



Endovascular Intervention with a Mobile C-Arm in the Operating Room

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Mobile C-arm fluoroscopic X-ray systems are used for various diagnostic imaging and minimally invasive endovascular procedures. One of the greatest advantages of a mobile C-arm is its ability to move around the patient. The purpose of this study was to address the optimal setting of the mobile C-arm and the operating table, as well as the proper position of the operator and assistants for each procedure. In addition, methods to minimize radiation exposure to the operator and medical staff are described. Both the optimal setting and the proper position were classified by 5 types. These include the setting for aortic and inferior vena caval procedures (type I); left lower extremity (LE) intervention with an up-and-over technique (type II); right LE intervention with up-and-over technique, or bilateral LE vascular intervention with antegrade access (type III); arteriovenous fistula/graft intervention (type IV); and central vein catheterization (type V).

Key Words: Fluoroscopy, Endovascular procedures, Aorta, Lower extremity, Catheterization

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INTRODUCTION

Mobile C-arm fluoroscopic X-ray systems are used for various diagnostic imaging and minimally invasive surgical procedures. In the operating room (OR), they help visualize procedures for neurology, cardiology (e.g., percutaneous valve replacement), pain management, nephrology (e.g., kidney drainage), gastroenterology, and orthopedic specialties. In addition, the mobile C-arm is frequently used in vascular surgery due to the specialty's frequent use of endovascular procedures. Such vascular procedures include endovascular aortic aneurysm repair, peripheral vascular intervention, and dialysis vascular access [1-4].

Most vascular surgeons began their endovascular procedures using a mobile C-arm in the OR [5], primarily due to availability, comfort, and ease of scheduling. One of the greatest advantages of the mobile C-arm is its ability to move around the patient. It enables achievement of an

optimum angle for a high-quality image without causing discomfort to the patient [6].

However, there are several drawbacks to using mobile C-arm imaging. Often, it lacks the precision to perform more complex procedures, such as aortic fenestrated grafts and small vessel catheterizations. Moreover, its tendency to overheat limits its use. Therefore, the time added for the mobile C-arm to cool down contributes to an already time-consuming procedure. In addition, it can be uncomfortable for an operator to perform a procedure due to an improper setting of the mobile C-arm system and the operating table. The purpose of this paper is to address the optimal settings for the mobile C-arm and the operating table, and the proper positions for the operator and assistants for each procedure. In addition, methods to minimize radiation exposure for the operator and medical staff are described.

MOBILE C-ARM SYSTEM

Most systems consist of two-wheeled units, one supporting the C-arm and the control console, and the other supporting display monitors, image processing, and recording devices. The mobile C-arm consists of a curved arm with an X-ray tube mounted on one end, and an image intensifier or flat-panel digital detector on the other (Fig. 1). The stand is constructed so that the C-arm can perform both linear and rotating motions for optimum positioning with respect to the patient.

X-rays are produced by the X-ray tube when a stream of

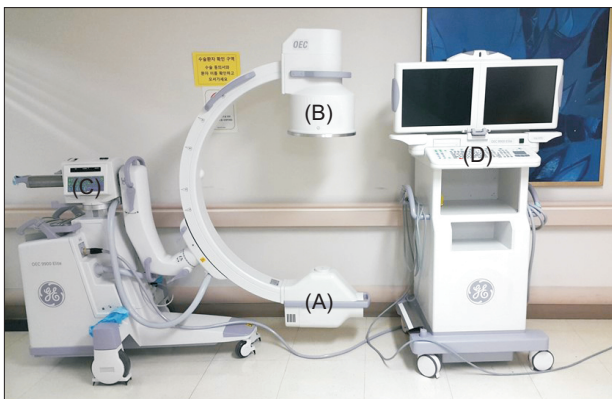


Fig. 1. Composition of the mobile C-arm system. The mobile C-arm consists of a curved arm with an X-ray tube (A) mounted on one end and an image intensifier (B) flat-panel digital detector on the other; it also consists of a control console (C). The separate equipment (connected by cable) is the supporting display monitors and image processing and recording devices (D).

electrons, accelerated to high velocities by a high-voltage supply, collides with the tube's target anode [7]. A set of collimators confines the primary beam to the approximate size and shape of the diagnostic interest [8]. X-rays emerging from the patient carry the image information to the input phosphor of an image intensifier, or to a flat-panel digital detector (Fig. 2). The energy of the X-rays detected at the input phosphor is emitted as light that causes the photocathode to release electrons. These electrons are accelerated and focused to produce an image on the output screen. All fluoroscopic systems use a camera to scan and transmit the image to a remote display monitor. Flat-panel detectors use a scintillator material to convert X-rays to visible light, which is translated into a signal suitable for digital display.

MINIMIZING RADIATION EXPOSURE

Minimizing radiation exposure is an important concern to the patient and the operating team performing the endovascular procedure. Intraoperative dose monitoring is mandatory, and compliance with dose monitoring should be tracked as a part of ongoing quality assurance. Documentation of images and fluoroscopy time or dose should be recorded after the procedure [9]. Recommendations to minimize radiation exposure are shown in Table 1.

The three most protective means of reducing radiation exposure to the operators and other medical staff in the room during fluoroscopy are related to exposure time, distance from the radiation source, and shielding [9]. Minimization of time spent in a radiation field is the main principle of radiation safety and exposure reduction. Fluoroscopy time should be minimized to protect patient and staff, but

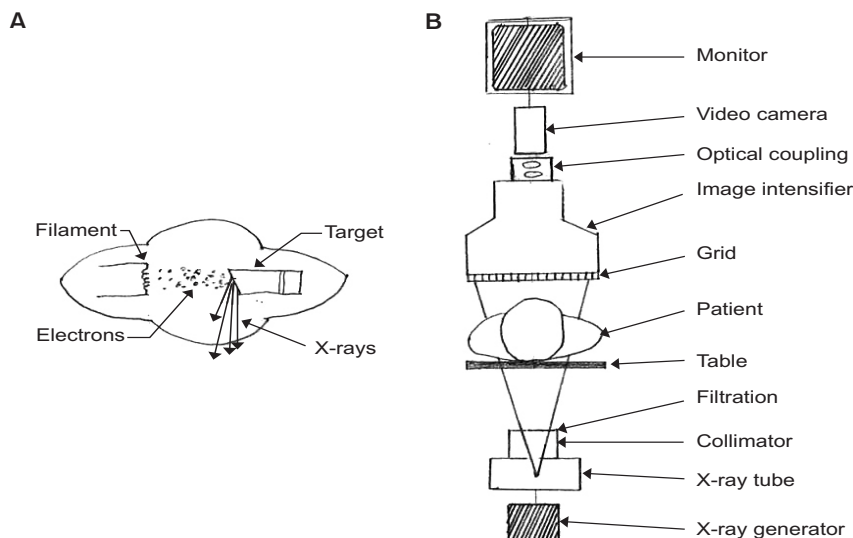


Fig. 2. Process of fluoroscopic imaging. (A) X-rays are produced by the X-ray tube when a stream of electrons collides with the tube's target anode (B). X-rays produced by the X-ray generator pass through the patient's body and carry the image information to the input phosphor of an image intensifier, or to a flat-panel digital detector.

a balance must be reached between the protective clinical use of X-rays and minimizing fluoroscopy time.

Radiation dose rates increase or decrease according to the inverse square of the distance from the source [9]. As mentioned previously, the main source of radiation exposure to fluoroscopic staff is scattered radiation from the patient, not from the X-ray tube. Understanding the inverse square law can help personnel to decrease their exposure to scattered radiation. The inverse square law states that exposure at a distance from a point of radiation is inversely proportional to the square of the distance. Distance is a powerful protector against radiation exposure.

Lead garments, lead gloves, thyroid shields, leaded safety eyeglasses, lead drapes, and clear leaded glass barriers between the patient and the operator all reduce exposure to medical personnel from scattered radiation [10,11]. Most state regulations require that all persons, including staff or other patients, be at least 2 meters away from the X-

ray tube or the exposed area of the patient's body, or they must be protected by a lead apron [9].

SETTING OF THE OPERATING TABLE

C-arms work in conjunction with patient tables specifically designed for X-ray imaging. A table should allow free positioning of the C-arm around the patient [12]. Some tables are designed to move and rotate to allow better patient access for procedures, and to aid imaging angles. Tables also need to be X-ray translucent so they do not interfere with imaging. Carbon fiber tables are usually used in this role because they are strong and lightweight [13].

If the specifically designed X-ray translucent table is not available, the regular operating table should be adjusted. During the procedure, the rotating C-arm should move under the table freely. Also, the system should be able to transmit the beam through the region of interest. The useful adjustment of a regular operating table for an endovascular procedure is shown in Fig. 3. For diagnostic or therapeutic procedures above the inguinal region of the body, such as endovascular abdominal aortic aneurysm repair, the operating table should be adjusted to cover the entire body above the inguinal area, as shown in Fig. 3A. On the other hand, the operating table should be adjusted for the procedures of the lower extremity, as shown in Fig. 3B.

Table 1. Minimizing radiation exposure

Use ultrasound imaging when possible
Position the image intensifier as close to the patient as practicable
Maximize distance from the radiation source
Use the exposure pedal as sparingly as possible
Use pulse fluoroscopy whenever possible
View and save images with last-image-hold
Collimate to use the smallest field of view practicable
Position and collimate without using fluoroscopy
Use magnification only when necessary
High-dose or detail modes should be used only when necessary
Use highest kVp possible to produce acceptable image contrast
Minimize overlap of fields in repeated acquisitions

PROPER SETTING FOR SPECIFIC PROCEDURES

Various endovascular procedures can be performed with a mobile C-arm system and conventional operating table. However, the optimal setting for the system, as well as the

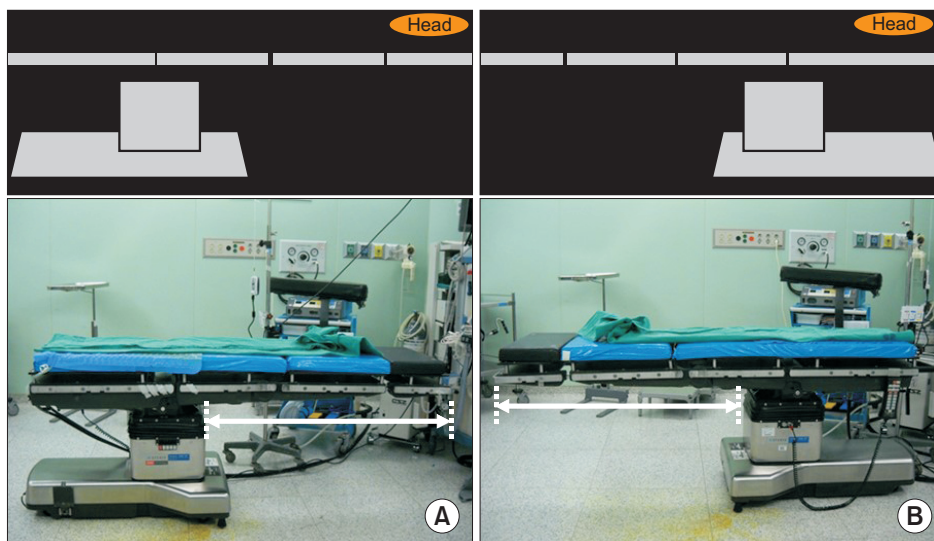


Fig. 3. Optimal adjustment of the operating table. (A) For procedures of vessels of the abdominal and thoracic cavities, it is useful to adjust the operating table with longer upper portion (arrow). (B) On the other hand, the adjustment of the longer lower portion enables the performance of a variety of procedure of the lower extremities (arrow).

proper position of the endovascular team, is necessary for maximum comfort during the procedure. With these settings, an operator is able to access the vessel with comfort, properly deliver the guidewire and endovascular devices, and use the closing devices with safety. An assistant and scrub nurse should be able to handle and deliver the de-

VICES with ease. There are five types of adjustments for endovascular equipment and team positions. A list of specific procedures with each setting is shown in Table 2.

1) Type I. Aortic, vena caval, and splanchnic vessel intervention

Table 2. The possible procedures with the each setting

Setting	Possible procedure
Type I	Endovascular thoracic aortic aneurysm repair Endovascular abdominal aortic aneurysm repair Procedures for the iliac arteries and veins Procedure for the inferior vena cava Procedures for splanchnic arteries or veins Procedures for vascular disease of the upper extremity
Type II	Left LE vascular intervention with up-and-over technique
Type III	Right LE vascular intervention with up-and-over technique Right/left LE vascular intervention with antegrade access
Type IV	Arteriovenous fistula/graft intervention
Type V	Chemoport insertion Permanent catheter insertion for hemodialysis PICC catheter insertion

LE, lower extremity; PICC, peripherally inserted central catheterization.

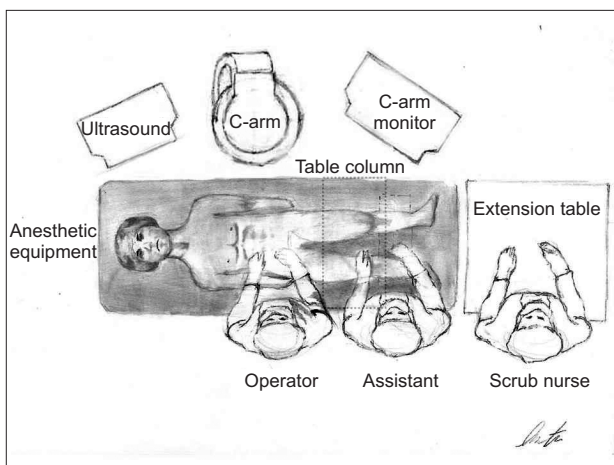


Fig. 4. Position of endovascular equipment and the team for the aortic, vena caval, and splanchnic vessel intervention. After the patient is placed in a supine position with the table setting as shown in Fig. 3A, the endovascular team is positioned at the right side of the patient. The scrub nurse with an extension table is positioned at the right side of the assistant. All endovascular equipment including ultrasound, a C-arm, and the C-arm monitor are placed at the left side of the patient.

A patient is placed in the supine position using the table setting as shown in Fig. 3A. The C-arm can be moved from the head to the patient's knee joint because the table column is positioned at the level of the knee joint. The endovascular team is positioned at the right side of the patient. The ultrasound equipment is positioned at the uppermost portion of the patient's left side (Fig. 4). After successful access using ultrasound, the system is moved in such a way as to allow for the free movement of the mobile C-arm system around the table. Then, the C-arm is moved to the region of interest. An assistant is positioned at the right of the operator, and a scrub nurse with an extension table is positioned at the right of the assistant. This position enables the delivery of the endovascular devices without discomfort for the team. A C-arm monitor is placed to the left side of the patient so that the operator can look at the C-arm monitor during the procedure (Fig. 4).

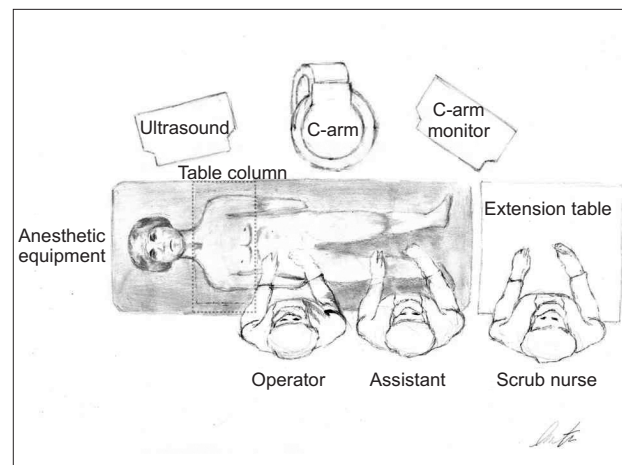


Fig. 5. Position of endovascular equipment and the team for the intervention of left lower extremity vessel. After the patient is placed in a supine position with the table setting as shown in Fig. 3B, the endovascular team is positioned at the right side of the patient. The scrub nurse with an extension table is positioned at the right side of the assistant. All endovascular equipment including ultrasound, a C-arm, and a C-arm monitor are placed at left side of the patient. This position enables the performance of the retrograde up-and-over technique.

2) Type II. Intervention for the vessel of the left side

The operating table is set as shown in Fig. 3B. The endovascular team is positioned at the right side of the patient. A scrub nurse with an extension table is positioned at the side of an assistant. All endovascular equipment, including the ultrasound, the C-arm, and the C-arm monitor are placed at the left side of the patient (Fig. 5). After access of the right femoral artery under ultrasound guidance, the ultrasound equipment is moved far from the patient. Then the guidewire is passed across the abdominal aortic bifurcation and inserted into the vessel of the left lower extremity (the retrograde up-and-over technique). Other endovascular devices can be delivered from the access site to the left side. Sometimes, the abdominal aortic bifurcation cannot be imaged because the C-arm cannot be moved to the upper side due to the position of the table column. This situation can be overcome by cranial rotation of the C-arm (Fig. 5).

3) Type III. Intervention for the right vessel with the up-and-over technique and for the vessels of both sides with antegrade access

The operating table is set as shown in Fig. 3B. The endovascular team is positioned at the left side of the patient. An assistant and scrub nurse with an extension table are positioned at the side of an operator. All endovascular equipment including ultrasound, a C-arm, and a C-arm monitor are placed at the right side of the patient (Fig. 6). This position enables the operator to perform the retrograde up-and-over technique for the intervention of right leg vessels or antegrade access for intervention of both sides (Fig. 6).

4) Type IV. Intervention for hemodialysis access on the left upper extremity

The operating table is set as shown in Fig. 3A. The endovascular team is positioned at the left side of the patient. The assistant and scrub nurse with an extension table are

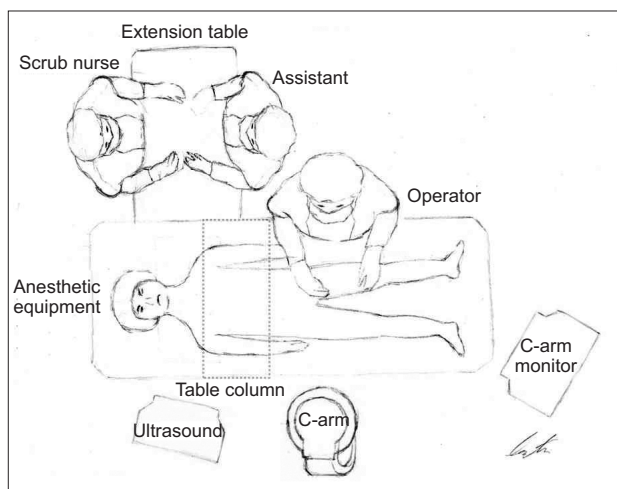


Fig. 6. Position of endovascular equipment and the team for right lower extremity (LE) vessel intervention with the up-and-over technique, and antegrade access of the vessels of both sides. After the patient is placed in a supine position with the table setting as shown in Fig. 3B, the endovascular team is positioned at the left side of the patient. The assistant and scrub nurse with an extension table are positioned at the side of the operator. All endovascular equipment including ultrasound, a C-arm, and a C-arm monitor are placed at right side of the patient. This position enables the performance of the retrograde up-and-over technique for the intervention of right LE vessels, or antegrade access for intervention of the left LE vessel.

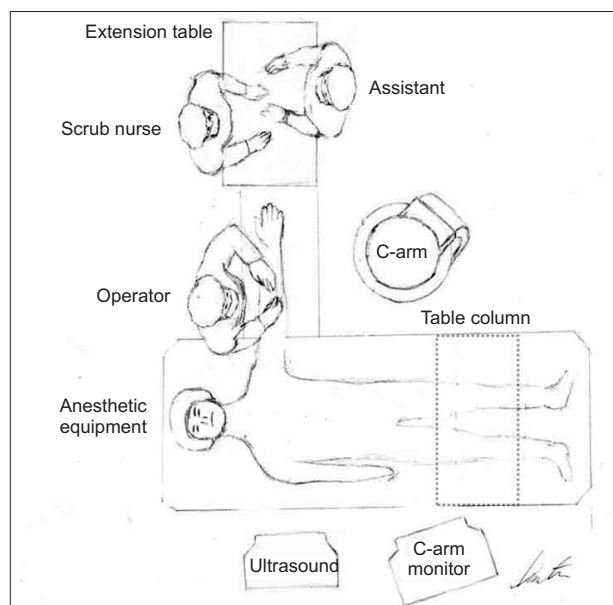


Fig. 7. Position of endovascular equipment and the team for the intervention of hemodialysis access of the left arm. After the patient is placed in a supine position with the table setting as shown in Fig. 3A, the endovascular team is positioned at the left side of the patient. The assistant and scrub nurse with an extension table are positioned at side of the operator. A C-arm is placed at left side of the patient. This can be moved to the left axilla of the patient, enabling the scanning of all areas of the left arm and central vessel. An ultrasound and a C-arm monitor are placed at right side of the patient.

positioned at the side of the operator. A C-arm is placed at the left side of the patient. This can be moved though the left axilla of the patient, enabling a scan of all areas of the left arm and central vessel. An ultrasound and a C-arm monitor are placed at the right side of the patient. This setting enables the performance of interventions for failed radiocephalic and brachiocephalic fistulas, as well as for a failed arteriovenous graft of the left upper extremity (Fig. 7).

5) Type V. Intervention for central vein catheterization

The operating table is set as shown in Fig. 3A. The operator is positioned at the right side of the patient's neck. With this position, easy access of the right internal jugular vein or subclavian vein is allowed. The scrub nurse with an extension table is positioned at the right side of the patient. In this position, the scrub nurse can deliver the necessary devices for the procedure with ease. All endovascular equipment including ultrasound, a C-arm, and a C-arm monitor are placed at the right side of the patient. This position enables the operator to perform the insertion of an inferior vena cava filter via the right internal jugular vein (Fig. 8).

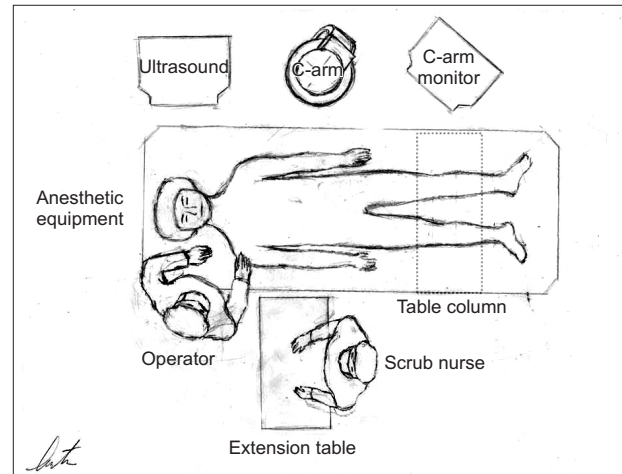


Fig. 8. Intervention of central vein catheterization through the left jugular or subclavian vein. After the patient is placed in a supine position with the table setting as shown in Fig. 3A, the endovascular team is positioned at the right side of the patient. An operator is positioned at the right side of the patient's neck, and a scrub nurse with an extension table is positioned at the right of the patient. All endovascular equipment including ultrasound, a C-arm, and a C-arm monitor are placed at right side of the patient.

CONCLUSION

Mobile C-arm fluoroscopy systems include an image intensifier with a monitor. Fluoroscopic equipment and the proper positioning of the operator and medical staff can be set for a wide variety of endovascular procedures.

CONFLICTS OF INTEREST

The author has nothing to disclose.

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