

Development of the OPESCOPE PLENO Surgical X-ray TV System

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1. Introduction

Following last year's release of the ACTIVO, the OPESCOPE series lineup of surgical X-ray TV systems was further bolstered by the addition of the PLENO. The ACTIVO is a specialized system for orthopedic applications that goes one better than earlier systems. It mainly uses fluoroscopy and offers an 8 frame memory even in the smallest configurations. The PLENO is a mobile C-arm imaging system that is equipped with the latest image-processing technology. It is not restricted to orthopedics and can be used for a wide range of applications, including cranial and abdominal angiography. In the development of these models, we strove to attain the conflicting goals of high image quality and low dose. In this article, we will focus on the features of the PLENO, which is the superior model of the two.



Fig.1 OPESCOPE PLENO

2. Development Items and Basic Specifications

The PLENO's basic specifications are shown in Table 1. Speedy operability and image quality are particularly important aspects for orthopedic applications. The PLENO's features and functions are described below.

2.1. C-arm Operability

C-arm positioning is performed manually using a fully balanced mechanism that incorporates vertical motion. This mechanism, which enables nimble positioning, has been highly regarded for some time. Furthermore, a handle equipped with a C-arm lock-free button has been added on the image-tube side. (See Fig.2.) Taking advantage of the fully balanced mechanism, which is a

feature of the OPESCOPE series, it is possible for the operator to temporarily release the lock and move the C-arm in the vertical, lateral, or longitudinal directions.

X-ray tube capacity	100 kHU fixed anode (0.6 mm focus)
CCD camera	1,024 × 1,024 matrix, 12 bits
I.I.	9/6 inches, 2 fields of view
Fluoroscopy mode (1)	Continuous fluoroscopy and pulsed fluoroscopy (15 fps max.)
Fluoroscopy mode (2)	Normal, High Quality, or Low Dose
C-arm operation	Manual operation incorporating vertical motion (fully balanced mechanism)
Virtual operation	Image rotation, collimator operation (possible for both monitor and C-arm)
Monitor	18 inch LCD, 2 sets (vertical motion possible)
DSA	7.5 fps max. (programmable sequence)
IBS (automatic brightness correction)	Fixed ROI at center or estimated ROI

Table 1 PLENO Basic Specifications



Fig.2 Handle Equipped with C-arm Lock-free Button

2.2 Fluoroscopy Modes Ensuring High Image Quality

We equipped the X-ray tube, which exerts the greatest influence over image quality, with a fixed anode offering a capacity of 100 kHU, the largest capacity in the industry. This makes it easily possible to satisfy the X-ray conditions for any application. The system incorporates the functionality to perform pulsed fluoroscopy at a

maximum frame rate of 15 fps as a standard feature, achieving a dosage approximately half that for continuous fluoroscopy. In addition to the conventional Normal dose mode, the high-dose High Quality mode (HLC: High Level Control) and the low-exposure Low Dose mode are also available. It is possible to switch between these modes at the touch of a button. These dose modes can also be used in combination with pulsed fluoroscopy, mentioned earlier, as well as standard continuous fluoroscopy. For example, if pulsed fluoroscopy is used together with High Quality mode, an image quality higher than the conventional level can be obtained at a dose less than the conventional continuous-fluoroscopy dosage. The system is also equipped with a mechanism that automatically inserts the Multi Beam Hardening filter (four selections available, including "filter OFF") suitable for the examined region.

2.3 Exposure Reduced with Virtual Operation

We developed a PC-based image-processing system, which determines image quality and operability, specialized for the PLENO. Providing Windows¹⁾ with a flexible interface allows simple, intuitive operation. As an example of a representative function, we will briefly describe the Virtual function, which is very effective for reducing exposure. With conventional mobile C-arms, there is no way of knowing the direction from which fluoroscopy was applied to the patient and so functions that can, for example, perform image rotation are required. This means that rotational image positioning is required before treatment (and during treatment, if the fluoroscopy direction changes). In order to minimize this exposure, we provided the system with Virtual Image Rotation and Virtual Collimator functions. (Fig.3.) The operation is described below.

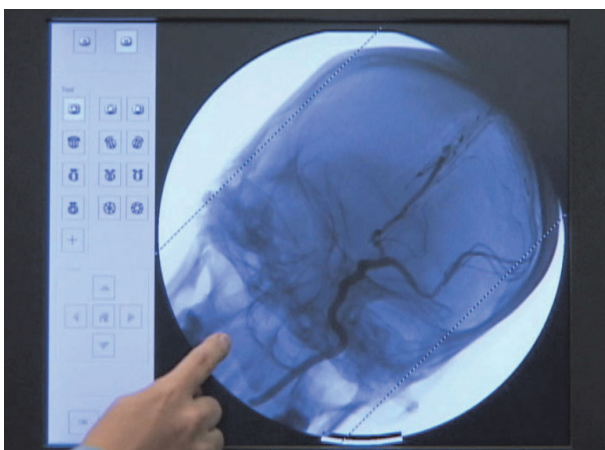


Fig.3 Image Rotation and Collimation Using Virtual Operation in the "Last Image Hold" Window

On performing the minimal level of fluoroscopy, the fluoroscopic image is captured and displayed as the LIH (Last Image Hold) image. Using the drag-and-drop function, perform virtual operations on this monitor display image, such as image rotation or vertical inversion, insertion of the octagonal collimator, or opening/closing and rotation of the rectangular collimator. (Fig.3.) The image on the monitor rotates in real time in accordance with the operations and the position is reconstructed when fluoroscopy is performed afterwards. Furthermore, with the PLENO, the same virtual operations are possible from the C-arm cart, not only the monitor. If the image-rotation switch on the C-arm cart is pressed with the LIH image displayed, the LIH image displayed at the monitor can be rotated and the collimator can be inserted just as if fluoroscopy were actually being performed at that time.

2.4 Introduction of New Type of IBS

We have also provided completely new functions in the area of IBS (Image Brightness Stabilizer), which automatically controls the X-ray conditions. The conventional method was to set a fixed ROI (Region of Interest) at the approximate center of the image and to adjust the X-ray conditions to attain an appropriate level of brightness for this region. This method, however, presents some problems. For example, if the part to be examined lies slightly outside the ROI, the X-ray conditions may not be set to appropriate values and it may not be possible to view the relevant part. In particular, when moving relatively small parts, such as finger joints, to reposition them, the object image may not always completely cover the ROI and some means of rectifying this, such as setting the X-ray conditions manually, is required. The problem can be temporarily solved by making the ROI smaller but this leads to other problems, such as excessive fluctuations in the X-ray conditions. In answer to this problem, we have developed a method for the PLENO where, instead of setting a fixed ROI, the image-processing system automatically estimates the location of the ROI within the entire region irradiated by X-rays. This means that, even if the desired ROI moves away from the center of the image, the X-ray conditions are changed appropriately.

2.5 Comprehensive DSA Functions

To facilitate the continuous image acquisition used, for example, when performing cranial or abdominal angiography, in addition to DSA and serial imaging (DA), we have equipped this system with Shimadzu's own original RSM-DSA, that makes it unnecessary for patients to hold their breath, and Blurred Mask-DSA (where the

mask image used in standard DSA is blurred). Also, no matter which method is used to obtain images, the images can be converted to other formats afterwards. For example, images acquired with DA can be converted to RSM-DSA images and RSM-DSA images can be converted to standard DSA images. The rate at which images are acquired (i.e., the frame rate) can be set to a fixed rate (7.5 fps max.), or a variable rate can be used (program sequence). This makes it possible to use different rates within the same angiography procedure. For example, a high rate could be used during the arterial phase and a low rate used during the venous phase. The feature helps realize significant reductions in the volume of contrast medium used and the level of exposure to the patient and operator.

2.6 Improved Monitor Cart

New ideas have also been incorporated in the PLENO's monitor cart. Not only have 18-inch LCD screens been included as part of the standard configuration, but the monitor has been mounted on a movable support, taking advantage of the lighter and thinner body. With conventional models, the monitor was fixed at standing height, making it necessary for the operator to look up at the monitor when seated. With this model, the height of the monitor can be adjusted to the height of the operator's field of view. (Fig.4.)

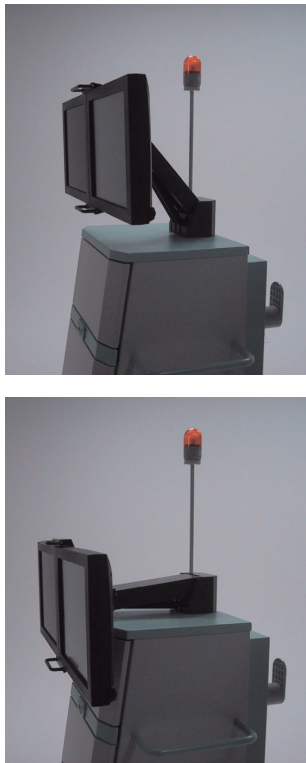


Fig.4 Height-adjustable Monitor Cart

3. Conclusion

While retaining the important features of earlier models, such as manual control of vertical C-arm motion, a fully balanced mechanism, and cable-free design, the PLENO and ACTIVO were developed with the aims of improving fluoroscopic images and reducing exposure, as well as realizing greater cleanliness, smaller dimensions, less weight, and greater speed.

A completely new style has also been adopted. This is not just a case of a superficial improvement in appearance. In addition to providing a light steering handle that utilizes the principle of leverage and mounting two large wheels on either side to reduce the sense of weight, we have also changed the brake positions and adopted a structure that allows the operator's feet to slide in under the equipment. This attention to detail makes for greater ease of use. (Fig.5)

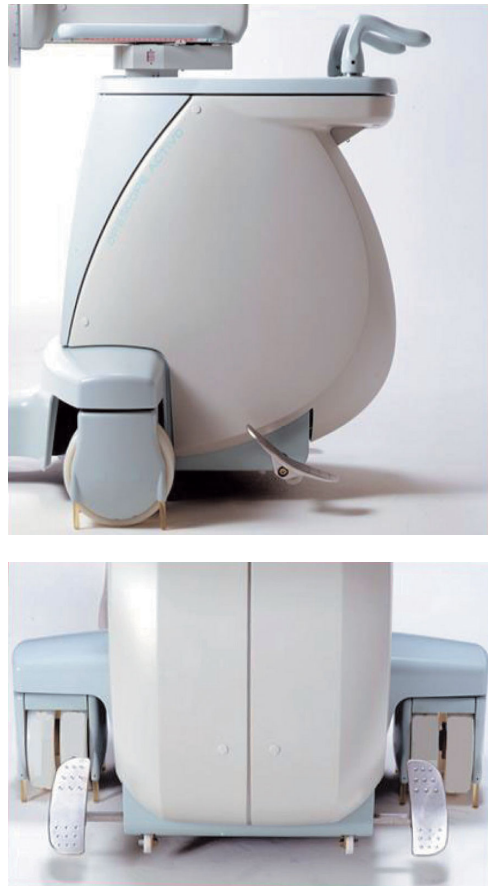


Fig.5 Modifications in the Shape, Steering Handle, Wheels, and Brakes Produce a C-arm with Greater Operability

In addition to orthopedic applications, this product lineup will make it possible to handle a wide variety of techniques, such as cranial and abdominal angiography and IVR. We hope that the range of application will continue to expand.

1) Windows is a registered trademark of Microsoft Corporation.