Development of the OPESCOPE ACTENO

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1. Introduction

The OPESCOPE Series Surgical Mobile C-Arm System offers:

- C-arm cart construction with no protruding cables
- Fully manual positioning, including vertical movements
- Pulsed fluoroscopy at 15 fps

This leads to following points that contribute to the popularity of the system:

- Sterile and compact
- Rapid positioning operations
- High image quality but low X-ray exposure dose

Shimadzu has developed the new OPESCOPE ACTENO range that further builds on the previous functions.
In this paper, we introduce the range of advanced functions offered by ACTENO, including:

- Fluoroscopic image display functionality added to the C-arm cart for all models
- Extended distance from X-ray tube to I.I.
- Narrower C-arm cart body
- More compact monitor cart
- Folding monitors to save space
- 1-megapixel TV camera as standard for higher image quality
- Boost-pulsed fluoroscopy as standard is a powerful tool for imaging thick objects, such as lateral radiography of the lumbar spine
- Virtual collimation further reduces X-ray exposure
- Realtime dose and cumulative dose monitor display functions (the demand for which is likely to grow in the future).

Fig. 1 OPESCOPE ACTENO

2. Basic Specifications and Development Topics

Table 1 summarizes the ACTENO basic specifications. The most important factors in the field of orthopedics, in particular, are quick operation and high image quality. The features and functions of ACTENO are described below.

X-ray tube capacity	100 kHU fixed anode (0.6 mm focal point)
CCD camera	1000 × 1000, 12 bit
Image intensifier	9/6-inch, 2 field of view switchable, or 6/4-inch, 2 field of view switchable
Fluoroscopy mode (1)	Continuous fluoroscopy, or Pulsed fluoroscopy (15 fps max.)
Fluoroscopy mode (2)	Normal or Low Dose
C-arm operation	Fully manual positioning, including vertical motions (Fully counterbalanced)
Virtual operation	Image rotation, collimator operation (Operations from C-arm cart)
Monitors	19-inch LCD, 1 or 2 monitors
IBS (Image Brightness Stabilizer)	Fixed at center of region of interest, or Predicted region of interest

Table 1 OPESCOPE ACTENO Major Specifications

2.1 Improved C-arm Operation

C-arm positioning follows the popular fully counterbalanced manual positioning method, including vertical motions. This method ensures rapid positioning. The greater 780 mm distance from the X-ray tube cover surface to I.I. (previously 700 mm) and the wider 670 mm C-arm depth (previously 660 mm) enhance the freedom of positioning. The width of the C-arm cart body has been reduced from 880 mm to 800 mm, making it more maneuverable.

An optional handle with C-arm lock-release button is available at the I.I. side to exploit the benefits of the fully counterbalanced OPESCOPE manual positioning. It allows the operator to temporarily release the C-arm lock to position the C-arm as required **(Fig. 2)**.

Fig. 2 Handle with C-arm Lock-Release Button

2.2 Improvements to the Monitor Cart

Improvements have also been made to the monitor cart. A monitor vertical movement / swing adjustment mechanism and folding mechanism for twin monitors can be added as monitor support options. The vertical movement adjustment mechanism allows the monitor height to be adjusted to match the operator's line of sight **(Fig. 3)**. The swing adjustment mechanism permits fine adjustment of the monitor orientation, without moving the monitor cart. The folding mechanism improves visibility during travel and reduces storage space requirements **(Fig. 4)**.

2.3 High Image Quality (One Megapixel)

ACTENO features a 1-megapixel CCD camera. The Normal, Low Dose 1, Low Dose 2, High Quality, and Boost Pulse (short-burst increases in X-ray output for patients with high body thickness) exposure dose modes combined with a pulse rate to 15 fps allow the optimal fluoroscopy condition to be selected for the region and procedure. The camera offers detailed images over a larger field of view.

The image stability is also improved. To maintain constant system sensitivity and minimize the effects of noise, sophisticated control circuitry has been added to the Image Brightness Stabilizer (IBS) that automatically controls the X-ray conditions. In addition, the Auto Window Level Control (AWC) function performs realtime processing according to the pixel value histogram of the displayed image to automatically adjust the image gradation and display images with stable density.

Fig. 3 Monitor Cart Vertical Movement Adjustment Mechanism

Fig. 4 Monitor Cart Folding Mechanism

The system also permits density adjustment to match the user's preferences by push-button operation. The brightness buttons added to the C-arm cart operating console allow rapid adjustment of the density in seven steps from -2 to +4 **(Fig. 5)**.

Fig. 5 Brightness Buttons

2.4 New Communications Control Method

Improvements have also been made to the cart cable that connects the C-arm cart to the monitor cart, which has to be installed, cleaned, and stored for each procedure.

The cart cable handles power supply and transmission of image data and other data. It contains multiple cables for different applications combined in a complex manner. In the past, this inevitably resulted in a thick and heavy cable which was difficult to route.

In addition, data traffic is now significantly heavier than previous systems to support the realtime display of exposure dose and other information.

ACTENO adopts a new high-speed communication control method that supports higher speeds and multiplexing. It results in a lighter cable that is only two-thirds the previous diameter, and makes it much easier to handle the cart cable.

2.5 Virtual Operations Contribute to Reduced Exposure

ACTENO offers virtual operations as standard. Mobile C-arm systems generally require an image rotation function, as there is no way to determine the direction in which fluoroscopy was performed with respect to the patient. Therefore, the image rotation position needs to be determined prior to treatment (and during the treatment, if the fluoroscopy direction changed). The virtual image rotation and virtual collimator functions provide powerful tools to minimize X-ray exposure dose during this operation.

The operation is as follows. Virtual operations on the Last Image Hold (LIH) image displayed on the monitor perform image rotation with respect to the C-arm cart, vertical and horizontal inversion, octagonal collimator insertion, and opening, closing, and rotation of the parallel hole collimator **(Fig. 6)**. This image is then reproduced when fluoroscopy is performed **(Fig. 7)**.

2.6 New Exposure Dose Display Function

The X-ray dose management functions have been enhanced to meet the demands for stricter management of exposure dose in recent years. The X-ray conditions during fluoroscopy and size of collimator opening are monitored. This information is used to work out the calculated dose per unit area, which is displayed on the image monitor in realtime **(Fig. 8)**. By installing the optional area dosimeter, the display can be changed to indicate the actual exposure dose.

ACTENO meets the stringent requirements for exposure dose management in the 3rd Edition of the IEC60601 standard.

Fig. 6 Virtual Collimation Setting Screen

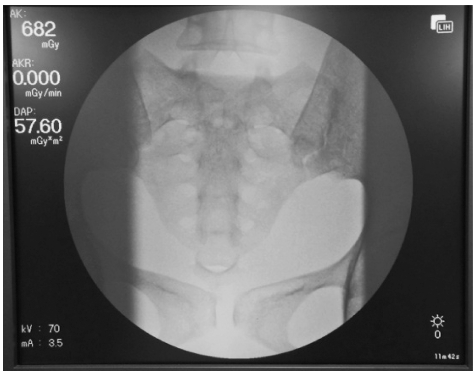

Fig. 7 Fluoroscopy Screen after Virtual Collimation

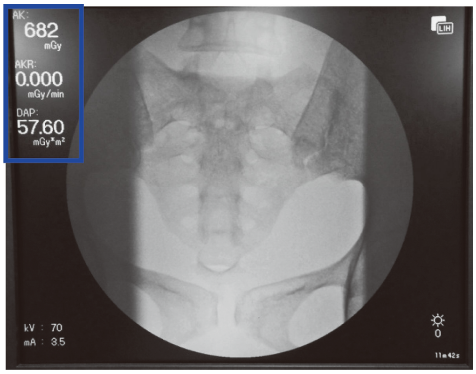

Fig. 8 Exposure Dose Display

3. Conclusions

This paper introduced the OPESCOPE ACTENO Surgical Mobile C-Arm Imaging System. It inherits the fully counterbalanced C-arm vertical motion and cableless construction of previous models, with new features to improve fluoroscopic image quality and reduce X-ray exposure dose. You will find that the OPESCOPE ACTENO is even easier to use.