Radiopaque Ruler-Guided Frozen Elephant Trunk Technique

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Frozen elephant trunk (FET) technique combines open surgery and endovascular repair for extensive thoracic aortic aneurysms. When a FET is inserted into the descending thoracic aorta, it is difficult to confirm its proper positioning. Here we report a radiopaque ruler-guided FET technique. On the basis of preoperative computed tomography, we create a roadmap which shows the relationship between the descending thoracic aorta and vertebrae. During surgery, a radiopaque ruler placed beneath the patient’s back provides the accurate target position under fluoroscopy. Our technique is effective to prevent spinal cord injury because it avoids an overly deep implantation of a FET.

Keywords: thoracic aortic aneurysm, open surgery, endovascular repair

Introduction

Frozen elephant trunk (FET) technique is a hybrid surgical and endovascular repair for aortic diseases involving the aortic arch and descending thoracic aorta. Antegrade delivery of a stent graft through a median sternotomy can treat extensive aortic lesions in a single stage.1)

When a FET is inserted into the descending thoracic aorta, it is very difficult to confirm its proper positioning. A shallower implantation than the target position is inadequate because it leads to type Ib endoleak. Conversely, an overly deep implantation of a FET can lead to spinal cord injury.2,3) Here, we describe the FET technique using a radiopaque ruler under fluoroscopy, which enables the precise deployment at the target position.

Technique

A 73-year-old male, who had a distal arch aneurysm with a maximal diameter of 55 mm, underwent a total arch replacement using the FET technique. Based on preoperative computed tomography (CT), we created a roadmap which showed the relationship between the thoracic aorta and vertebrae (Fig. 1). We decided the target position of a FET according to following criteria: i) the distal landing zone is >20 mm and ii) FET is never inserted over T7. If an implantation of a FET over T7 is needed to secure an adequate landing zone, we consider that the FET technique is contraindicated. In this patient, the target position was set at the lower border of T6.

Before starting surgery, a radiopaque ruler (LeMaitre Stent Guide 270 mm, LeMaitre Vascular, Burlington, MA) was placed beneath the left side of the patient’s back, and then we confirmed the graduation of the ruler which indicated the target position under fluoroscopy. Prophylactic cerebrospinal drainage was not routinely performed.

After exposure of the left axillary artery using an infraclavicular approach, a median sternotomy was performed. The left pleural cavity was opened, and a hole was bored in the 2nd intercostal space. Thus, an extra-anatomical bypass route from the mediastinum to the left axillary artery was created. After systemic heparinization, cardiopulmonary bypass was established by cannulation of the ascending aorta and right atrium. While systemic cooling, an 8-mm Triplex vascular prosthesis (Terumo, Tokyo, Japan) was anastomosed to the left axillary artery. Circulatory arrest was induced at a rectal temperature of 25°C. After clamping the ascending aorta, cold crystalloid cardioplegia was administered through the aortic root cannula. Selective cerebral perfusion was initiated using balloon catheters cannulated into the brachiocephalic and left common carotid artery. The left subclavian artery was ligated and perfused using the 8-mm graft which was anastomosed to the left axillary artery. The aortic arch was transected between the brachiocephalic and left common carotid artery. The orifice of the left common carotid artery was stumped. A 33 × 90 mm J Graft Open Stent (Japan Lifeline, Tokyo, Japan) was inserted into the descending thoracic aorta and deployed at the target position.
Radiopaque Ruler-Guided FET Technique

The FET technique, also called open stent grafting, is a procedure which combines open surgery and endovascular repair for aortic diseases, including aneurysms and aortic dissection. An implantation of a stent graft into the descending thoracic aorta through a median sternotomy can treat extensive aortic diseases in a single stage.\(^1\) Furthermore, the FET technique avoids an additional left thoracotomy and a distal anastomosis in a deep and narrow surgical field.

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ruler has two major advantages. First, it enables quick and easy confirmation of the target position in a busy radiographic field, including a sternal retractor, a probe of TEE, central and Swan-Ganz catheters, and electrocardiogram wires. The use of fluoroscopy during hypothermic circulatory arrest requires approximately 5 min. Second, it serves as a guide for the stent graft at increments of millimeters. Although the target position was set at the border of the vertebra in this case, the radiopaque ruler-guided FET technique can allow the placement of the target position anywhere by measuring the distance from the border of the referenced vertebra. However, when using the radiopaque ruler-guided FET technique, it is important to not change the angle of view through the fluoroscope before and during surgery.

In the present case, the operative duration was 407 min, and the duration of hypothermic circulatory arrest was 90 min. As mentioned above, the time required for fluoroscopy was negligible. Indeed, femoral artery perfusion with balloon occlusion of a FET may be an effective option for reducing the duration of hypothermic circulatory arrest despite the risk of retrograde aortic dissection. Meanwhile, left subclavian artery rerouting and intraoperative aortography may prolong operative duration. However, aorto-left axillary bypass, in addition to the FET technique, avoids vascular anastomosis in a deep and narrow surgical field. This advantage results in complete hemostasis at the anastomotic sites, allowing the maintenance of high blood pressure postoperatively. A mean blood pressure of over 90 mmHg is recommended after thoracic endovascular aortic repair to prevent spinal cord injury.

We consider the fluoroscopy-guided FET technique to be the most reliable method to confirm the proper positioning of a FET, and the additional use of a radiopaque ruler has two major advantages. First, it enables quick and easy confirmation of the target position in a busy radiographic field, including a sternal retractor, a probe of TEE, central and Swan-Ganz catheters, and electrocardiogram wires. The use of fluoroscopy during hypothermic circulatory arrest requires approximately 5 min. Second, it serves as a guide for the stent graft at increments of millimeters. Although the target position was set at the border of the vertebra in this case, the radiopaque ruler-guided FET technique can allow the placement of the target position anywhere by measuring the distance from the border of the referenced vertebra. However, when using the radiopaque ruler-guided FET technique, it is important to not change the angle of view through the fluoroscope before and during surgery.

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We consider
intraoperative aortography to confirm the absence of type Ib endoleak to be crucial in the management of blood pressure after FET implantation.

**Conclusion**

In summary, we describe the radiopaque ruler-guided FET technique. This simple technique enables implantation of a FET at the accurate target position. Avoiding an overly deep implantation of a FET is important to prevent spinal cord injury.

**Disclosure Statement**

The authors have no conflict of interest to declare.

**Author Contribution**

Study conception: AI
Data collection: AI
Treatment of the patient: AI, TK
Writing: AI
Critical review and revision: KM, TJ
Final approval of the article: all authors
Accountability for all aspects of the work: all authors

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