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PICTORIAL REVIEW

Current role of hybrid CT/angiography system compared with C-arm cone beam CT for interventional oncology

¹T TANAKA, MD, PhD, ²Y ARAI, MD, PhD, ³Y INABA, MD, PhD, ⁴M INOUE, MD, ¹H NISHIOFUKU, MD, PhD, ¹H ANAI, MD, PhD, ⁵S HORI, MD, PhD, ⁶H SAKAGUCHI, MD, PhD and ¹K KICHIKAWA, MD, PhD

¹Department of Radiology, Nara Medical University, Kashihara, Nara, Japan

²Department of Diagnostic Radiology, National Cancer Center Hospital, Tokyo Japan

³Department of Diagnostic and Interventional Radiology, Aichi Cancer Center Hospital, Nagoya, Aichi, Japan

⁴Department of Radiology, Nara Prefectural Nara Hospital, Nara City, Nara, Japan

⁵GateTower Institute for Image Guided Therapy, Izumisano, Osaka, Japan

⁶Department of Radiology, Nara Prefectural Mimuro Hospital, Sango, Nara, Japan

Address correspondence to: Dr Toshihiro Tanaka

E-mail: toshihir@bf6.so-net.ne.jp

ABSTRACT

Hybrid CT/angiography (angiography) system and C-arm cone beam CT provide cross-sectional imaging as an adjunct to angiography. Current interventional oncological procedures can be conducted precisely using these two technologies. In this article, several cases using a hybrid CT/angiography system are shown first, and then the advantages and disadvantages of the hybrid CT/angiography and C-arm cone beam CT are discussed with literature reviews.

A hybrid CT/angiography system was developed in 1992. Professor Y. Arai, Director of the National Cancer Center, Tokyo, Japan, first introduced this system in Aichi Cancer Center (Nagoya, Japan).¹ This system integrates a CT scanner and an angiography unit, which are arranged in line using a common patient table. This permits CT, conventional fluoroscopy and angiography to be performed on the same table without having to move the patient, thereby omitting the risk of needle and catheter dislocation or compromising sterile conditions owing to patient transportation. This system is used for various interventional oncologic procedures.² Nearly 10 years ago, the initial development of the C-arm cone beam CT technology, in which CT-like images were obtained from a flat-panel detector, was reported. With the improvement in detector technology, C-arm cone beam CT is now being used in various interventions worldwide. These two technologies, which provide cross-sectional imaging as an adjunct to angiography, allow interventional oncological procedures to be precisely conducted.

The question is whether there are still any roles for the hybrid CT/angiography system after the introduction of the C-arm cone beam CT. First, this article provides our experience with cases using the hybrid CT/angiography system, along with a review of the previously published literature. Then, the advantages and drawbacks of the

hybrid interventional CT/angiography system and C-arm cone beam CT are summarized, and the current role of the hybrid CT/angiography system for interventional oncology is discussed.

PART I. UTILITY OF THE HYBRID CT/ ANGIOGRAPHY SYSTEM

Diagnosis of liver tumours

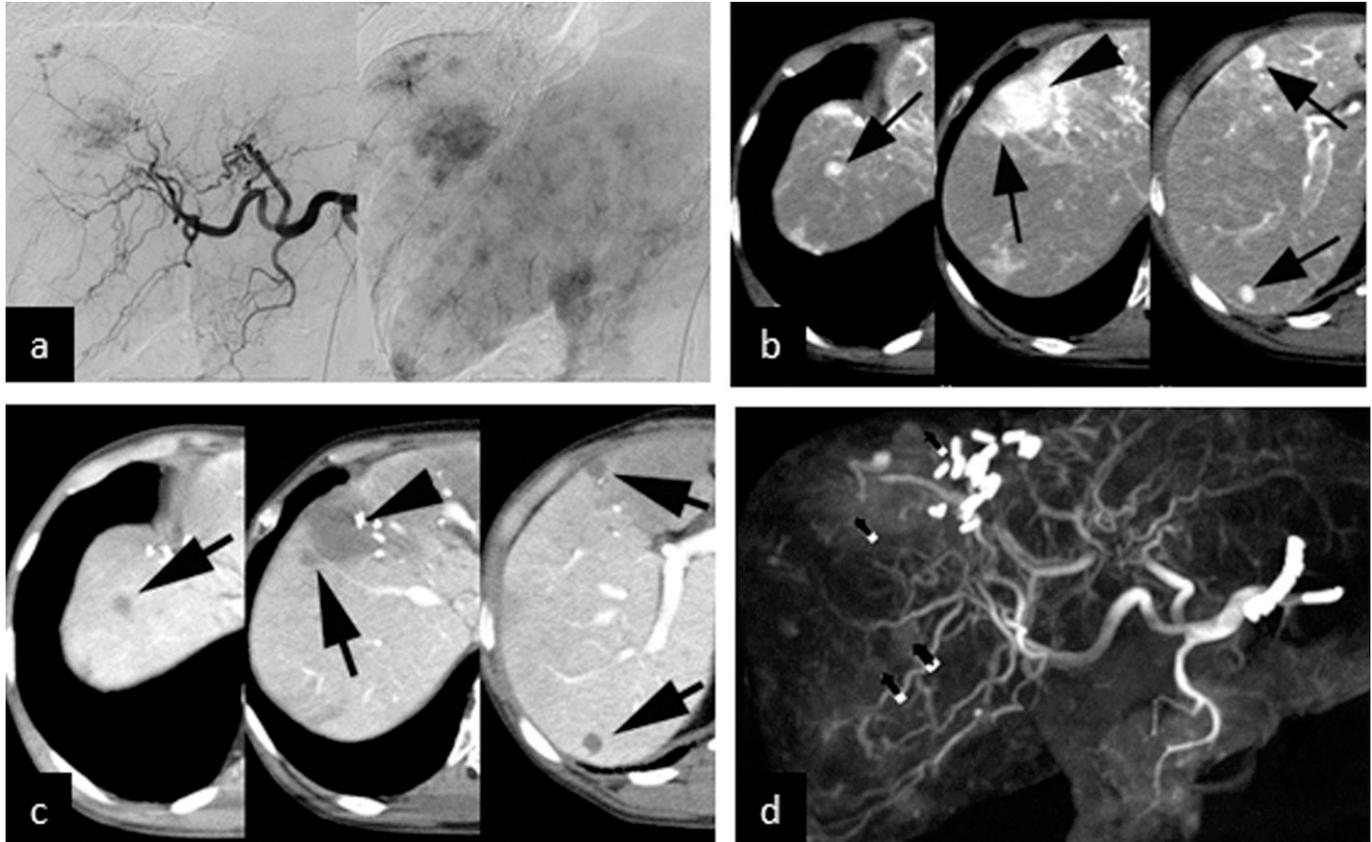
A hybrid CT/angiography system is suitable for conducting CT arterio-portography (CTAP) and CT hepatic arteriography (CTHA).³ The combination of CTAP and CTHA is considered the most sensitive modality for the detection of hepatocellular carcinoma (HCC). The combination of CTAP and CTHA is useful to identify HCCs before transarterial chemoembolization (TACE). Using the three-dimensional (3D) co-ordinate system of CT angiography, the targeted artery for embolization can be identified in 3D-reconstruction of maximum intensity projection imaging of CTHA (Figure 1).

Intra-arterial tumour therapy

Superselective transarterial chemoembolization for hepatocellular carcinoma

An interventional CT/angiography system is helpful for superselective TACE of HCCs to find tumour-feeding arteries and to predict embolization areas (Figure 2). Several reports have demonstrated the value of the hybrid CT/

Figure 1. Transarterial chemoembolization for multiple hepatocellular carcinomas (HCCs) with arterioportal (AP) shunts in a cirrhosis patient: (a) an angiography shows multiple stains that include HCCs and AP shunts; (b) CT hepatic arteriography (CTHA) shows that the main tumour (arrow head) and four small nodules (arrows) are enhanced; (c) CT arterio-portography (CTAP) clearly shows that all HCCs (arrowhead and arrows) are depicted as the round perfusion defects. From these CTHA and CTAP findings, HCCs are easily diagnosed; and (d) three-dimensional reconstruction of maximum intensity projection imaging of CTHA, which has the HCCs marked using a workstation (Ziostation™; Ziosoft Inc., Redwood City, CA), shows the tumour-feeding arteries. This navigation image is helpful to determine which branches should be embolized.



angiography system for superselective TACE,⁴ and one report showed that longer survival time was achieved by TACE using a hybrid CT/angiography system than when using a conventional angiography system alone.⁵

Transarterial chemoembolization through extrahepatic collateral arteries for hepatocellular carcinoma

In HCCs located in the subcapsular regions of the liver, extrahepatic collateral vessels frequently develop and supply the tumours. It is occasionally difficult to detect the extrahepatic collateral feeding arteries on angiography when the tumour stain is fine and in certain situations when it is hidden by the enhancement of other organs. CT arteriography via extrahepatic collateral vessels is helpful to find the tumour-feeding arteries (Figure 3).⁶

Transarterial chemoinfusion/transarterial chemoembolization for various malignant tumours

In transarterial chemoinfusion (TAI)/TACE for malignant tumours, it is vital to achieve optimal drug distribution, because tumours are frequently supplied by several feeding arteries (Figures 4 and 5). CT arteriography via each feeding artery is useful to ensure proper drug distribution covering the entire

tumour.⁷ In addition, high-contrast resolution CT arteriography via the catheter before TAI/TACE is important to avoid non-targeted TAI/TACE of critical organs, which can lead to severe complications (Figures 6 and 7).

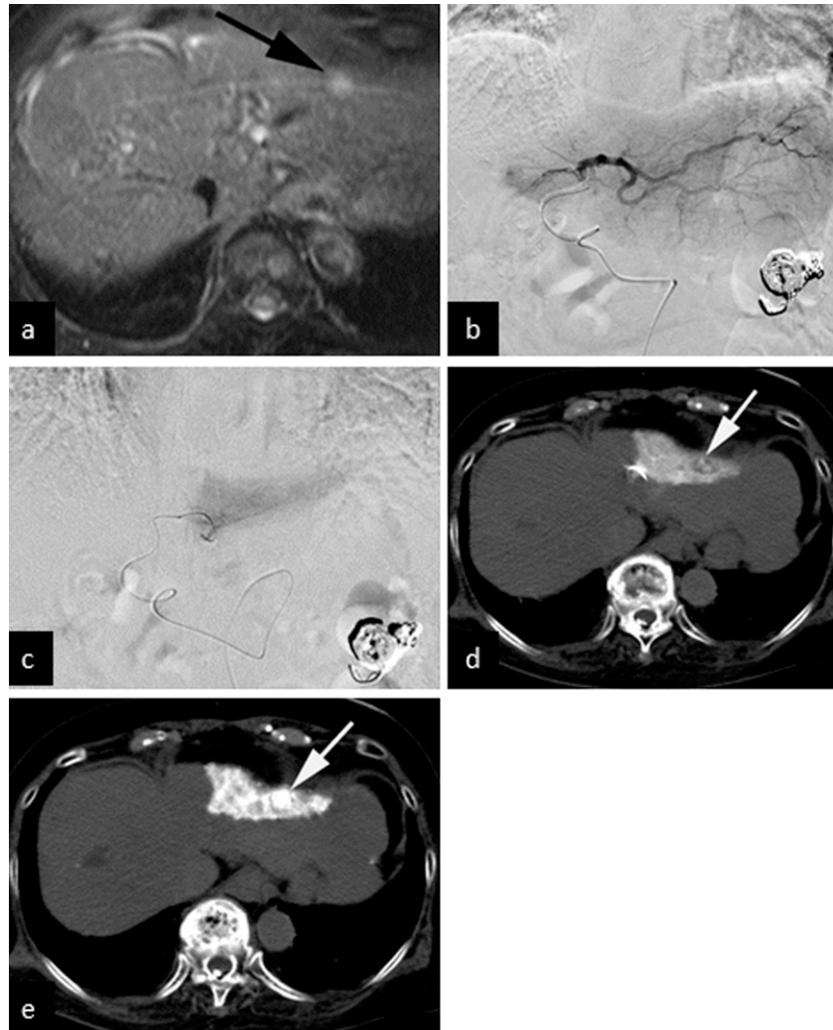
Tumour ablation

A hybrid CT/angiography system is useful for the combination of CT-guided needle/electrode insertion and angiography in the same session (Figure 8). Lipiodol-TACE/TAI prior to radio-frequency ablation is helpful to detect a tumour on an unenhanced CT owing to the accumulation of iodinated oil in the tumour (Figure 9).⁸ CT-guided puncture during CTAP is also a useful technique to clearly place the needle/electrode into the small tumour owing to the high detectability of CTAP (Figure 10). Thermal ablation for tumours adjacent to the gastrointestinal tract is a major challenge owing to the risk of stomach or bowel perforation. A hybrid CT/angiography is one of the image-guided tools for performing such a complicated procedure (Figure 11).

Percutaneous drainage

A hybrid CT/angiography system is useful in percutaneous drainage using the Seldinger technique.⁹ With CT guidance alone, visibility during the procedure along the patient's z-axis, head-foot

Figure 2. Superselective transarterial chemoembolization (TACE) for small hepatocellular carcinoma recurrence in a patient with poor liver function (Child-Pugh score 8): (a) a contrast-enhanced MRI shows a slightly hypervascular tumour in the left hepatic lobe (arrow); (b) it is difficult to depict the tumour stain in the left hepatic angiography; (c) a microcatheter is inserted into the suspected feeding branch; (d) selective CT arteriography demonstrates enhancement in the tumour (arrow); and (e) unenhanced CT immediately after TACE shows the dense lipiodol retention inside and around the tumour (arrow).



direction, is limited. Hence, the insertion of a guide wire and a drainage catheter frequently remains difficult after a successful needle puncture of the targeted lesion. Conventional fluoroscopy is helpful to introduce a guide wire and to insert a catheter over the wire (Figures 12 and 13).

PART II. COMPARISON OF THE HYBRID CT/ ANGIOGRAPHY SYSTEM WITH C-ARM CONE BEAM CT

The recent C-arm cone beam CT technology allows real-time fluoroscopy, angiography and multisectional CT-like images in a single unit, and it is now widely used in various interventions in cancer patients. In this part, the advantages and drawbacks of the hybrid CT/angiography system compared with the cone beam C-arm CT are reviewed. In addition, we will consider the clinical settings in which the hybrid CT/angiography system should be strongly recommended. To the best of our knowledge, there have been no previous reports comparing the hybrid CT/angiography system and cone beam C-arm CT.

The advantages of a hybrid CT/angiography system

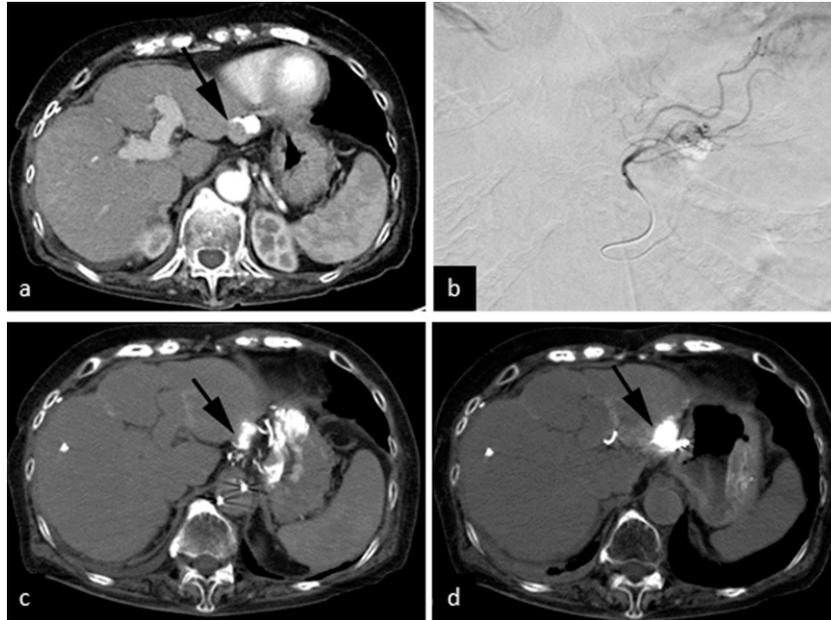
High-contrast resolution of CT

High-contrast resolution, due to lower scatter radiation, higher radiation doses (mA) and faster scan speed of a conventional multidetector-row CT (MDCT), is clearly beneficial in a hybrid CT/angiography system when compared with the low-contrast resolution that is a critical problem for cone beam C-arm CT (Figures 14 and 15).

Large field of view

The field of view (FOV) of C-arm cone beam CT is limited to a maximum of 20–25 cm. In patients with a large body size and/or multiple and huge tumours, occasionally the whole liver cannot be scanned using C-arm cone beam CT (Figure 16). By contrast, conventional CT has a large FOV with a maximum of 50 cm. A large FOV is imperative, for instance, in the treatment planning of patients with multiple liver tumours so that the interventional radiologist has a proper grasp of the tumour numbers and their distribution areas.

Figure 3. Transarterial chemoembolization (TACE) through extrahepatic collateral arteries for small hepatocellular carcinoma (HCC) supplied by the left gastric artery: (a) intravenous contrast-enhanced CT shows HCC recurrence after TACE in the left lateral lobe of the liver (arrow). Because the tumour is not enhanced on the CT arteriography via the left hepatic artery, the presence of an extrahepatic collateral supply is suspected; (b) the tumour stain is difficult to detect clearly on the left gastric arteriography; (c) CT arteriography via the left gastric artery shows the enhancement of the tumour (arrow); and (d) a microcatheter is inserted into the feeding branch superselectively, and CT arteriography is obtained again, which shows that the tumour is enhanced more densely (arrow), and non-targeted embolization of the gastric wall could be avoided.



Minimal artefacts

C-arm cone beam CT images sometimes become obscure because of the following several artefacts (Figure 17). (i) Motion artefact: movement during the CT scan frequently disturbs the image quality of C-arm cone beam CT. A conventional CT of a hybrid CT/angiography system is less affected by motion artefact owing to the rapid scan speed and a motion correcting function. (ii) Metallic artefact: implanted metals with high attenuation develop alternate dark and bright streaks. With cone beam CT, this artefact is significantly visible in all directions, caused by the high attenuation, which is due to cone beam geometry. (iii) Truncated-view artefact: a partial volume artefact occurs when an object is not completely covered by a detector. Cone beam CT is affected by truncated-view artefact due to the limited FOV, whereas conventional CT is not, because the entire object is always within the scan field.

Real-time CT fluoroscopy

The important advantage of a hybrid CT/angiography system is that it allows the needle puncture to be conducted under real-time CT-fluoroscopy guidance, in which the operator can visualize the slices of interest in real time. By contrast, using C-arm cone beam CT, the needle is inserted under conventional fluoroscopy guidance. Recently, the technology of the C-arm cone beam CT-guided puncture has improved. However, it is not as precise as that of the hybrid CT/angiography system because of the following limitations. First, to fuse the two images using C-arm cone beam CT, it is imperative that the patients remain in the same diaphragm positions as during the planning scans. Second, with C-arm cone beam CT guidance, it is hard to observe the real-time changes in the body,

that is, bowel movements or bleeding caused by a puncture, without obtaining an additional CT scan.

The drawbacks of a hybrid CT/angiography system

High radiation exposure

Recently, there have been two published reports that compared the radiation doses of patients between conventional MDCT and C-arm cone beam CT. Bai *et al*¹⁰ demonstrated that the effective doses were significantly higher for MDCT than for C-arm cone beam CT. Strocchi *et al*¹¹ compared the patients' doses between real-time CT-fluoroscopy guidance and C-arm CT guidance in lung biopsies and showed that MDCT guidance techniques delivered 1.2–1.7 times higher doses than C-arm cone beam CT.

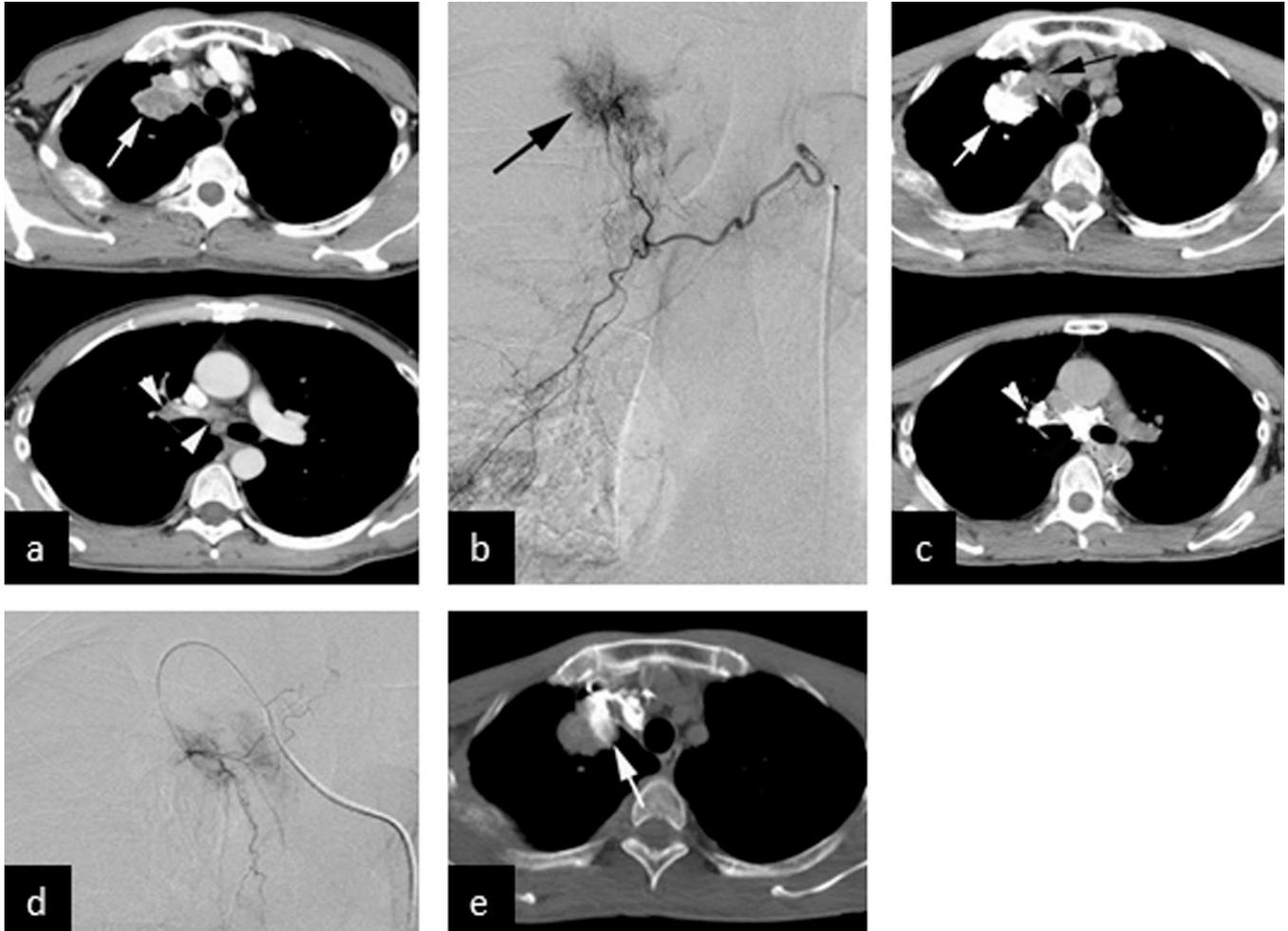
Limited angulation puncture with a narrow workspace

In real-time CT-fluoroscopy guidance, angulated needle punctures can be performed using the gantry tilting method. However, the tilting angle is limited to a maximum of 30°, and, furthermore, the workspace becomes narrow in the tilted gantry, which makes it impossible to perform a needle puncture. By contrast, C-arm cone beam CT allows an angulation range of up to 50° with a wide sterile workspace owing to the C-arm configuration.

Cost

A hybrid CT/angiography system is more costly than a C-arm cone beam CT. The price is dependent on the performance function levels, that is, a hybrid CT/angiography system with 16-slice CT or 64-slice CT. The hybrid CT/angiography system is approximately 1.5–2 times more expensive than the C-arm cone beam

Figure 4. Transarterial chemoembolization for non-small-cell lung cancer with lymph node metastases: (a) intravenous enhanced CT shows lung cancer in the right upper lobe (arrow) and mediastinum and hilar lymph node metastases (arrowheads); (b) the right bronchial arteriography shows the tumour stain of the lung tumour (arrow). However, the enhancement area does not show the extent of the tumour; (c) CT arteriography from the right bronchial artery shows the precise tumour enhancement area (white arrow) compared with the non-enhanced area (back arrow). (c) The lower picture shows that the mediastinum and hilar lymph nodes are also enhanced (arrowheads). (d) The internal thoracic arteriography; and (e) CT arteriography from the internal thoracic artery shows enhancement of the other side of the tumour (arrow).



CT in general. For example, the delivery price of a Siemens hybrid CT/angiography system with 64-slice CT is *ca.* \$2.1 million in Japan, whereas a Siemens C-arm cone beam CT is *ca.* \$1.4 million in Japan.

Recommended clinical settings for using hybrid CT/angiography system

Clinical settings in which the hybrid CT/angiography system would be strongly recommended are as follows: (1) in TACE or TAI, high-contrast resolution image is needed owing to high risk of severe complications caused by non-targeted embolization/chemoinfusion of critical organs, that is, the spinal cord or the gastrointestinal. (2) In tumour ablation or drainage, precise real-time image-guided puncture is needed for a puncture line adjacent to critical organs or major vessels, and movable target lesions, that is, near to the diaphragm.

CONCLUSION

The developments of the hybrid CT/angiography system and C-arm cone beam CT technology, which provide cross-sectional imaging as an adjunct to angiography, allow interventional oncological procedures to be precisely conducted. Currently, the demand for interventional oncology has increased with more challenging and complicated procedures. The hybrid CT/angiography system could be considered to maintain an important role particularly in such special procedures, that is, in cases that require high-contrast resolution CT or real-time CT-guided puncture.

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REFERENCES

- Inoue A. Development of a hybrid CT/angiography system. *Medical Review* 1992; **43**: 9–15.
- Tanaka T. Hybrid interventional CT/angiography system. In: Mahnken AH, Wilhelm KE, Rick J, eds. *CT- and MR-guided interventions in radiology*. Berlin, Heidelberg: Springer-Verlag; 2013: 515–29.
- Inaba Y, Arai Y, Kanematsu M, Takeuchi Y, Matsueda K, Yasui K, et al. Revealing hepatic metastases from colorectal cancer: value of combined helical CT during arterial portography and CT hepatic arteriography with a unified CT and angiography system. *AJR Am J Roentgenol* 2000; **174**: 955–61. doi: [10.2214/ajr.174.4.1740955](https://doi.org/10.2214/ajr.174.4.1740955)
- Takayasu K, Muramatsu Y, Maeda T, Iwata R, Furukawa H, Muramatsu N, et al. Targeted transarterial oily chemoembolization for small foci of hepatocellular carcinoma using a unified helical CT and angiography system: analysis of factors affecting local recurrence and survival rates. *AJR Am J Roentgenol* 2001; **176**: 681–8.
- Toyoda H, Kumada T, Sone Y. Impact of a unified CT angiography system on outcome of patients with hepatocellular carcinoma. *AJR Am J Roentgenol* 2009; **192**: 766–74. doi: [10.2214/AJR.08.1368](https://doi.org/10.2214/AJR.08.1368)
- Ishijima H, Koyama Y, Aoki J, Kawano T, Nakajima T, Ishizaka H, et al. Use of a combined CT-angiography system for demonstration of correlative anatomy during embolotherapy for hepatocellular carcinoma. *J Vasc Interv Radiol* 1999; **10**: 811–15.
- Kashiwagi N, Nakanishi K, Kozuka T, Sato Y, Tanaka K, Tsukaguchi I, et al. Vascular supply with angiography-CT for superselective intra-arterial chemotherapy in advanced maxillary sinus cancer. *Br J Radiol* 2010; **83**: 171–8. doi: [10.1259/bjr/16954991](https://doi.org/10.1259/bjr/16954991)
- Lee MW, Kim YJ, Park SW, Hwang JH, Jung SI, Jeon HJ, et al. Percutaneous radiofrequency ablation of small hepatocellular carcinoma invisible on both ultrasonography and unenhanced CT: a preliminary study of combined treatment with transarterial chemoembolization. *Br J Radiol* 2009; **82**: 908–15. doi: [10.1259/bjr/55877882](https://doi.org/10.1259/bjr/55877882)
- Tanaka T, Inaba Y, Arai Y, Matsueda K, Aramaki T, Dendo S. Mediastinal abscess successfully treated by percutaneous drainage using a unified CT and fluoroscopy system. *Br J Radiol* 2002; **75**: 470–3. doi: [10.1259/bjr.75.893.750470](https://doi.org/10.1259/bjr.75.893.750470)
- Bai M, Liu B, Mu H, Liu X, Jiang Y. The comparison of radiation dose between C-arm flat-detector CT (DynaCT) and multi-slice CT (MSCT): a phantom study. *Eur J Radiol* 2012; **81**: 3577–80. doi: [10.1016/j.ejrad.2011.09.006](https://doi.org/10.1016/j.ejrad.2011.09.006)
- Strocchi S, Colli V, Conte L. Multidetector CT fluoroscopy and cone-beam CT-guided percutaneous transthoracic biopsy: comparison based on patient doses. *Radiat Prot Dosimetry* 2012; **151**: 162–5.

Figure 5. Transarterial chemoembolization (TACE) for advanced breast cancer. Before TACE, angiography followed by CT arteriography via the tumour-feeding arteries was obtained: (a) via the right internal thoracic artery; (b) via the right lateral thoracic artery; and (c) via the thoracoacromial artery. The combination of the enhanced areas via these three arteries covers the entire tumour.



Figure 6. Non-targeted chemoinfusion to the right gastric artery during transarterial chemoinfusion for hepatocellular carcinoma: (a) angiography from the indwelling port-catheter system, which is placed in the proper hepatic artery, does not depict the right gastric artery; (b) CT arteriography via the port shows fine enhancement of the antrum wall of the stomach (arrow), and this is important when considering the risk of complication; (c) in this case, repeated 5-fluorouracil (5-FU) infusion via the port was conducted and an acute gastric mucosal lesion appeared (arrow), (d) with injection of indigo carmine dye via the port, the mucosal lesion was stained. This shows that non-targeted 5-FU infusion caused acute gastric mucosal damage.

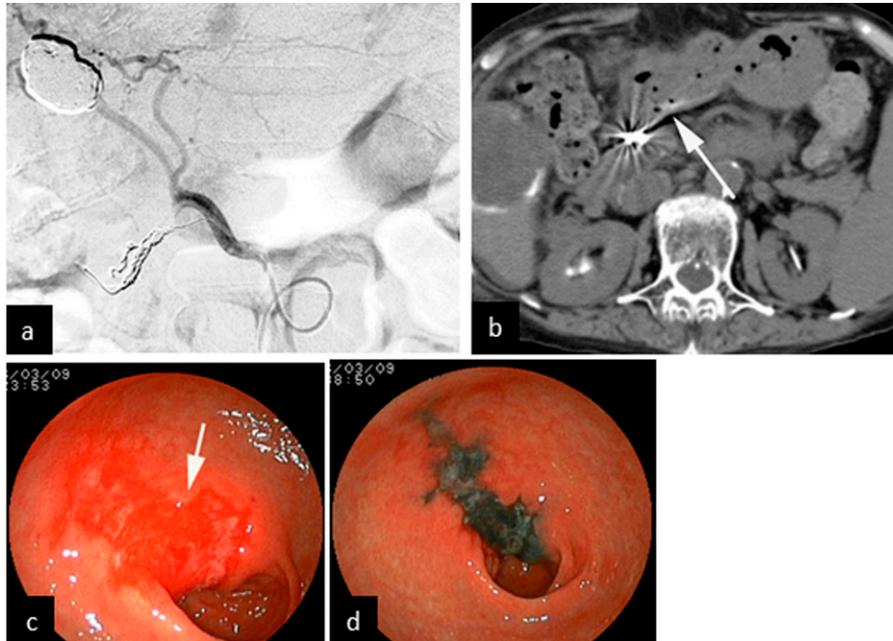


Figure 7. The anterior spinal artery depicted on CT arteriography before transarterial chemoembolization (TACE) for primary lung cancer: (a) on right intercostal arteriography, which is the feeding artery of lung cancer, it is difficult to find the connection to the anterior spinal artery; (b) CT arteriography via the right intercostal artery was conducted, which shows the enhancement of the artery in the spinal canal (arrow). Therefore, TACE was not performed owing to the possibility of severe complications.

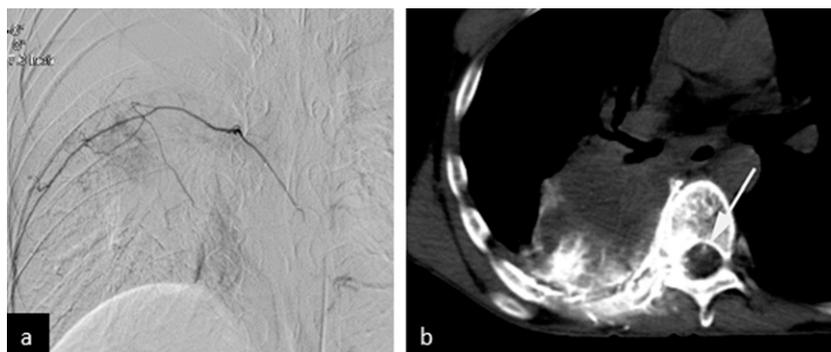


Figure 8. The combination of transarterial chemoembolization (TACE) and radiofrequency ablation (RFA) for hepatocellular carcinoma (HCC) in the same session: (a) CT shows local recurrence of HCC after TACE in the ventral and medial sides of the tumour (arrow); (b) additional superselective TACE was conducted; (c) after TACE, an radiofrequency electrode was inserted under CT-fluoroscopy guidance in the same session; and (d) CT after combined TACE and RFA shows that a large coagulation zone of 4 cm in diameter was obtained (arrow).



Figure 9. Lipiodol transarterial chemoembolization (TACE) prior to radiofrequency ablation to enhance small hepatocellular carcinoma (HCC): (a) unenhanced CT does not depict a tumour in the right hepatic lobe; (b) firstly, lipiodol TACE was conducted via the tumour-feeding artery. CT immediately after TACE depicted the HCC clearly (arrow); (c) then, under CT guidance, a radiofrequency electrode was placed in the tumour.

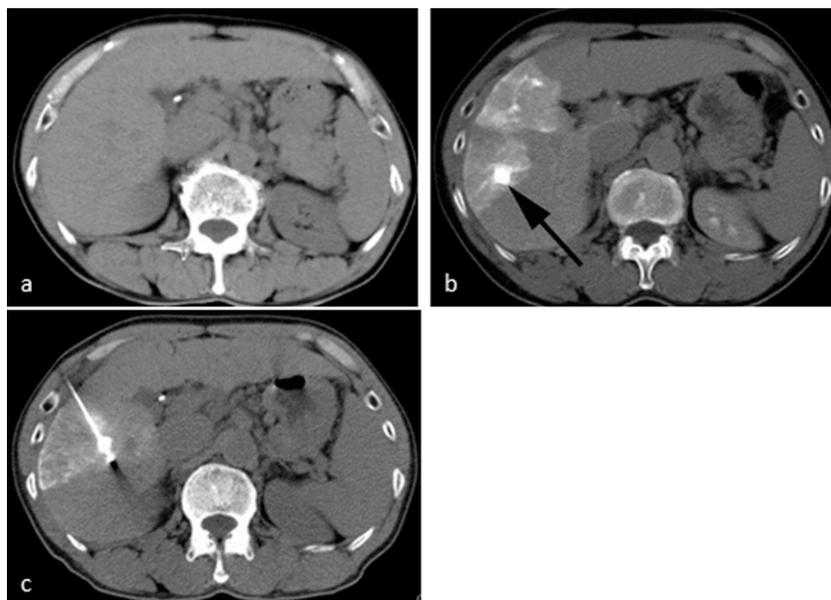


Figure 10. Radiofrequency ablation for tiny rectal metastases under CT arterio-portography (CTAP) guidance: (a) intravenous enhanced CT shows a small and slightly low attenuation tumour in the right hepatic lobe (arrow) and (b) during CTAP, the radiofrequency electrode is being inserted under CT-fluoroscopy guidance. CTAP clearly shows the tumour (arrow) and confirms that the electrode is successfully placed in the tumour (arrowhead).

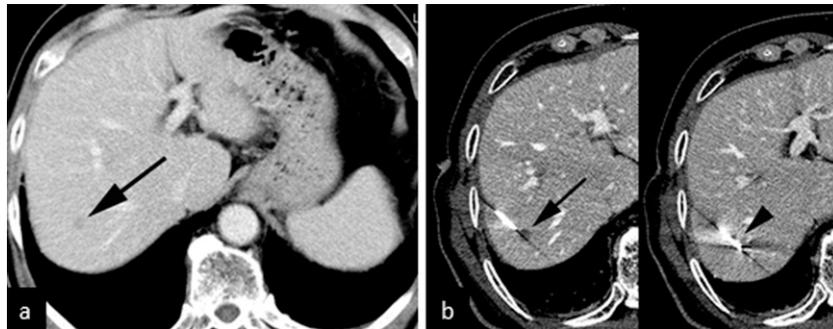


Figure 11. Liver metastasis adjacent to the stomach treated by radiofrequency ablation (RFA) with balloon catheter interposition: (a) CT shows a metastatic liver tumour adherent to the stomach (arrow); (b) hepatic arteriography: a microcatheter was inserted into the tumour-feeding artery (arrow) to combine transarterial chemoembolization (TACE) with RFA; (c) an A19G needle puncture under CT guidance, and a balloon catheter was placed between the tumour and the stomach using CT fluoroscopy and conventional fluoroscopy to avoid stomach perforation (arrowheads). A radiofrequency electrode was inserted into the tumour under CT guidance (arrow); (d) after TACE via a microcatheter, RFA was carried out. A conventional fluoroscopic image shows a microcatheter (white arrow), balloon catheter (black arrow) and radiofrequency electrode (arrowhead); and (e) CT after RFA shows the complete ablation of the tumour without complications.



Figure 12. Nephrostomy for non-obstructive uropathy owing to urine leaks after surgery for bladder cancer. (a) Under CT-fluoroscopy guidance, the right pelvis, which is not dilated, is punctured; (b) under conventional fluoroscopy guidance, a guide wire is inserted; and (c) a drainage catheter is placed in the pelvis.

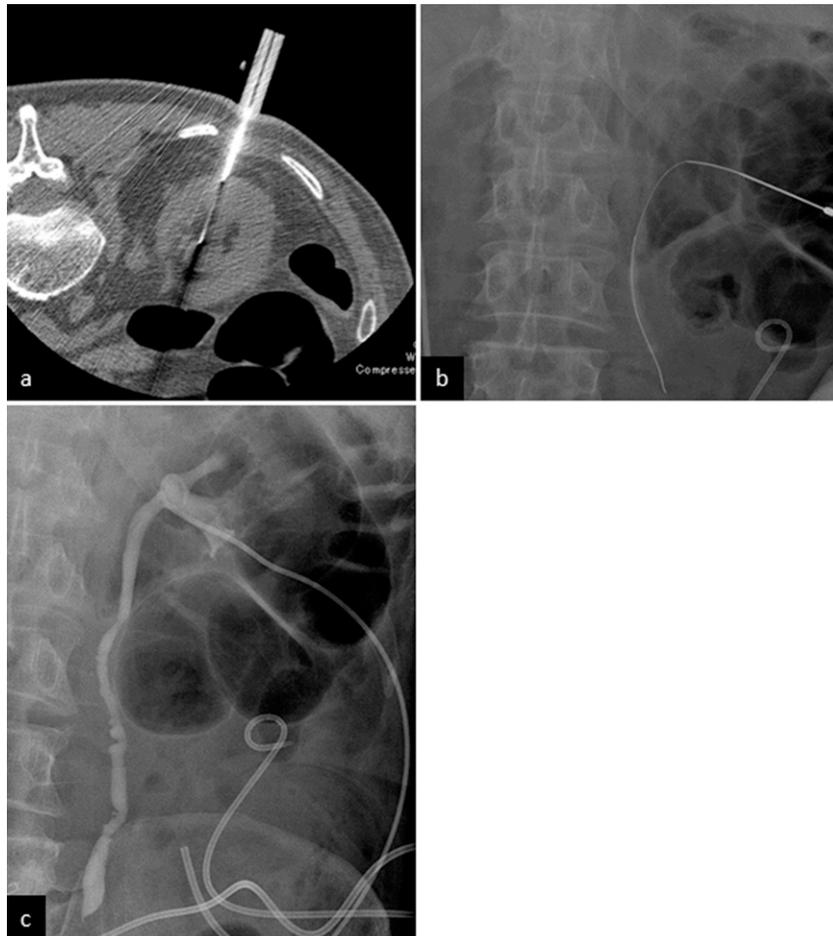


Figure 13. Drainage using a coaxial technique for the subphrenic abscess after surgery of pancreatic cancer: (a) an intravenous enhanced CT shows an abscess cavity in the left subphrenic region (arrow); (b) under CT-fluoroscopy guidance, a 22-G fine needle is used to puncture from the caudal site to avoid transpleural access; then, a 0.018-inch guide wire is inserted (arrows); (c) under conventional fluoroscopy guidance, a coaxial catheter introducer system is inserted along the 0.018-inch guide wire, and a drainage tube is inserted over the replaced 0.035-inch guide wire.

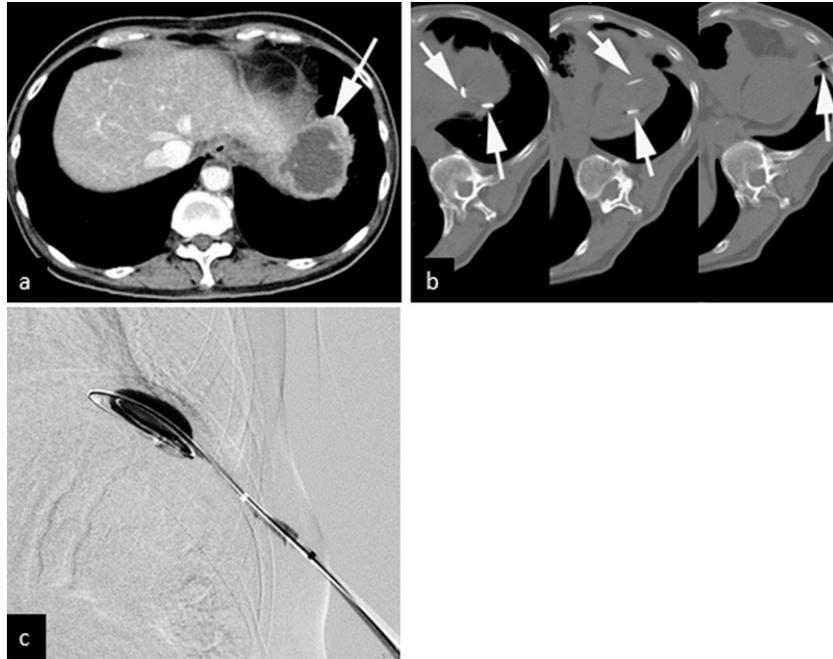


Figure 14. Small hepatocellular carcinoma (HCC) that is not clearly depicted using a cone beam C-arm CT: (a) intravenous enhanced CT clearly shows small HCC near the inferior vena cava (arrow); and (b) CT hepatic arteriography using a cone beam C-arm CT does not show the tumour clearly owing to the low-contrast resolution (arrow).

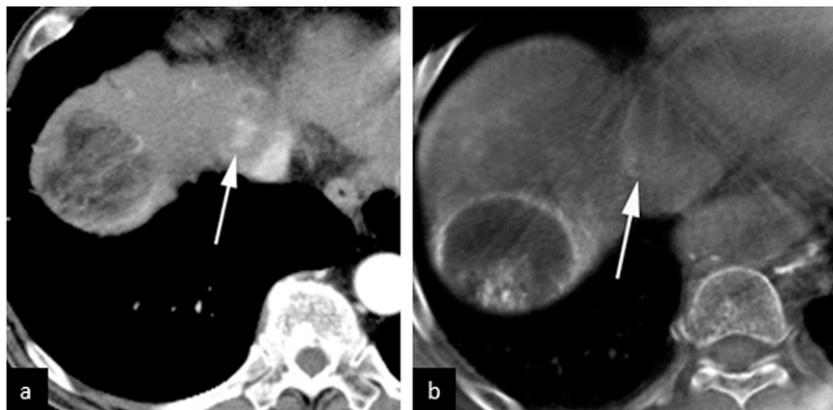


Figure 15. Colorectal liver metastases treated by trans-arterial chemoinfusion via an implantable port-catheter system: (a) a conventional CT hepatic arteriography via the port using a hybrid CT/angiography system shows the fine enhancement of the gastric wall (arrow), which means that the chemotherapy drugs will distribute to the stomach; (b) however, CT hepatic arteriography using a cone beam C-arm CT does not show the fine enhancement of gastric wall owing to low-contrast resolution (arrow). The stronger metallic artefact of coils placed in the gastroduodenal artery also disturbs visualization.

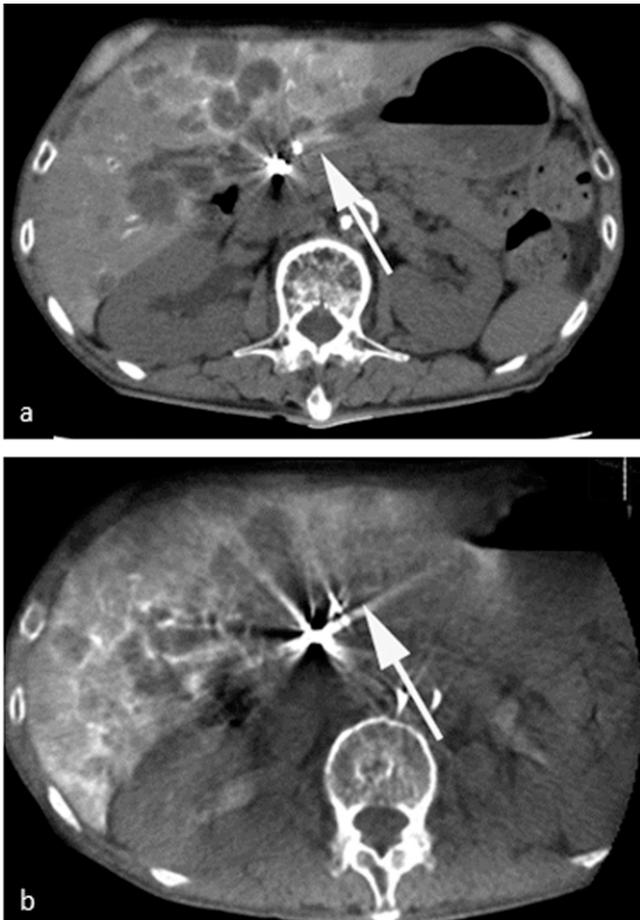


Figure 17. Artefacts of C-arm cone beam CT: strong motion and metal artefacts present owing to cardiac pacemaker on C-arm cone beam CT.

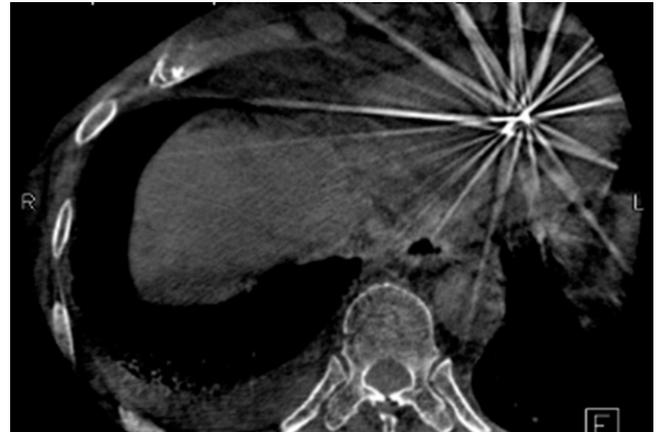


Figure 16. A hepatocellular carcinoma (HCC) nodule that is out of the scan field of C-arm cone beam CT: (a) intravenous enhanced CT with the field of view (FOV) of 35 cm shows multiple HCCs in the whole liver. A tumour was located in the subcapsular site of the left lobe (arrow). (b) Owing to the small FOV of 25 cm in C-arm cone beam CT, the tumour (arrow in [Figure 16a](#)) is not included in the scan field.

