# Utility of Clinical Applications Based on Direct-Conversion FPD

**Chairperson**
**Kimihiko Kichikawa, MD**
Professor and Chairman, Department of Radiology, Nara Medical University

The 68th Annual Meeting of the Japan Radiological Society (JRS) was held over four days, from April 16 to 19. On the 18th, Shimadzu held a luncheon seminar in partnership with the society. At this seminar, which was chaired by Kimihiko Kichikawa, MD (Professor and Chairman, Department of Radiology, Nara Medical University) and which was based on a theme of “Utility of Clinical Applications Based on Direct-Conversion FPD”, lectures were given by Yukunori Korogi, MD (Professor and Chairman, Department of Radiology, University of Occupational and Environmental Health) and Hiroyuki Nakagawa, MD (Associate Professor, Department of Radiology, Nara Medical University). The seminar was full to capacity, with a large number of physicians in attendance, indicating of high level of interest in the theme. Here, we will present details of these lectures.

# Utility of 3D Roadmap Function in Intracerebrovascular Treatment

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## Intracerebrovascular Treatment and Angiography Systems

The performance requirements of angiography systems used to perform intracerebrovascular treatment include the following: (1) the ability to visualize blood vessels and lesions with clarity and high definition; (2) the ability to facilitate simultaneous observation from multiple directions at freely set angles; and (3) the ability to clearly show microcatheters and guide wires together with blood vessel images or, in other words, to create a roadmap.

At some point in the history of angiography, DSA appeared, and with the subsequent appearance of flat panels, it became possible to obtain extremely well-defined images. Alongside this, roadmaps that could be used to guide various materials began to be used in the 60s. Regarding 3D images, rotational angiography and 3D angiography systems started being put to practical use in 1983 and 1994, respectively, and I maintained close contact with these technologies throughout my development as a physician. After that, the development of 3D roadmaps for 3D guidance started in 2005.

## Features of BRANSIST safire

A 3D roadmap function (Safire 3D-M) can be installed in Shimadzu’s BRANSIST safire, a cerebrovascular bi-plane system equipped with direct-conversion flat panel detectors. This system produces extremely clear high-definition images, and is characterized by its 9 × 9-inch panels, its 1,024 × 1,024 matrix, and the high degree of freedom it offers with arm positioning and movement (**Fig. 1**). Because the 9 × 9-inch FPDs are extremely compact, it is possible for the bi-plane system to closely follow the subject, and it is easy to obtain clear images while suppressing unwanted scattered radiation.

The C-arms cover a diverse range of motion and the frontal C-arm is a multi-pivot arm that supports parallel motion. This movement is particularly useful in radial approaches. With conventional systems, the table must be rotated a great deal in order to get the wrists into the field of view. This is unnecessary with this system. Free movement of the frontal C-arm in a lateral direction is an extremely important feature.

The way that the height of the lateral X-ray tube can be changed is another important characteristic. This makes it possible to make height adjustments with just the lateral X-ray tube and without having to adjust the height of the bed, which can influence the posture of the operator.


**Fig. 1** Features of BRANSIST safire

## Features of 3D Roadmap (Safire 3D-M)

The 3D roadmap is a guidance function based on 3D images. 3D-DSA images and fluoroscopic images are combined and displayed at the work station (**Fig. 2**). The combined image automatically changes in accordance with changes in the arm angle, the distance between the X-ray tube and panel, and the size of the field of view.
Experimental images are shown in **Fig. 3**. It shows that, when a composite change in angle is made, the 3D roadmap image automatically tracks the image changes caused by the complex movement of the X-ray tube. Although the size of the image changes as the operator closely follows the region of interest, the 3D roadmap image automatically changes in response. If fluoroscopy inch size is increased, the 3D roadmap image is enlarged accordingly.
This system is also equipped with functions for adjusting the tone and contrast of the image itself. The desired color can be selected, and the shading can be changed. Furthermore, displacements can be corrected manually if the patient moves.

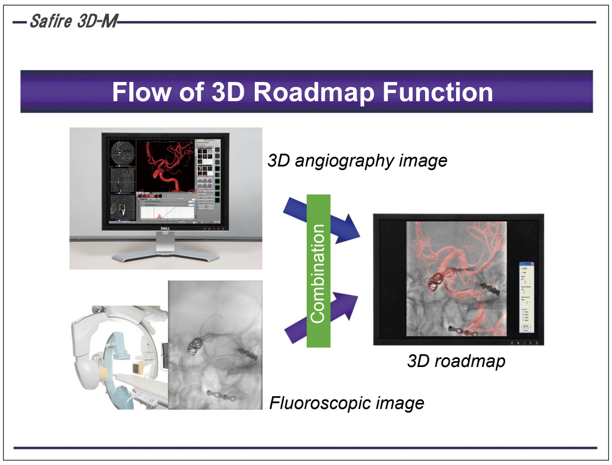


**Fig. 2** Flow of 3D Roadmap Function

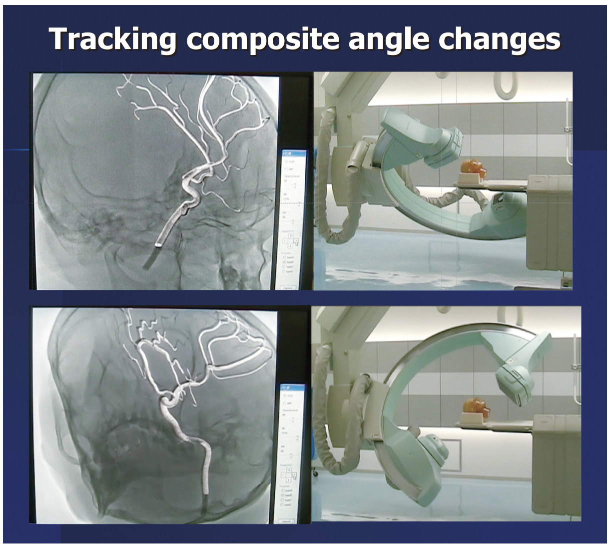


**Fig. 3** 3D Roadmap Image Tracks Changes in C-Arm Angle

## Flow of Actual Examination

First the working position in the frontal direction is determined, the system is rotated in a horizontal direction, and the table height is determined. After that, a general radiography image to which subtraction is applied in 3D mode is obtained, the system is returned to the rotation start position, and angiography is performed. The result of this angiography is automatically sent to the work station, where a 3D image is displayed in combination with a fluoroscopic image. Although this takes 1 minute 45 seconds, it does not cause any sense of irritation in practice.
At our hospital, an 8-screen configuration is used for angiography system monitors. This makes it possible to display frontal and lateral reference DSA images and fluoroscopic maps, and change their role in accordance with the situation.

## Example of Use of 3D Roadmap

**Fig. 4** shows an embolus for an unruptured aneurysm of the left internal carotid artery in a 67-year-old woman. In 3D roadmap images obtained before and after moving the C-arm, changing the angle, there are no displacements in the images and the coil can be clearly seen inside the artery. Extremely clear images are obtained.

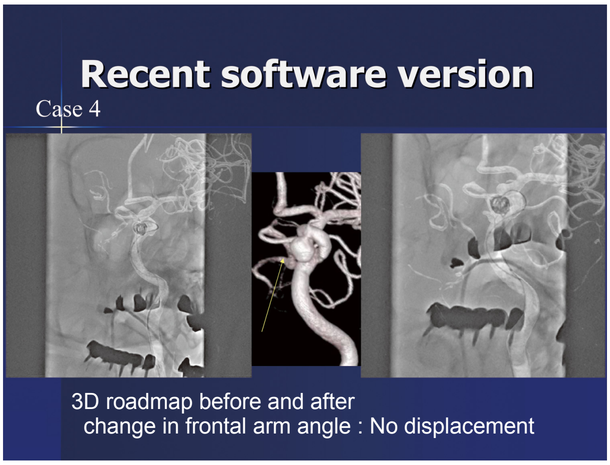
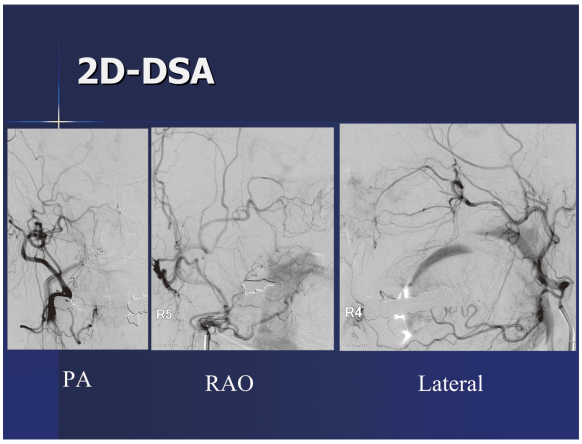
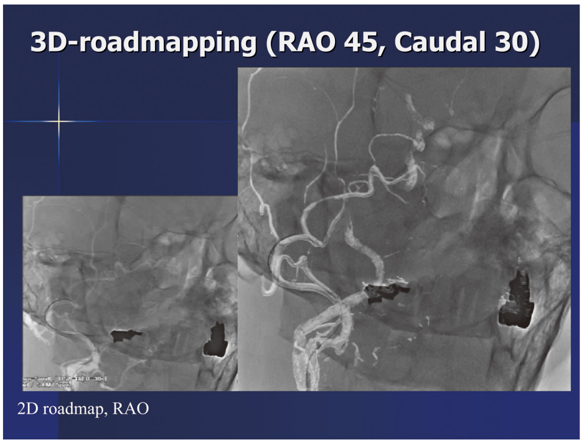


**Fig. 4** Good 3D Roadmap Images with No Displacement

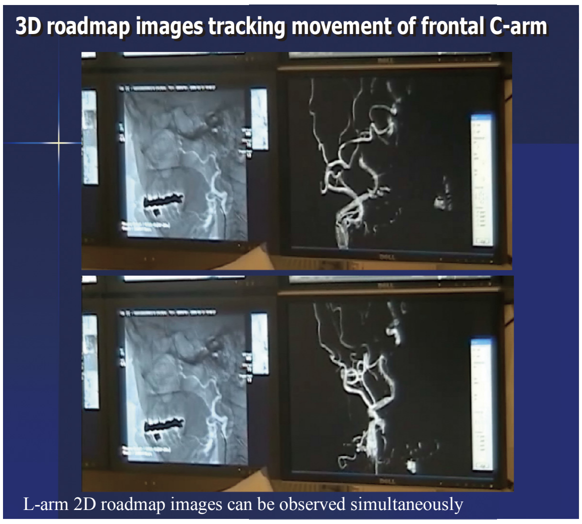
**Fig. 5** shows an embolus for a benign tumor in the head and neck region of a 71-year-old woman. There are parts that have spread to a cavernous hemangioma of the right maxillary sinus and the gums, and the densely stained tumor can be identified clearly with 2D-DSA (**Fig. 5a**). **Fig. 5b** shows a 3D roadmap image created using a 3D-DSA image. The top-right part of Fig. 5c shows another 3D roadmap image. Moving the C-arm with fluoroscopy turned off and viewing a 3D roadmap image that follows this movement (bottom-right part of **Fig. 5c**) makes it possible to consider the optimum angle. **Fig. 5d** shows a 3D roadmap image incorporating a fluoroscopic image that was obtained after changing the angle.



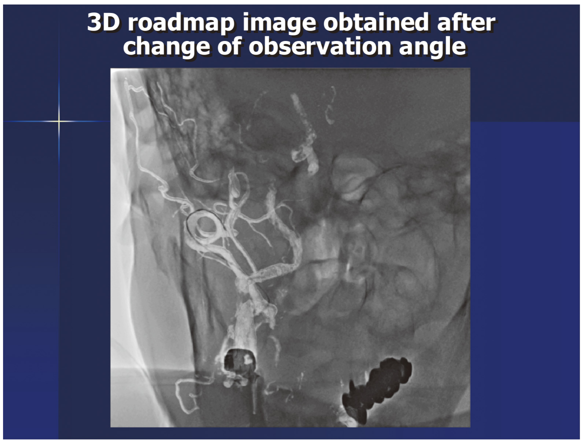
a) The deeply stained tumor can be identified



b) 3D roadmap image before change of angle



c) 3D roadmap images (right) tracking change of angle in frontal C-arm



d) 3D roadmap image after change of angle

**Fig. 5**

As can be seen from this example, it is possible to perform catheter and guide wire operations while simultaneously observing 3D roadmap images, live images of the normal state without contrast medium, and 2D roadmap images.
Although this technology is extremely useful, there are points that must be noted. The 3D roadmap images do not track table movement or lateral movement of the frontal C-arm and so it is necessary to determine, to a certain extent, the position in which intervention is carried out and to align the central axis. Also, depending on the images created as part of the data used for the roadmap, blood vessels in surrounding areas may not be displayed. This is because only 90% of the region for the acquired data is normally used in reconstruction. Although this problem can be eliminated by simply enlarging the reconstruction region, it is necessary to check the display region.

## Summary

3D roadmap images are useful auxiliary tools for IVR procedures performed on central nerves and the head and neck region. With BRANSIST safire, the 3D roadmap images automatically track the movement of the frontal C-arm, 2D-DSA and 3D-DSA images are simultaneously displayed, and it is possible to observe live images while viewing the corresponding DSA images. Furthermore, this system incorporates original features developed by Shimadzu, such as the ability to simultaneously use a 2D roadmap, even from the lateral position, which allows complex IVR procedures for the head and neck region to be executed safely and reliably. BRANSIST safire can be described as an extremely useful system.

# Clinical Application of Direct-Conversion FPD System: Centering on the Latest CT-Like Images

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## Overview of Shimadzu Direct-Conversion Flat Panel Detector

In comparison with indirect-conversion FPDs, which have a slightly longer history, the process by which Shimadzu's direct-conversion FPDs convert incident X-rays to images is extremely general, with little loss, is based on a principle that produces better images. Also, in contrast to I.I.-fluoroscopy systems, there is absolutely no distortion of the images, which are characteristically rectangular. On performing a comparison with MTF, an extremely good MTF that surpasses that of film screen systems is obtained.

## CT-Like Images with 9-Inch Model (Prototype)

The utility of IVR-CT is such that, after using it once, the thought of performing IVR without it is almost inconceivable. At the University of Occupational and Environmental Health, however, it was difficult to introduce IVR-CT because of space and budget restrictions and so, with an earnest desire to produce CT-like images with an angiography system, we considered, over a long period, the development of CT-like images (hereafter referred to as "FPD-CT") together with technicians from Shimadzu.
We already published a report about our consideration of a 9-inch FPD-CT prototype in JVIR in 2007. FPD-CT provides extremely useful information in relation to the use of transcatheter arterial embolization therapy (TAE) for liver tumors. Regarding the current treatment of hepatomas, the use of TAE for single cases of classic hepatocellular carcinomas is extremely uncommon, and is almost always performed on patients who have suffered repeated recurrences. For this reason, it is necessary to find densely stained images of small tumors. Another important point is that, because the catheter must be advanced right to the periphery, being able to clearly view densely stained tumor images with FPD-CT is extremely useful in IVR.
Several operators were asked whether they felt that FPD-CT was useful in IVR. As a result, it was reported to have been useful for 32 out of a total of 52 lesions (i.e., in about three-quarters of all cases) for reasons such as the following: "the involvement of other feeding vessels could be ascertained", "there was a greater degree of certainty in the prediction of therapeutic effects", and "it was possible to implement measures stopping chemicals reaching healthy tissue".

## Angiography System Equipped with Large 17-Inch FPD

It is fair to say that FPD-CT is sufficient for purposes such as tumor staining and conventional CTHA, and helps reduce examination times. Although it contributes to an overall reduction in exposure, with the 9-inch prototype, the small field of view restricts the range of application. Shimadzu has developed an extremely large 17-inch FPD (**Fig. 1**), and equipping this with FPD-CT functionality was our ultimate objective.
Also, a bi-plane system is required in neurological applications. We currently have both a large 17-inch FPD system and a 9-inch bi-plane system installed in our hospital, and I feel that, with these two systems, we have created an ideal environment for angiography and IVR.

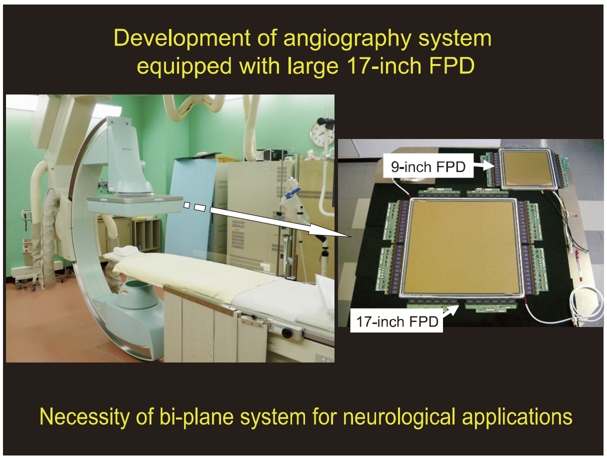


**Fig. 1** Large 17-Inch FPD System Installed in C-Arm

## Utility of FPD-CT Performed Using Large 17-Inch FPD

With the large 17-inch FPD, the number of pixels is 2,880 × 2,880, and the pixel pitch is 150 µm, the same as that for the 9-inch FPD. Selections of 9, 12, 15, and 17 are available as the size of the field of view. In contrast to the 16-inch I.I., its largest predecessor, the large 17-inch FPD enables the clear visualization of the four corners of the field of view, which I feel is extremely useful in actual imaging.

In so-called “cone-beam radiography” performed with an FPD, the rotation rate is approximately 20º/sec, and the reconstruction time in high-speed mode is 60 sec. A lot of time was required with the prototype but now the time required to display images is hardly enough to cause irritation on the part of the operator. Although the size of the reconstruction region is 26 cm × 18 cm, full reconstruction of the 26 cm in the axial direction is not possible. The difference in reconstruction range between the 9-inch FPD and 17-inch FPD in observation of the liver is clearly illustrated in **Fig. 2.** With the 17-inch FPD, the entire liver can be observed. Although the field of view in the axial direction may be slightly insufficient for larger patients, cases of hepatocellular carcinomas can be handled with hardly any problems.

Various attempts have been made to improve image quality. With FPD-CT, although the kind of noisy ring artifact shown in the left part of **Fig. 3** appears, this can be significantly reduced using an image processing filter, as shown in the right part of **Fig. 3**, and the image quality has improved since the first prototype.

In cases of multiple small hepatocellular carcinomas, patients like the one shown in **Fig. 4** are extremely common. With arterial phase CT, deeply stained images can be observed on both sides. With FPD-CT, both carcinomas are clearly visualized inside the reconstruction field of view. Because of the large imaging range of the 17-inch FPD, and because of the way that contrast medium can be clearly visualized when accurately injected, it can be said that the utility of FPD-CT images as those supporting IVR has increased significantly. Of course, it is not necessary to use CT to observe the state of lipiodol after injection. This can be done straight away by using FPD-CT as general CT without any contrast medium, as shown in **Fig. 5.**

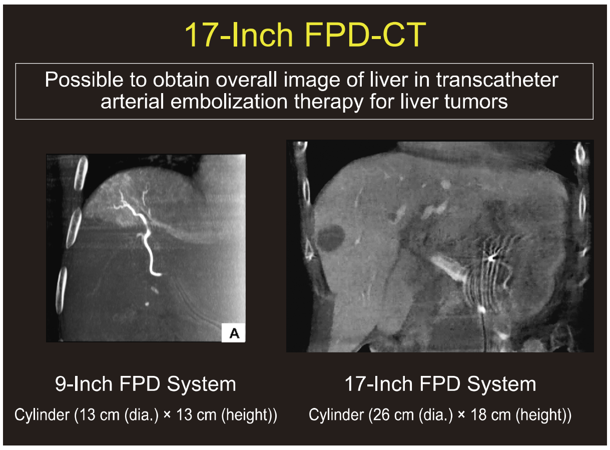


**Fig. 2** Comparison of FPD Reconstruction Regions for 9-Inch and 17-Inch FPDs

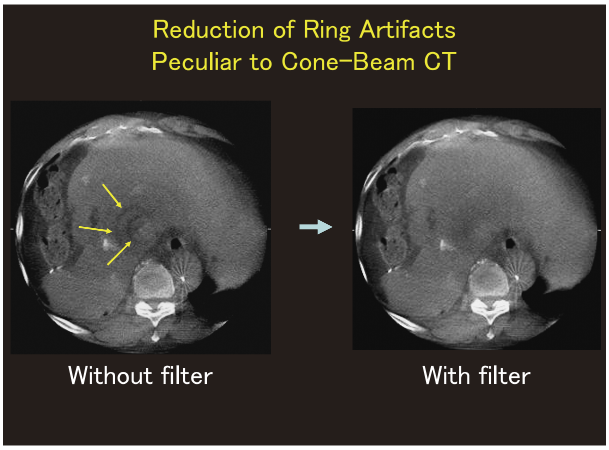


**Fig. 3** Reduction of Ring Artifacts with Image Processing Filter

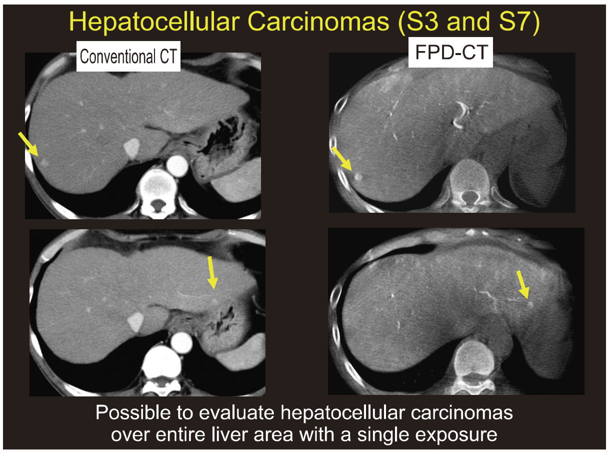


**Fig. 4** Comparison of Reconstruction Regions for Conventional CT and FPD-CT

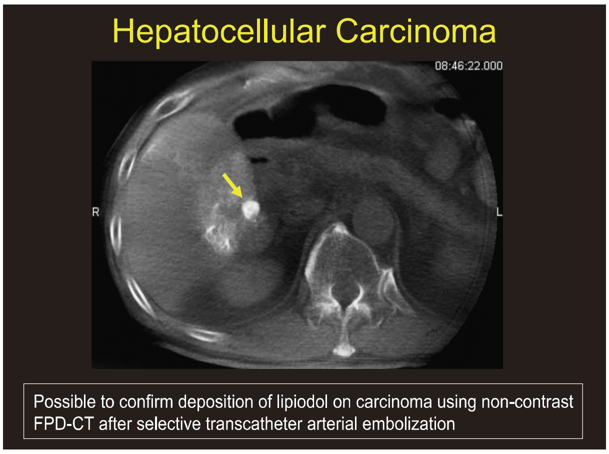


**Fig. 5** Immediate Confirmation of Lipiodol Deposition with FPD-CT

## Wide-Ranging Possibilities in Clinical Applications Offered by CT-Like Images (FPD-CT)

In addition to liver tumors, there are various other areas of application. **Fig. 6** shows an example of a BRTO (balloon-occluded retrograde transvenous obliteration). In the past, judgments about the way contrast medium had entered a varix were usually made with only fluoroscopic images. Adding FPD-CT to this makes it possible to refer to a larger number of section images, and allows operators to more precisely evaluate the entry into a varix. It is also possible to perform steric evaluation while rotating the data as a 3D image.

The large field of view seems to have helped the range of application expand into other areas, including chest and pelvic procedures. Imaging the chest gives the kind of image shown in **Fig. 7**. Because the lung field region has high contrast, it is natural that this much can be visualized, even with FPD-CT. In arterial injection chemotherapy, however, with 2D images, it is quite difficult to evaluate the extent to which a tumor can be visualized and the extent to which other structures in the mediastinum are affected. Using FPD-CT in such cases makes it possible to ascertain the staining range of the tumor, and it is possible to confirm that the chemical has been injected properly and to assess the extent to which it has flowed into healthy tissue.

Even with arterial injection used for cancer of the head and neck region, this function appears to be extremely useful, particularly for large tumors. Of course, from the position and spread of a tumor, it is possible to estimate, to a certain extent, which blood vessels are feeding it using previous experience. Even so, it is not uncommon for feeding arteries to exist in unexpected places. In such cases, confirmation is not possible without IVR-CT or FPD-CT and so, in arterial injection chemotherapy for cancer of the head and neck region, these techniques can be fairly described as indispensable.

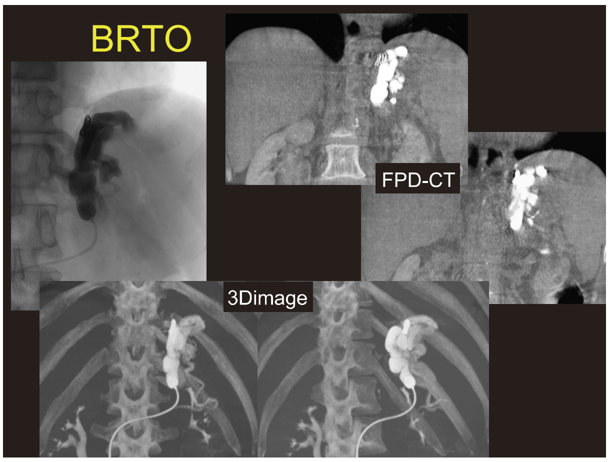


**Fig. 6** Fluoroscopic, 3D, and FPD-CT Images of BRTO

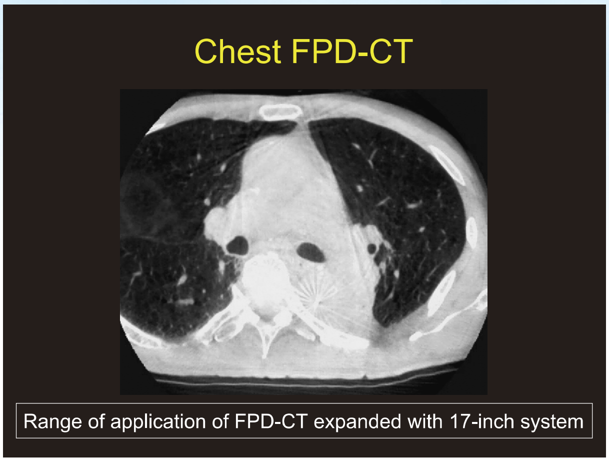


**Fig. 7** Application to Chest Region Utilizing Large Field of View

## Summary

In comparing IVR-CT and FPD-CT, it must be said that purchasing IVR-CT, if possible, is the best option. With only an FPD system, however, there are some advantages, such as the relatively low cost and the smaller space requirement, and with an IVR-CT system, some degree of movement between different systems is required. In consideration of these points, although the actual density resolution is lower, I believe that FPD-CT is sufficient for the objective of injecting contrast medium and observing its range of movement. Through the development of large-FPD systems and bi-plane FPD systems, it is likely that the range of application of FPD-CT in the field of IVR will continue to expand.