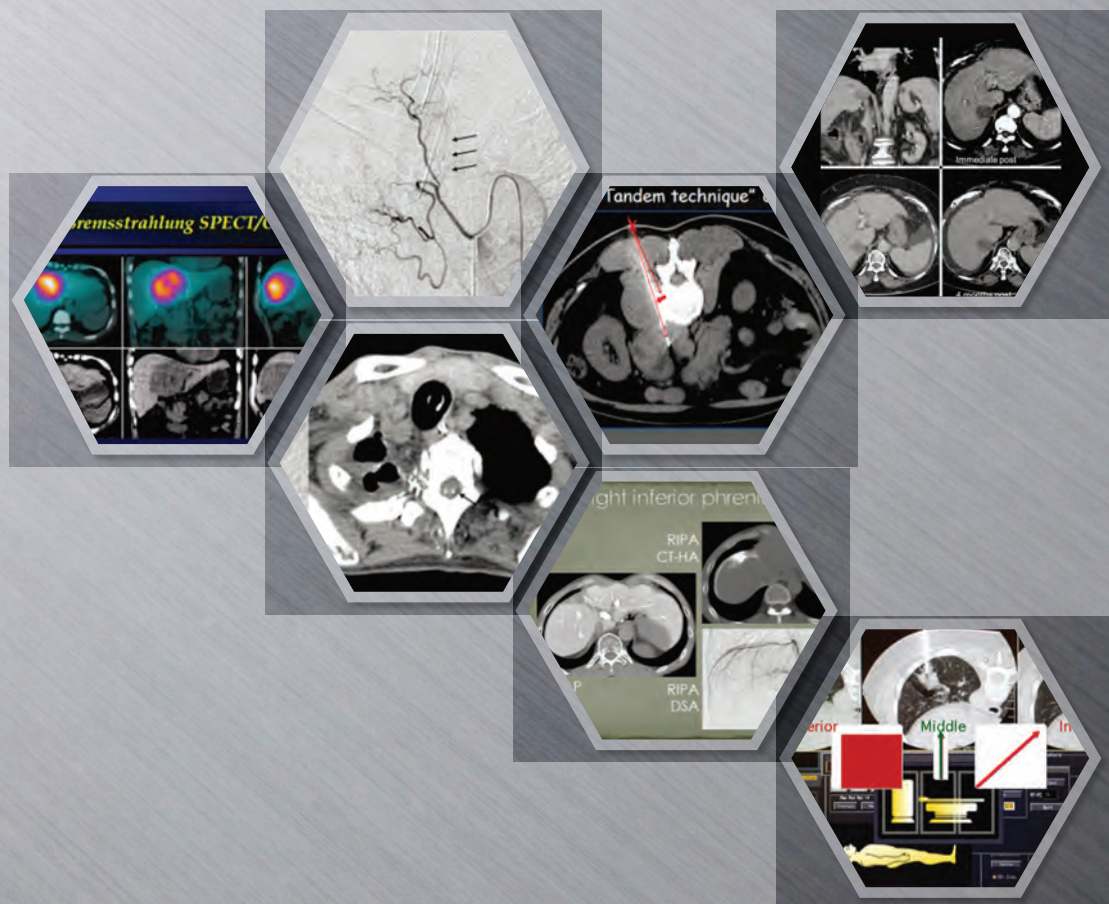




Singapore
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Interventional Radiology

Angio CT Studies Update 2013



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EDUCATIONAL SESSION REVIEW

Workshop: Interventional Radiology-CT Workshop 2013

Organised by: Interventional Radiology Centre, Department of Diagnostic Radiology, Singapore General Hospital

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Chair: Tan Bien Soo MD, Associate Professor, Department of Diagnostic Radiology, Singapore General Hospital

Speakers: Yasuaki Arai MD, Director of Hospital, Chief, Department of Diagnostic Radiology, National Cancer Center Hospital, Tokyo, Japan; Tay Kiang Hiong MD, Associate Professor, Department of Diagnostic Radiology, Singapore General Hospital; Farah Irani MD, Consultant, Department of Diagnostic Radiology, Singapore General Hospital; Miyuki Sone MD, Consultant, Department of Diagnostic Radiology, National Cancer Center Hospital, Tokyo, Japan; Apoorva Gogna MD, Associate Consultant, Department of Diagnostic Radiology, Singapore General Hospital; Mr Cornelio Padre, Senior Radiographer, Department of Diagnostic Radiology, Singapore General Hospital

Angio CT comprises an angiography system integrated with a CT scanner using a single patient table. The angiography system is equipped with the latest flat-panel detector system used for performing conventional angiography, and has additional capability for rotational DSA providing 3-dimensional angiographic images. The CT unit is a 16-slice multislice CT scanner which has additional CT fluoroscopic capability. The hybrid system is therefore capable of providing true intra-arterial CT angiography (IACTA) versus conventional CT angiography where contrast is administered intravenously. This integrated hybrid system has a unique advantage in performing angiography immediately after a CT scan without the need for patient transfer. The unit in the Department of Diagnostic Radiology, Singapore General Hospital was the first such system equipped with the latest platform installed in Asia outside of Japan (where it is termed Interventional Radiology Angio CT) and adds a whole new dimension to interventional radiology. This symposium discussed the routine and novel applications of this technology currently underway at the hospital.

Glossary of terms

AFP	alfafeto protein
Angio CT	angiography and CT
BCLC	Barcelona Clinic Liver Cancer staging and treatment strategy
CD-CTA	catheter-directed CT angiography
CR	complete response
CT	computed tomography
CTAP	CT arterial portography
CTHA	CT hepatic arteriography
DSA	digital subtraction angiography
EHS	extra-hepatic supply
GDA	gastroduodenal artery
HAIC	hepatic artery infusion chemotherapy
HCC	hepatocellular carcinoma
HFA	hepatic falciform artery
HCV	hepatitis C virus
IACTA	intra-arterial CT angiography
IPA	inferior phrenic artery
NASH	non-alcoholic steatohepatitis
PEA	parasitized extrahepatic artery
PET-CT	positron emission tomography-CT
RFA	radiofrequency ablation
SIRT	selective internal radiation therapy
SMA	superior mesenteric artery
SPECT	single-photon emission computed tomography
TACE	transcatheter arterial chemoembolization

20 years with Angio CT

**Yasuaki Arai MD, Director of Hospital, Chief, Department of Diagnostic Radiology,
National Cancer Center Hospital, Tokyo, Japan**

Background

In 1983, an article was published presenting a new diagnostic modality called CT arterial portography (CTAP) and CT hepatic arteriography (CTHA).¹

More accurate diagnoses for liver tumors could be obtained with this technique (Fig. 1), however the procedure required complex steps; we had to insert a catheter into superior mesenteric artery (SMA) or hepatic artery in the angio suite and then move the patient into the CT room for imaging. Angio CT was developed as a hybrid diagnostic system combining angiography and CT, so that it made CTAP/CTHA easier, faster and safer.

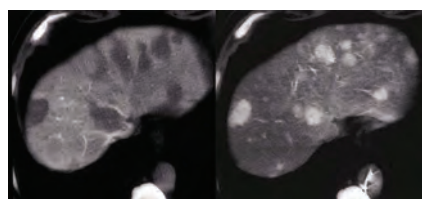


Figure 1. Defect of contrast at CTAP (left) and strong enhancement of tumor with CTHA (right).¹

More accurate treatment of liver cancer

Once we had the Angio CT, we found that it presented many opportunities to improve the treatment of our patients. Transcatheter arterial chemoembolization (TACE) is a procedure in which the blood supply to a tumor is blocked (embolized) following the administration of a chemotherapeutic agent into the artery supplying blood to the tumor. Angio CT can be used to detect the right feeder to a tumor, providing more accurate microcatheterization, and leading to successful TACE.

Angio CT has also helped us to evaluate drug distribution in hepatic artery infusion chemotherapy (HAIC).

In this example of a female patient with liver metastases from colorectal cancer, a year of treatment had shrunk all the tumors in her liver except for one new tumor, which occurred during treatment and had grown (Figure 2). It was unclear to us why drug distribution had failed to treat this specific tumor. We investigated the cause using Angio CT and found that this particular tumor had an extrahepatic blood supply. Based on this knowledge, we performed embolization of the right inferior phrenic artery with glue, then the chemotherapeutic agent could be delivered to the tumor.

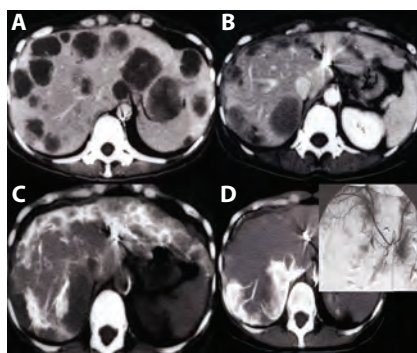


Figure 2. (A) A case of multiple liver metastases from colorectal cancer. (B) One tumor (arrow) was grown after a year of treatment. (C) CT-angiography via the indwelling catheter showed the tumor was not enhanced. (D) DSA and CT-angiography via the right inferior phrenic artery showed stains and enhancement.

Better understanding of the hemodynamics of the liver

Angio CT has also improved our understanding of the hemodynamics of the liver. In this example of a patient with HCC, blood flow to the tumor remained even though a balloon catheter was inflated in the feeding artery. Lipiodol also flowed

into the tumor and accumulated there despite the artery being blocked with the inflated balloon. We investigated further using Angio CT images under the infusion of contrast media via the micro-balloon catheter, and compared images of tissue enhancement with and without balloon occlusion (Fig. 3). This revealed that similar amounts of contrast medium were being delivered to the tumor in both cases, but less blood reached the normal liver tissue surrounding it when the balloon was inflated. With this phenomenon, we have hypothesized that this could be explained by differences in tissue pressure within the liver. Normal liver is supplied by the hepatic artery (high pressure) and the portal vein (low pressure) whereas the tumor is exclusively by the hepatic artery. Therefore, when we occluded the blood supply in the hepatic artery, pressure was higher in the normal parenchymal tissue than the tumor. When we infused the drug it reached the tumor first and then overflowed to the healthy liver tissue.

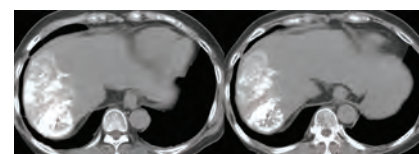


Figure 3. Under balloon inflation, enhancement of liver is shown weakly. CTA without balloon occlusion (left) and CTA with balloon occlusion (right)

Impact of Angio CT on survival

A unified CT system helps to improve survival of patients with liver cancer compared with conventional angiography alone. In a cohort of over 1,300 patients treated for HCC, the survival rate was higher in patients who underwent pretreatment ex-

amination using Angio CT than in those who underwent examination without it ($P < 0.0001$).² The survival rate was higher when focusing solely on patients with stage I HCC ($P = 0.0093$) or those who underwent TACE ($P = 0.0023$). Cone-beam CT also improved outcomes of patients undergoing ultrasensitive TACE as treatment for small HCC lesions that could not be demonstrated on angiography.³ Using this technology, 81.8% of cases were completely or adequately embolized.

Cost-benefit of cancer treatment

In the field of colorectal cancer treatment, the number of chemotherapy drugs and variety of formulations has increased since the introduction of 5-FU in the 1950s. During this period, the median survival time has lengthened from around 12 months in 1980

to the current prognosis of over 2 or even nearly 3 years according to some data. However, this must be weighed against the economic cost of providing cancer treatment, which has increased 100-fold since the 1950s. In the field of HCC treatment, the SHARP study demonstrated that sorafenib significantly improved median survival over placebo, but only by 2.8 months and at a financial cost of \$6000 per month.⁴ ASCO launched a "Cost of Cancer Care Task Force" in August 2007 to address the cost-benefit of therapies for oncology. Cost reduction is the most important global issue in medicine today.

Will the cost of Angio CT prevent its use in the future?

There is no doubt that Angio CT has increased the benefit of interventional radiology and could be an exceptionally valuable tool to all patients.

However, it will never become a standard treatment available to anyone in the world due to its high financial cost. If the cost could be reduced we could equalize this balance and make this brilliant technology more accessible.

In conclusion, Angio CT was originally developed to address safety concerns, and has improved many aspects of interventional radiology and expanded the field. It has become the standard procedure in some countries. If we are going to make Angio CT the global standard, we must put more effort into addressing the cost-benefit balance.

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Angio CT for Selective Internal Radiation Therapy

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Selective internal radiation therapy (SIRT) is a targeted treatment for inoperable liver tumors that delivers millions of radioactive microspheres directly to the cancerous tissue. Yttrium-90 (Y90) radiation is carried in glass or resin microspheres which are introduced into the hepatic arterial system via a transfemoral micro-catheter. At 32 microns the microspheres are small enough to pass through the hepatic arteries but lodge in the capillary bed within the tumor. Landmark trials have shown that SIRT can shrink tumors and improve survival.^{1,2}

Reducing risk of complications at Singapore General Hospital (SGH)

The most feared complication with SIRT is inadvertent damage to healthy tissue outside the liver, for instance causing radiation ulcers in the stomach and intestines due to non-target embolization of the radioactive spheres into branches of gastric arteries or the gastroduodenal artery (GDA). The hepatic and mesenteric

vascular anatomy is complex and variable, and the blood supply can be altered by prior surgical resection or TACE, and there may be extra-hepatic supply (EHS) to particularly large tumors.

To avoid deposition of Y90 spheres outside the liver, the 2006 Radio-embolization Brachytherapy Oncology Consortium guidelines recommend prophylactic coil embolization of extrahepatic arteries.⁴ Despite embolization

of up to 87% of GDA and bowel collaterals, the literature reports gastrointestinal ulceration in at least 4% of cases.⁵ The superior images that we can obtain using the hybrid Angio CT suite allow us to accurately map the hepatic and extrahepatic vasculature (Fig. 1), as well as to identify vessels that should be embolized to prevent non-target embolization of the radioactive spheres. This has helped us reduce unnecessary embolization (our coil embolization rate is

only 23%) and yet achieve good treatment outcomes with low complication rates.

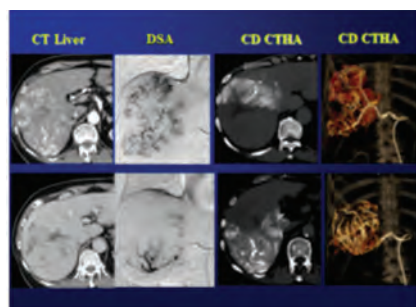


Figure 1. Catheter-directed CTHA provides valuable cross-sectional information in addition to 3D depiction of vascular anatomy

Another strategy that we have at SGH is the use of CTHA images in conjunction with SPECT/CT for dosimetry calculations that are personalized to each patient. The methodology allows accurate determination of doses to be delivered to the tumor to maximise tumor kill and minimize injury to healthy liver.⁶ Overall, these strategies reduce the need for embolization and lead to accurate delivery of the right amount of radioactivity (Fig. 2).

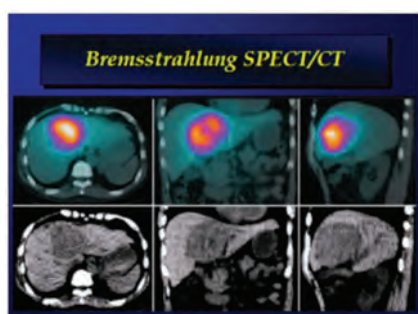


Figure 2. Bremsstrahlung SPECT/CT image showing successful delivery of radioactivity concentrated in the tumor with no leakage outside the liver

Improving detection of falciform artery

The hepatic falciform artery (HFA) is an occasional terminal branch of the left or middle hepatic artery. In patients with this anatomy, non-target radiation injury can occur along the anterior abdominal wall causing

skin rash, epigastric pain and skin necrosis. Prophylactic coiling of the HFA is generally recommended but it can be difficult to detect. Our data have shown that intra-arterial CTHA using Angio CT is superior to DSA and 99mTc-MAA SPECT/CT (52.3% versus 11.9% and 13.3%, respectively, $p < 0.0001$) for the detection of HFA (Fig. 3).⁷

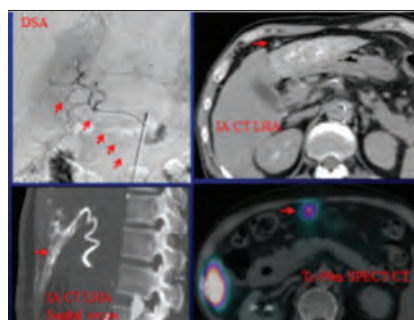


Figure 3. Example of HFA on selective DSA (top left). CTHA (top right, bottom left) and 99mTc-MAA SPECT/CT (bottom right).

Radioembolization into inferior phrenic artery (IPA) is feasible and safe

Up to 30% of patients with HCC may have tumor blood supply through parasitized extrahepatic arteries (PEAs) and in most cases the artery involved is the IPA. Radioembolization through PEAs is generally considered to be contraindicated because of the high risk of non-target embolization. In a retrospective analysis of 108 patients, we showed that radioembolization through the right IPA is feasible and safe with the use of CD CTA in addition to DSA and SPECT/CT (Fig. 4).⁸

Improved survival time with personalized dosimetry

In a recent abstract submitted to ASCO 2013, we have analyzed tumor response and overall survival patterns among our patients.⁹ Among 103 patients, we found a target lesion response rate of 98.3% with an overall disease control rate

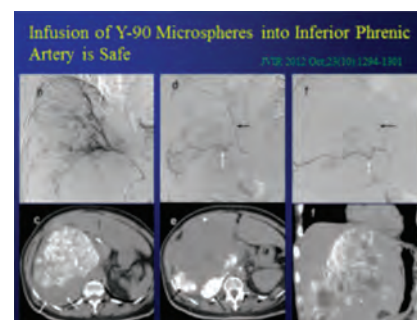


Figure 4. IA CTA images show blood supply to a large tumor from right hepatic artery and IPA

of 64.7%. In the majority of cases (69.2%), progression was due to new lesions. Patients with intermediate HCC (BCLC B) survived for 23.8 months compared with 17.2 and 16.9 months by in Western studies.^{1,2} Those with advanced disease (BCLC C) survived for 13.6 months compared with 7.3 and 10.0 with Western studies.

In summary, Angio CT is an invaluable tool when carrying out SIRT. It allows us to deliver the right amount of radioactivity very accurately, thereby increasing effectiveness and decreasing complications. It decreases unnecessary embolization of extrahepatic vessels and therefore reduce procedure time. It is also superior to either DSA or SPECT-CT in detecting the HFA and makes it feasible and safe to radioembolize tumors supplied by the IPA.

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Mesenteric and bronchial embolization

Farah G Irani MD, Consultant, Department of Diagnostic Radiology, Singapore General Hospital

Catheter-directed intra-arterial CT angiography (IAC TA) is an impressive technological achievement, but is it truly a valuable tool or an expensive gimmick? In our practise we have used the hybrid suite (IAC TA) during mesenteric and bronchial embolization procedures and have reviewed how much value it adds over the gold-standard DSA treatment. Cases studies where both techniques have been used during the same procedure allowed comparison of their usefulness.

IAC TA in bronchial artery embolization (BAE)

Hemoptysis is the coughing up of blood from the respiratory tract below the level of the larynx. Massive hemoptysis is loss of >300 mL/day and is life-threatening due to the risk of asphyxiation rather than hypovolemia. In the large majority of cases the source of bleeding is the high pressure bronchial circulation, but occasionally can be the pulmonary arterial circulation. It can be caused by a variety of different conditions including pulmonary tuberculosis, pneumonia, lung abscess, bronchiectasis, chronic inflammatory lung diseases, chronic bronchitis, cystic fibrosis, lung cancer, trauma, or an aneurysm. Conservative management of patients with massive hemoptysis is associated with a mortality rate of 50 to 100%. The reported mortality rates for surgery performed for massive hemoptysis range from 7 to 18%, but this increases to 40% in the emergency setting.¹

Bronchial artery embolization (BAE) has become an established non-surgical procedure in the management of massive and recurrent hemoptysis since it was first described in 1973.² It is the selective embolization of the hypertrophied bronchial arteries supplying abnormal lung parenchyma using embolic material delivered via a catheter. The bronchial arteries can give rise to spinal arteries and, thus, it is vital to correctly identify the anatomy of the bronchial vasculature to avoid embolization of the spinal arteries. Although rare, occurring in 2 to 4% of

patients who undergo the procedure, spinal cord ischemia is the most feared complication of treatment since it can result in paraplegia.

We carried out a retrospective review of eight patients with a history of tuberculosis (except one with bronchiectasis), who were referred for BAE in whom both DSA and IAC TA were performed to look for spinal arteries. In one patient, the spinal artery was clearly visible on the DSA and it was confirmed on IAC TA by the presence of spinal cord enhancement. In two patients, using DSA alone, it was unclear if there was a spinal artery, but IAC TA confirmed cord supply (Fig. 1), resulting in more superselective embolization of the bronchial vessel avoiding the spinal artery. In the remaining five patients no supply to the cord was detected on IAC TA or DSA.

Thus using IAC TA, we were able to accurately determine the presence of spinal arteries in three of our eight cases and confirm their absence in the remaining five.

To us, IAC TA proved invaluable; in detecting the presence or absence of

spinal arteries and thus avoiding non target embolization. Hence, using both techniques together increases the interventionalist's confidence and ability to perform bronchial artery embolization safely and accurately.

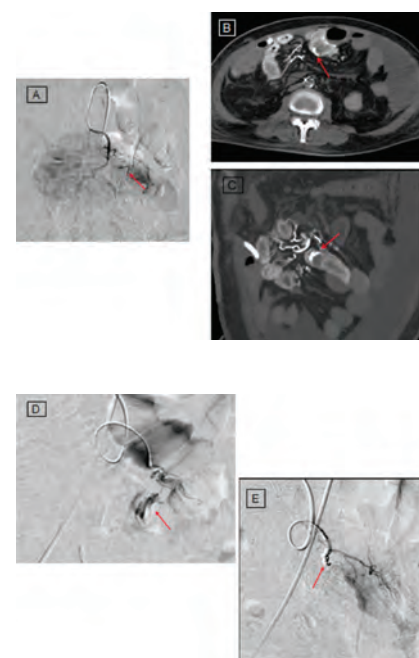


Figure 2. Case 1: 58-year-old male patient presented with melena and IV mesenteric CTA showed bleeding within a jejunal loop. (A) On selective angiogram of a jejunal branch it was not possible to be sure of bleed from a tiny distal branch due to motion artifact from peristalsis. (B) IAC TA in this branch showed active contrast extravasation from a small distal branch, which was traced back to the parent artery on coronal reformatted images (C). Further super selective catheterization of this tiny branch showed the bleed conclusively (D) which was coil embolized successfully (E) with no further extravasation.

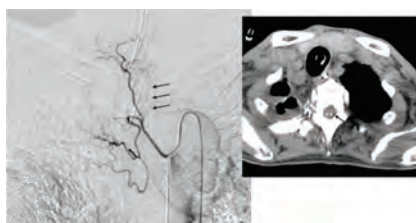


Figure 1. Faint artery visible with DSA (black arrows) is confirmed as a spinal artery because of enhancement within the posterior portion of the cord, as seen on IAC TA (right)

IACTA in mesenteric embolization

Bleeding from the gastrointestinal tract is a major cause of morbidity and mortality in hospitalized elderly patients. Currently DSA is considered the gold standard in managing these patients because it is both diagnostic and therapeutic. We performed a retrospective review of 34 procedures in 31 patients to see whether combining

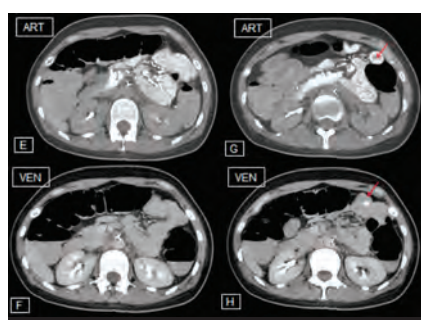
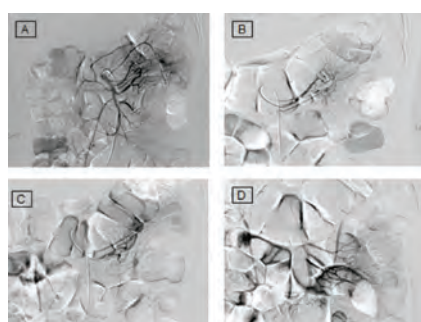


Figure 3. Case 2: 28-year-old female presented with massive gastrointestinal bleeding and hemodynamic instability. Mesenteric IV CTA showed focal enhancement of contrast in the jejunum loop during the arterial phase, which persisted in the venous phase. DSA in multiple branches of the superior mesenteric artery (A,B,C,D) failed to identify the source of bleeding. IACTA showed normal jejunal loop on the left (E,F) and abnormal thickened loop of proximal jejunum with small round focal area of contrast enhancement on arterial phase (G) which persisted into the venous phase without diffusing (H) raising the possibility of an aneurysm or vascular malformation. The patient went to surgery where a small loop of abnormal jejunum was resected with a histology diagnosis of a cirroid aneurysm.

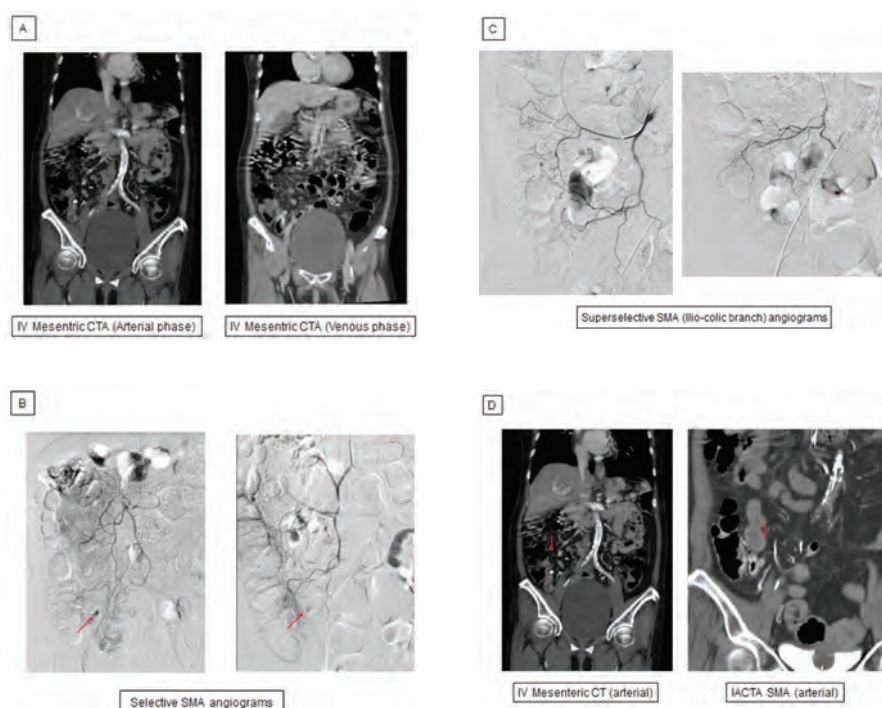


Figure 4. Case 3: 69-year-old female patient presented with malena and IV mesenteric CTA showed a bleeding diverticulum in the ileo-colic region (A). Due to her co-morbidities she was a very poor surgical candidate and was hence referred for embolization. On the selective SMA runs the bleeding diverticulum was identified (B), but on super-selective catheterization of the branch arteries for embolization no bleeding or abnormality could be identified (C). IACTA from the SMA showed no abnormal enhancement or active contrast extravasation in the ileo colic region confirming spontaneous cessation of bleeding on table (D). The procedure was terminated and the patient did not have any recurrence.

IACTA with DSA improved our ability to identify the region of bleed and the bleeding vessel over DSA alone. Here we present three case studies illustrating the role of IACTA in mesenteric embolization.

Overall, IACTA was statistically superior in the detection of regional bleed compared with DSA ($p=0.031$). There was also a positive trend for detecting the bleeding vessel on IACTA ($p=0.25$). It was particularly helpful in detecting bleeds in the jejunum. It allowed for better anatomical delineation as there was minimal image degradation from respiratory or peristaltic motion artefacts which often distorts the DSA. Further, it allowed for confident and accurate embolization and helped avoid non target embolization. A negative IACTA

improved the operator's confidence in determining no active bleed and terminating the procedure. Therefore, the combination of IACTA with DSA adds great value in the context of mesenteric embolization by improving the safety and precision of the procedure.

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The change of IR techniques on Angio CT

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Historically, we interventional radiologists have performed procedures with the help of two-dimensional images obtained by X-ray fluoroscopy, which is sufficient in most cases. However, some cases may need more information to detect the lesion, such as for needle puncture. A three-dimensional image is helpful to confirm the location accurately, however we should consider if we really need such information for treatment. For example, in the puncture needle procedure, we might detect the target by feeling the resistance of the needle inserting into a tumor, or by using aspiration of fluid collection. We shouldn't rely on three-dimensional images too much. The advantage of Angio CT is we can use both X-ray fluoroscopy and CT depending on what we need on a case-by-case basis.

Needle puncture tandem technique

Needle puncture to the target lesion is sometimes difficult because it moves with a patient's breathing. If there is a coordinate in a patient's body on images, it makes the accurate detection and puncture of the target much easier. The tandem technique makes such a coordinate in a patient's body, suggesting the location of the target lesion. We insert a 20-22G needle as a coordinate near the target, followed by the subsequent insertion of a treatment needle, either in parallel or at an angle to the first needle, leading to the exact target. In the example shown, we have used the tandem technique to position a cryogenic needle in exactly the right location to treat a renal tumor (Fig. 1).

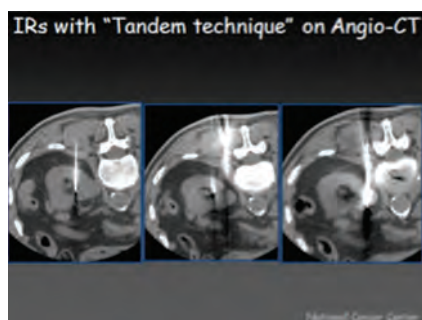


Figure 1. Angio CT showing insertion of fine needle into a renal tumor (left) to guide subsequent parallel insertion of cryogenic needle (middle) exactly to target (right)

A variation on this technique has the same principle, but without inserting a guide needle. Instead, it uses the known position of a bone to orientate the biopsy needle. In the example shown, we inserted a biopsy needle to deliberately touch bone and then adjusted the direction along the bone by the smallest angle of the needle to the target tissue beyond (Fig. 2).

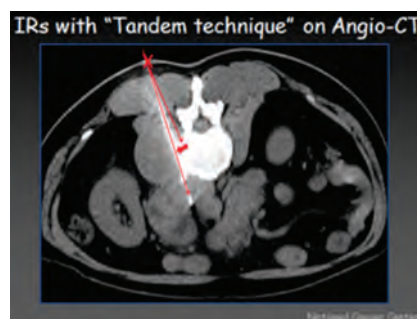


Figure 2. CT image of insertion of biopsy needle using bone instead of a guide needle to calculate coordinates in the tandem technique principle

Combination of CT and X-ray fluoroscopy images

There are many situations where CT and X-ray fluoroscopy used together can improve patient outcomes. Examples discussed here are: radiofrequency ablation (RFA); endoprosthesis of intractable liver abscess; post-operative massive ascites; and cryogenic ablation with intra-arterial lipiodol administration.

Using both images combined, we can do a difficult RFA such as when a liver tumor lies adjacent to the stomach. Inserting a balloon catheter between the tumor and stomach, then inflating to push the stomach and liver further apart, we are able to ablate tumors without heat damage to stomach (Fig. 3).

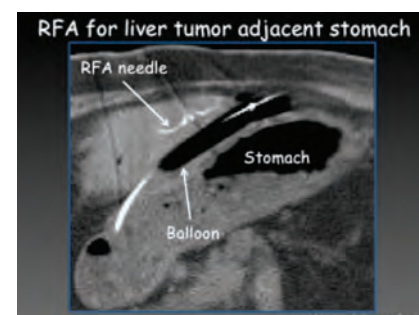


Figure 3. Tandem technique to inflate balloon catheter between liver tumor and stomach to prevent heat injury during RFA

Although the drainage of a liver abscess is usually a straightforward procedure, it is sometimes hard to remove the drainage tube due to recurrent fever and sepsis after clamp of the drainage tube. When we confirmed a communication between the abscess cavity and a small biliary duct under the injection of contrast media into the abscess cavity, there was a stenosis between the small biliary duct and the posterior hepatic duct. We punctured the posterior biliary duct through the abscess cavity, and then placed a stent there with CT and fluoroscopic images.

After the procedure the contrast media injected into the abscess cavity flowed smoothly into the posterior biliary duct, and we finally could remove the drainage tube. (Fig. 4).

The injection of OK-432 into an intra-peritoneal localized region is sometimes effective for postoperative lymphatic intractable ascites. But, it should be injected exactly around the leakage point of lymphatic fluid. We repeated percutaneous catheter insertions and injections of OK-432 into the target point, and finally the ascites disappeared.

In a patient with a large renal tumor, we administered lipiodol during an angiography. Subsequently,

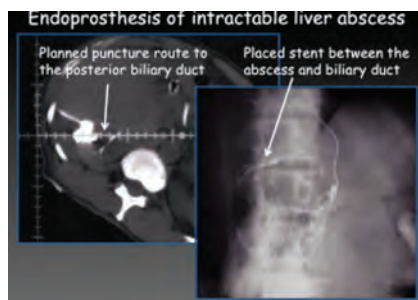


Figure 4. Endoprosthesis between the abscess cavity and the posterior biliary duct. A stent is placed percutaneously between abscess cavity and the posterior biliary duct.

we punctured the tumor with four cryogenic needles under fluoroscopy, each time checking the final position with CT (Fig. 5).

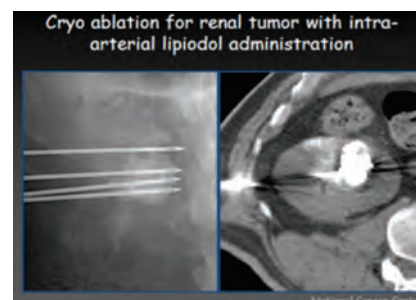


Figure 5. Insertion of four cryogenic needles into a renal tumor (left) led to accurate cryogenic treatment (right)

In conclusion, using the hybrid Angio CT, our interventional radiology technique has improved. Further experience will continue to refine our techniques and help to discover new applications with this technology.

Routine procedure of TACE with Angio CT

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Transcatheter arterial chemoembolization (TACE) with Angio CT is a powerful tool for obtaining images for the treatment of hepatocellular carcinoma (HCC).

Angio CT facilities at NCC

At the National Cancer Center (NCC) in Tokyo, we have the facilities, resources and personnel to perform TACE with Angio CT as a routine procedure in the diagnosis and treatment of patients with HCC. A team of eight interventional radiologists, four radiographers and four nurses have access to three angio suites, including two Toshiba Angio CT suites (Fig. 1). Of the 3,858 patients who underwent interventional



Figure 1. Interventional radiology suite at NCC

radiology (IR) procedures at NCC in 2012, 11% were for the vascular IR for hepatic malignancies.

Asian Standard TACE for HCC patients at NCC

HCC is the fourth most commonly occurring cancer in Japan and accounts for over 40,000 deaths every year. In the majority of cases (80%), it is related to infection by hepatitis C virus (HCV). Treatment recommendations for HCC are based on the extent of liver damage and the quantity and size of the tumors. At NCC we make treatment decisions in a weekly multidisciplinary conference primarily based on the 2009 Japanese Guidelines for the treatment of early- and intermediate-stage HCC patients. These guidelines recommend TACE in patients who have stage A/B liver damage caused by multiple tumors (≥ 4) or a small number of large tumors (≥ 3 cm). Across Japan, TACE is

used in approximately a third of HCC patients, with surgery and ablation also accounting for a third each (according to National Surveillance data for 2004/2005).

In our practice, we adopt the Asian Standard superselective TACE as follows. After we have carried out an initial CT scan, we insert a 5F sheath and catheter into the femoral artery under local anesthetic and conscious sedation. First, we perform CT during arterial portography (CT-AP) by placing the catheter at the superior mesenteric artery and using a dilute contrast material (370 mg/L, x3 dilution) along with prostaglandin E1 to detect HCC through the absence of portal vein blood flow (Fig. 2A). Next, we insert a catheter or microcatheter at the celiac trunk, common or proper hepatic artery to perform digital subtraction angiography (DSA) (Fig. 2B) and CT during hepatic arteriography (CT-HA) (Fig. 2C). DSA allows us to anatomically map the

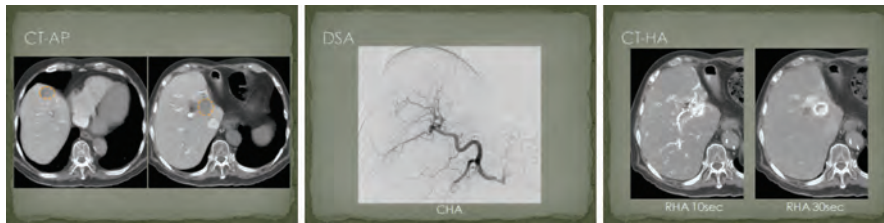


Figure 2. Imaging carried out as per Asian Standard in TACE for HCC: (A) CTAP, (B) DSA and (C) CTHA

tumor while CT-HA is necessary to confirm the arterial blood flow in the tumor comparing to the image from CT-AP.

The final procedure is chemo-embolization using an EPI+lipiodol mixture with gelatin sponge to block the feeding arteries. In this process the EPI and lipiodol is mixed manually by agitating with two syringes and a three-way stopcock to create an emulsion (Fig. 3A). Gelatin sponge is used as the embolic material and this can be obtained commercially in Japan as spherical, 1mm in

diameter, ready-to-use particles in a vial (Fig. 3B). Cut cubic particles (1 mm) prepared from a sheet gelatin sponge are also used. Embolization endpoint is the disappearance of the tumor staining and stasis in feeding arteries. After all of these procedures are complete, we can immediately check the treated area using CT. In case accumulation is incomplete, additional DSA and CTA is performed to seek feeding arteries toward the deficient area. These techniques allow us to visualize the HCC tumor and the blood vessels that supply it,



Figure 3. Preparation of materials for chemoembolization: (A) mixing EPI and lipiodol (B) cutting gelatin sponge or use bottled one

and to minimize the embolized area in normal liver parenchyma. Since treatment is repeated as necessary with progression of the tumor, it is known as “on-demand TACE”.

TACE to identify extrahepatic blood supply (EHS)

It has been reported that in 17% of HCC cases, tumors are supplied by vessels outside the liver (extrahepatic supply, EHS).¹ This can occur if the tumor is particularly large, is located in a subcapsular/bare area, or if growth is exophytic. EHS can also be a consequence of surgery or repeated TACE. In the example shown in Figure 4, we used CT-AP and CT-HA to identify an EHS, in this case from the right IPA. This is invaluable information in selecting appropriate treatment.

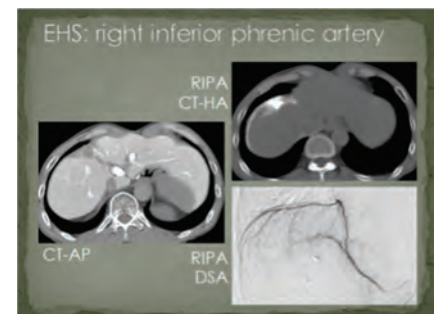


Figure 4. EHS from the right inferior phrenic artery

Angio CT for miscellaneous cases: complex RFA, drainages

Apoorva Gogna MD, Associate Consultant, Department of Diagnostic Radiology, Singapore General Hospital

The most common applications of Angio CT in our center are trans-arterial chemo-embolization (TACE) and mesenteric artery and bronchial artery embolizations. However, in selected cases, we also have found Angio CT to be very useful in difficult radiofrequency ablations (RFA), complex drainages, complex arterial embolization, portal vein embolization, aortic endoleak localization, renal tumor embolization, and imaging of mesenteric veins or pulmonary arteries. I will discuss some of these examples below.

Complex radiofrequency ablations

Case 1: A 79-year-old female patient with non-alcoholic steatohepatitis

(NASH) and hepatitis B related cirrhosis presented with a 2.8 cm hepatocellular carcinoma (HCC) in hepatic segment 4B. She was referred for RFA as she was not a surgical candidate.

However, imaging revealed a large recanalized umbilical vein adjacent to the tumor (Fig. 1), which we felt would significantly increase her risk of local recurrence due to heat sink effect.

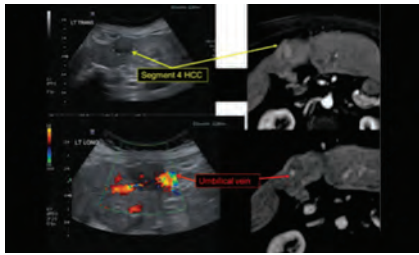


Figure 1.

Under ultrasound and Angio CT guidance, the recanalized umbilical vein was punctured directly, and coil embolization performed to occlude the vein (Fig. 2). Then, an uneventful RFA of the tumor was performed. Follow up MRI at 7 months, and ultrasound at 12 months, showed a decrease in size of the ablation cavity without any residual enhancement (Fig. 3), consistent with complete response (CR). target embolization. Hence, using both techniques together increases the interventionalist's confidence and ability to perform bronchial artery embolization safely and accurately.

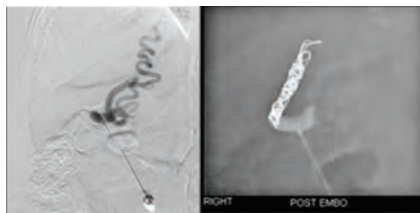


Figure 2.

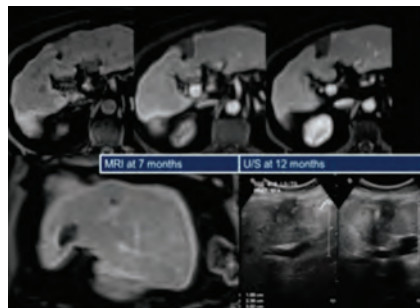


Figure 3.

Case 2: A 62-year-old male patient with history of nasopharyngeal carcinoma (in remission post radiotherapy) presented with a new incidental 2.5 cm HCC on routine PET-CT follow up imaging (Fig. 4). The patient refused surgery, and was referred for RFA. However, as the tumor was abutting the right portal vein, there was a

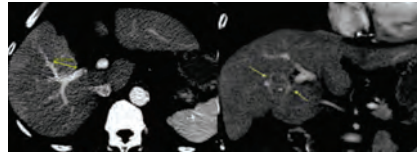


Figure 4.

significant risk of local recurrence due to heat sink effect. A peripheral segment 5 portal vein branch was punctured under ultrasound guidance, and a vascular sheath inserted into the vein under fluoroscopy (Fig. 5). Then, a 5.5 French Fogarty catheter was advanced into the portal vein, and inflated to occlude the portal vein flow. RFA of the tumor was then performed for 12 minutes, with intermittent deflation of the balloon and saline flushing to prevent portal vein thrombosis. Post ablation, the sheath was removed, and the hepatic tract embolized with coils to prevent bleeding. Follow up imaging at 12 months (Fig. 5) showed CR.

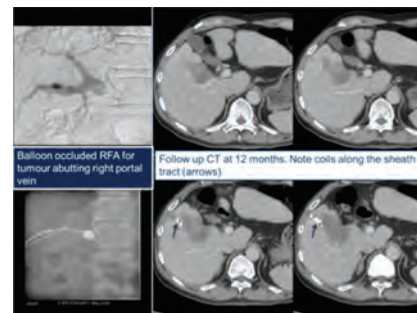


Figure 5.

Case 3: A 77-year-old female patient with child's A NASH-related cirrhosis, portal hypertension and previous upper GI bleed presented with two HCCs in the right lobe – a 1.9 cm lesion in segment 7 abutting the inferior vena cava (IVC) and a 3.7 cm lesion in segment 8 (Fig. 6). Using Angio CT guidance, a Coda balloon was advanced into the IVC via a right femoral approach, and inflated to occlude the IVC intermittently during RFA of the 1.9 cm tumor (Fig. 7). Also, a three-probe RFA of the larger lesion was performed using a switchbox controller (not shown). At 4 months we found CR of the smaller lesion abutting the IVC (Fig. 8), but partial

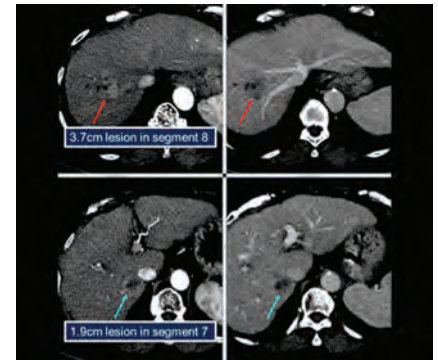


Figure 6.

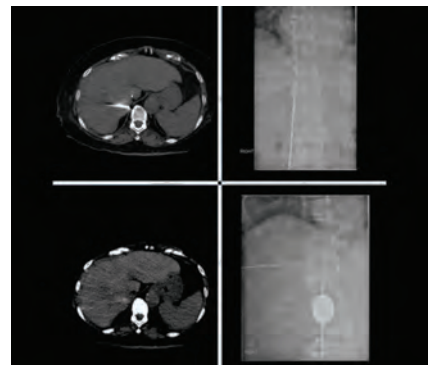


Figure 7.

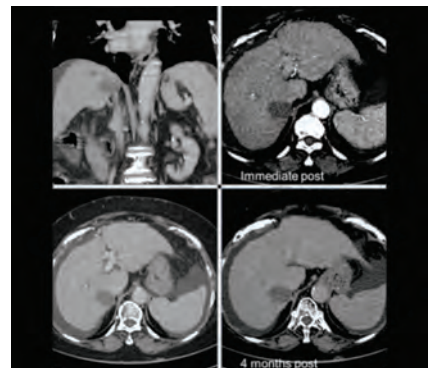


Figure 8.

response (PR) of the larger tumor, due to a small residual component. This was successfully ablated with one further RFA session resulting in CR for both lesions.

The protective effect due to convective cooling (i.e. preventing adequate tumor ablation) caused by large vessels abutting tumors (called "heat-sink effect") is well described in the literature. A study by de Baere and colleagues¹ reported the impact of temporary percutaneous balloon occlusion on the outcome of RFA in tumors that abut large vessels.¹ They divided the patients into four groups: large tumors (defined as greater than 3.5 cm) abutting large vessels

(defined as hepatic or portal vein branches with diameter greater than or equal to 4 mm), small tumors abutting large vessels, large tumors without abutting vessels and small tumors without abutting vessels. They found that for both small and large tumors abutting large vessels, balloon occlusion RFA negated the heat sink effect of the vessels, resulting in recurrence rates similar to those of lesions where no adjacent vessel was present. However, large lesions continued to have significantly higher local recurrence rates compared to small lesions.

Complex drainages

In the majority of drainages, a single imaging modality is sufficient but in certain cases e.g. with narrow therapeutic window and adjacent vital structures, it is helpful to have CT combined with fluoroscopy to facilitate access and drain placement.

Case 4: A 65-year-old female patient presented with sepsis two weeks after a Whipple operation for invasive gallbladder adenocarcinoma. High drain fluid amylase levels suggested the presence of a pancreatic leak. CT imaging showed an abscess in the gallbladder fossa, tracking posteriorly along the portal vein (Fig. 9). There was a very narrow window for percutaneous drainage due to the adjacent hepatic margin and duodenum, as well as multiple omental vessels. Under ultrasound and CT guidance, a 21G needle was inserted into the collection (Fig. 10). We then switched

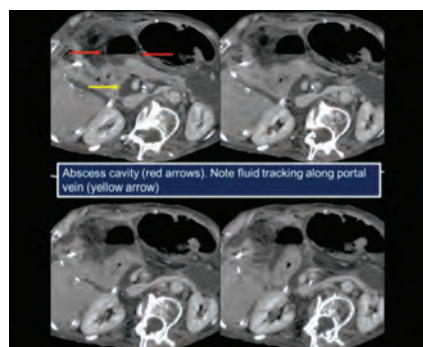


Figure 9.

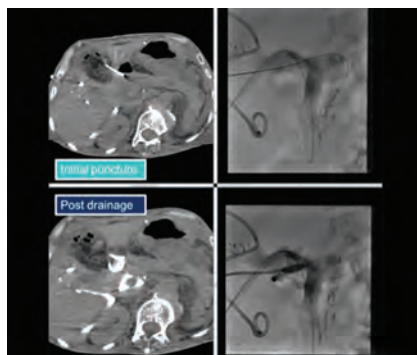


Figure 10.

to fluoroscopy, and localized the cavity with contrast injection. After serial dilatation, a drainage catheter was inserted into the collection under fluoroscopic guidance and the fluid was evacuated. Then, an immediate completion CT was performed on table (Fig. 10) to confirm complete abscess evacuation (including the fluid around the portal vein), good drain position, and exclude complications. The patient went on to recovery and discharge.

Complex splenic artery pseudo aneurysm embolization

Case 5: A 60-year-old immunocompromised female patient with history of rheumatoid arthritis developed necrotizing pancreatitis with severe sepsis. Following laparotomy and necrosectomy, she presented on the 10th postoperative day with heavily blood stained drain output. CT suggested a small pseudoaneurysm of the splenic artery. Digital subtraction angiography (DSA) showed the aneurysm, but the respiratory artefacts made it very difficult to visualize the small arterial feeders to this aneurysm. While we considered main splenic artery embolization or covered stenting, Angio CT was performed demonstrating the feeders to the aneurysm elegantly (Fig. 11). The microcatheter was advanced to the ostium of the small feeders and Lipiodol was injected to opacify the aneurysm. Then, the aneurysm was directly punctured under CT

guidance (Fig. 12), and injected with glue, resulting in successful control of bleeding.

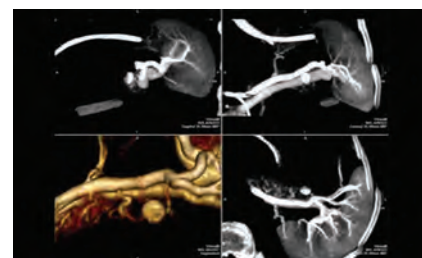


Figure 11.

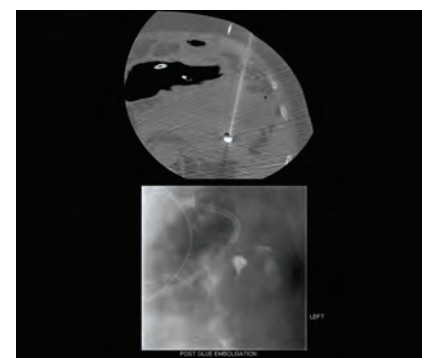


Figure 12.

Portal vein embolization

Case 6: A 67-year-old female patient with hilar type II cholangiocarcinoma was referred for portal vein embolization of the right lobe and segment 4 to facilitate hypertrophy of the left hepatic future liver remnant, prior to an extended right hemihepatectomy. In addition to DSA, the Angio CT provided much greater diagnostic confidence in identifying the small segment 4A branch (Fig. 13) which was then safely embolized (in addition to the rest of the right lobe). The patient went on to have a successful resection.

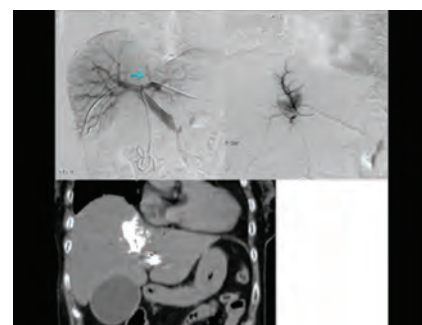


Figure 13.

Mesenteric vein imaging

Case 7: A 54-year-old male patient with history of alcohol abuse and superior mesenteric vein thrombosis presented with acute recurrent small bowel hemorrhage. Intravenous contrast enhanced CT was initially performed, again showing superior mesenteric vein thrombosis and multiple mesenteric venous collaterals. As part of his diagnostic workup and intervention, Angio CT was performed via direct injection into the superior mesenteric artery (SMA). The images (Fig. 14) show the significantly improved anatomic detail of the mesenteric vessels obtained via direct catheter injection of the SMA.

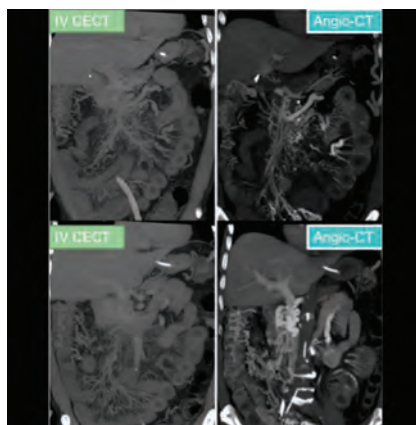


Figure 14.

In conclusion, the combination of CT and fluoroscopy in the same angiography suite has several advantages over single imaging systems

where patients otherwise have to be physically moved between rooms. Potential applications include clarification of anatomy, facilitation of complex interventions, increased operator confidence and improved patient safety. We must not forget however, that these imaging procedures so add to patient and operator radiation dose, and ALARA principles must always be observed when deciding appropriate treatment.

References

1. de Baere et al. Radiology 2008;248:1056–1066

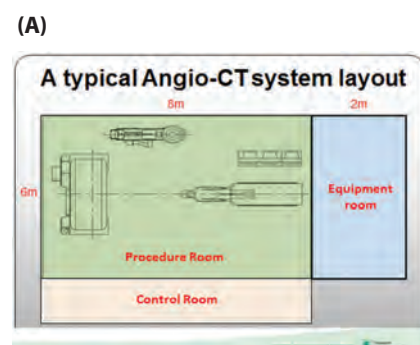
Physics and technical aspects of Angio CT

Mr Cornelio Padre , Senior Radiographer, Department of Diagnostic Radiology, Singapore General Hospital

Careful consideration and planning should be performed before setting up an Angio CT suite, to make sure that it will provide facilities that will fulfil your needs. Will the system be easy to use? Will the radiation dose be within acceptable limits? Will you achieve a high level of accuracy? Is intervention the primary purpose of the system or will you use it for diagnostic imaging as well?

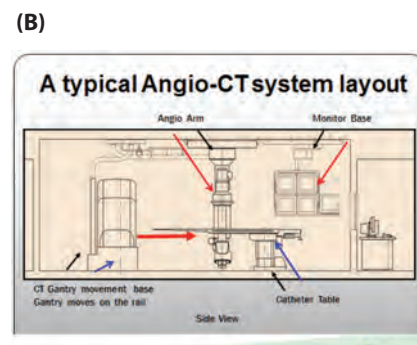
Guide to setting up an Angio CT suite

To install a system you will need to identify a space at least 8 m by 6 m for the CT gantry, C-arm, table and monitors. You should also allow a further 2 m for the equipment in an adjacent room. The figure shows the typical layout for an Angio CT suite (Fig. 1).



Key features of the angiography system

We installed this system at SGH in 2008 and it has a number of key features that make it a highly accurate and efficient system. Firstly, the C-arm is ceiling-suspended so it can move laterally making it easier to perform fluoroscopy during transradial intervention. Ceiling suspension



also keeps the floor clear of obstacles, which can be critical in an emergency situation, in terms of safety and ease of movement in the room. The C-arm can rotate at a speed of 30 degrees per second, which helps to keep examination time to a minimum. Secondly, the flat panel detector (30 cm x 40 cm) is suitable for imaging the abdomino-pelvic, thoracic, head and peripheral regions (Fig. 2).

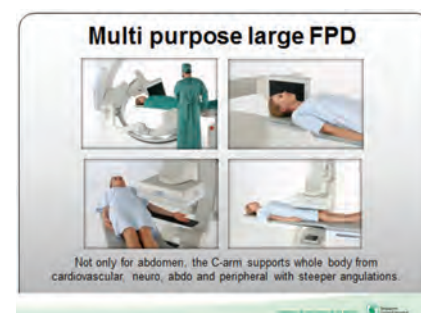


Figure 2. Versatility of the flat panel detector

Figure 1. Typical layout of an Angio CT suite showing floor plan (A) and side view (B)

Another key feature of the system is its digital processing power. While one is performing an interventional procedure, the system can play back information from the diagnostic examination in parallel. The automation in the system facilitates routine examinations by automatically setting the C-arm rotation, exposure settings and display. In addition, when the C-arm returns to a position that has already been used for a given patient, it will automatically display any previous images. Similarly, on selecting a previous image, the C-arm can automatically move to the exact position of image acquisition.

Another important consideration is radiation safety. The system has several built-in features to help minimize exposure to radiation during fluoroscopy. The live zoom function allows one to magnify the fluoroscopic image up to 2.4 times without any additional radiation dose to patient and operator. The grid controlled X-ray tube and virtual collimation software are other dose saving features. Collimation, in this instance, is the process of restricting the detection of emitted radiation to a given area of interest. Finally, the use of X-ray beam hardening filters helps cut out radiation which is absorbed by the body or scattered around the room.

Key features of the CT system

The CT equipment is a 16-slice self-propelled multi-slice CT system with a gantry aperture of 720 mm and a scan range of 1100 mm. It allows one to perform real time multi-slice CT fluoroscopy (Fig. 3). In a manner similar to the automatic positioning features of the angio C-arm, the CT gantry can be programmed in the same way. If the operator pre-enters the coordinates at the tableside control console, then the C-arm, CT gantry and table height will move

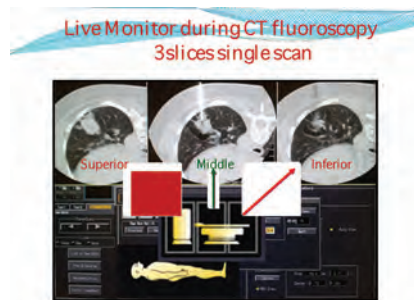


Figure 3. CT guided biopsy of the left lung nodule.

automatically. Sensors within the C-arm and CT gantry automatically restrict movement within safe areas to prevent any collision between the two systems. An issue with many CT suites is image distortion during helical scanning, caused by slight bending of the table as the patient passes through the scanner. This image distortion is avoided with the system since it is the gantry that moves during scanning rather than the tabletop.

Intra-arterial CT Angiography (IA CTA) in the Angio CT suite

Since 2008, one of the main applications of our Angio CT suite has been in performing IA CTA. This is the acquisition of CT images whilst directly injecting contrast media into the blood vessel via a catheter. IA-CTA is an additional imaging technique that supplements conventional Digital Subtraction Angiography (DSA) to improve the accuracy and efficiency of interventional procedures (Fig. 4). Although there are many factors that can affect the quality of an IA CTA procedure, such as the vascular anatomy, catheter positioning, contrast medium used and scanning technique, we believe that the most important aspect is to carry out an accurate review of the acquired images. Since catheter shift or movement is unavoidable during the injection of contrast media, it is

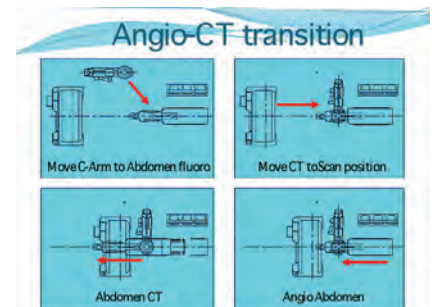


Figure 4. Angio CT transition during alternate DSA and IA-CTA image acquisitions.

crucial to closely compare its position between the DSA and the CTA images (Fig. 5). It is the DSA image that we rely on as a reference prior to IA-CTA. Furthermore, it is important to make the best use of the workstation for multi-planar and maximum-intensity projection reconstructions to create three-dimensional images for evaluation. Although this can be time-consuming, it is the only way to confirm and justify the reliability and usefulness of IA-CTA, and thus identify any technical error that occurred during image acquisition.

In conclusion, Angio CT is a very unique system and it requires careful planning of both layout and configuration before installation to optimize its clinical application. Once a system is functional, the team must receive adequate training so that everyone understands its role in the interventional case workflow and procedure protocol for more efficient clinical applications.

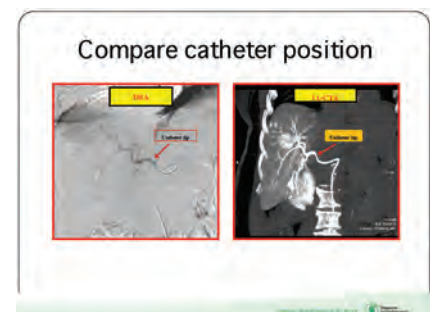
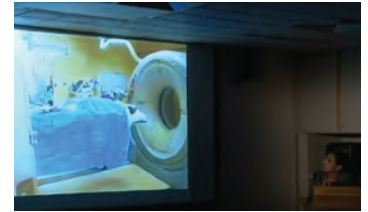


Figure 5. Compares the consistency of catheter positions between DSA and IA-CTA images during review.

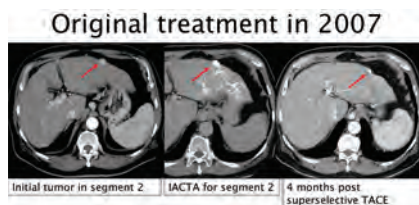
Live case details

Richard Lo MD, Senior Consultant, Department of Diagnostic Radiology, Singapore General Hospital; Shaun Chan MD, Associate Consultant, Department of Diagnostic Radiology, Singapore General Hospital



The patient is a 76-year-old Chinese male with history of Child's A liver cirrhosis secondary to chronic hepatitis B, portal hypertension and esophageal varices. He was diagnosed with a solitary segment 2 hepatocellular carcinoma (HCC) in 2007, for which he underwent treatment with superselective transarterial chemoembolization (TACE) to segment 2 in NCC-East Hospital in Tokyo, Japan, with complete response on imaging.

He remained well on surveillance until 2010, when a hypervascular lesion was observed at the margin of the initial tumor site on MRI. For this, he underwent successful CT guided radiofrequency ablation (RFA) in 2010 in Singapore General Hospital (SGH).

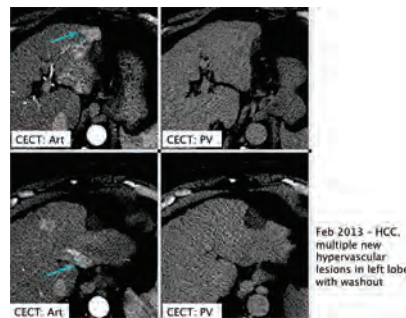


About 1 year later, two new suspicious lesions were detected on MRI in segment 3 and segment 5, for which a second session of RFA was performed successfully in SGH, with reduction of serum alphafeto protein (AFP) to baseline.

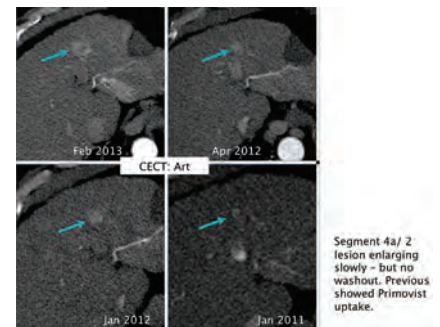
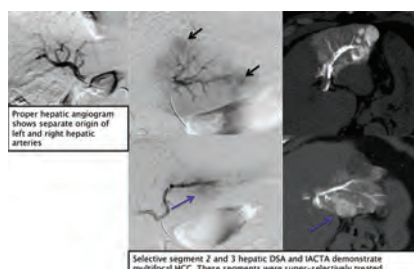


At the time of the live case demonstration, he presented with elevation of serum alphafeto protein about 15 months after the last treatment session. Multiphasic CT imaging showed multiple (greater than 5) new hypervascular lesions involving the lateral segment left lobe. The portal vein branches remained patent, but a small arteriportal shunt was noted

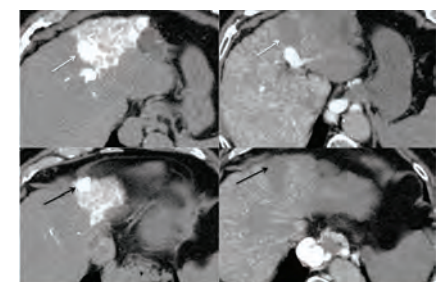
in segment 2. Additionally, several indeterminate lesions were noted in the right lobe and segment 4A, showing faint arterial enhancement but no definite washout on the initial diagnostic CT scan. Decision was made for liver directed treatment with TACE using the Angio CT suite.



Under fluoroscopic guidance, a 5 French Cobra catheter was positioned into the superior mesenteric artery (SMA), and intra-arterial CT arteriography (CTAP) was performed using direct power injection into the SMA and imaging of the liver in portal venous phase. Following this, the celiac artery was selected and a 2.7 French Progreat microcatheter was advanced into the proper hepatic artery. Intra-arterial CT imaging of the liver (IACCTA) was then performed in the arterial phase.



The above images confirmed multiple HCC foci in segments 2, 3 and 4A while the indeterminate lesions in the right lobe did not show features of HCC. IACCTA was performed super-selectively in the segment 2 and 3 branches of the left hepatic artery, which confirmed supply to all the tumor lesions, including the two lesions in segment 4A. Chemoembolization of these two branches was then performed using a mixture of 20 mg mitocycin C, 20 mg doxorubicin and 10 mL Lipiodol, followed by gelfoam slurry until stasis. Immediate post procedure CT showed satisfactory Lipiodol retention in all the tumor nodules.



Follow up CT 6 weeks after the live case demonstration showed dense Lipiodol uptake and reduction in size of all the treated nodules, except for a 1.7 cm lesion in the medial segment 4A which showed washout of the originally retained Lipiodol, and arterial enhancement. This lesion showed tumor supply from the segment 4 branch, for which an additional TACE treatment was performed to treat the segment 4 artery territory.

The above case demonstrates the utility of the hybrid Angio CT suite in the following aspects:

1. CTAP and IACTA may provide additional diagnostic information for indeterminate lesions. The imaging may also be useful if significant time has elapsed between the original diagnostic imaging and the day of treatment. We use this modality routinely in our practice for HCC, especially when single lobe treatments are planned, e.g. with Yttrium-90 radioembolization, to exclude disease in the contra-lateral lobe.
2. Precise delineation of lesion related artery branches for super-selective liver directed treatments.

The IACTA also assists us in understanding complex arterial anatomy to facilitate super-selective catheterizations.

3. IACTA helps exclude non-target embolizations e.g. to gastric mucosa, phrenic arteries, falciform arteries or cystic artery which can occasionally be difficult to exclude confidently on digital subtraction angiography.
4. The immediate post procedure CT allows confirmation of the area of distribution of treatment (for Lipiodol) in a fast and efficient manner.