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Thoracic vertebra interbody fusion surgery with robotic assisted system in a swine model

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ABSTRACT

Minimally invasive procedures have been increasing in spine surgery, and interest in robotic systems has inclined. In this study, we aimed to evaluate feasibility of a robotic-assisted thoracic spine interbody fusion in a swine model. Neurosurgeons performed the surgical procedures with robotic surgery certificates on the Da Vinci Xi Surgical System. Surgical approaches were applied using four ports while the swine was in the left lateral position. The surgical procedure was accomplished in 70 min including positioning and preparation of robotic system (20 min), placement of ports and thoracic dissection and confirmation of level with the C-arm system (10 min), discectomy and cage insertion (15 min), control of cage position via the C-arm system and closure (10 min). This study showed the anterior thoracic approach with robotic surgery is safe and feasible with providing a wide working area and high image quality.

1. Introduction

Instrumental surgeries are commonly done in spine surgeries, and complications can be seen in these operations. Surgeries with robotic systems have begun to develop aiming for having less complicated procedures [1]. Among the robotic systems (RS), the Da Vinci system has been approved by the FDA in 2000 [2]. Robotic systems have been widely used in surgical interventions such as in retroperitoneal, transoral, and transperitoneal routes. However, it could not have taken a conventional place routine spine pocedures [3]. Surgeries done with the da Vinci system were preferred in spine surgeries because of their minimally invasive nature, fewer complications such as damage to the vessel and ureter, and successful dissections [4].

There are advantages and disadvantages of using robotic systems in spine surgeries. In spinal surgeries, surgeons might experience muscle fatigue and pain due to long surgical times and demanding surgical techniques. Robotic systems could increase comfort of spine surgeons and shorten operation time due to their minimally invasive nature. However; cost of RS is very high and demanding. Ih recent years, da Vinci RS has been used in some types of spine procedures: paraspinal schwannomas, neurofibromas, and transoral route odontoidectomies [5]. Literature about approaching anterior thoracic spine for interbody cage insertion and fusion with da Vinci RS is scarce. Our aim was to depict advantages and disadvantages of the robotic system by making an anterior approach to the thoracic vertebra with the robotic system in a pig model.

2. Material and method

Study protocol has been approved by Acıbadem Mehmet Ali Aydınlar University Clinical Simulation and Advanced Endoscopic Robotic Surgery Training Center and by ethic committe of the same university. A robotic anterior approach was done to the thoracic spine using one frozen swine cadaver weighing 54 kg. Surgical procedures were done by a neurosurgeon with a robotic surgery certificate for the Da Vinci Xi Surgical System.

The swine was put into left lateral decubitus position. The robotic surgical approach was accomplished using four ports: 12 mm port for camera, two 8 mm ports for robotic arms, and 12 mm auxiliary port for discectomy and cage insertion. During the procedures, CO2, was used for pneumatization. During the trials, an 8 mm da Vinci Xi 3D camera with 0 degree endoscope was used. An 8 mm 30 degree endoscope was also available for use

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where necessary. Curved bipolar dissector, bipolar forceps, and robotic instruments were used for dissection and homeostasis. Disc removal and cage deployment were done through an auxiliary surgical port using a curette, punch, and a viewing cage. Thoracic procedure time was recorded. Anatomical structures encountered during the procedures, robotic maneuvers in the field of discectomy, and deterioration in the surrounding vital structures were recorded.

3. Results

In the thoracic approach, endoscopic camera ports and two robotic arms were placed intercostally (Fig. 1). While air pressure was increased via pneumatization with CO2, the right lung was deflated. Thus, a suitable corridor was provided for approaching the thoracic vertebrae. At this stage, thoracic vertebral bodies under the anterior longitudinal ligament were observed medial to the rib and behind the right lung (Fig. 2). Cauterization and dissection of the anterior longitudinal ligament and 7th and 8th costal with curved bipolar forceps revealed the intervertebral disc and vertebral bodies superior and inferior to the disc. T7 and T8 vertebral bodies were located behind the VCI (Fig. 3). Level of the intervertebral disc was confirmed using the C-arm system.

The 4th (auxiliary) port was placed for discectomy procedure and was used by an assistant surgeon with the endoscopic view of the robotic system. Endoscopic discectomy was done using punch and curette, preserving the VCI and right lung (Fig. 4). After discectomy, the intervertebral cage was inserted through the auxiliary port. (Fig. 5). The cage's level and position in the intervertebral disc space were verified using the C-arm system. (Fig. 6). No deterioration was observed in vital structures during the procedures. Radiographs in the procedure showed that the cage was successfully positioned in the center of the disc space.

The thoracic procedure was completed in 70 min: positioning and preparation of the robotic system (20 min); port placement, connection, and intrathoracic placement of robotic arms (15 min); confirmation of level with thoracic dissection and C-arm system (10 min); discectomy and cage insertion (15 min); control and closing the cage position with the C-arm system (10 min).

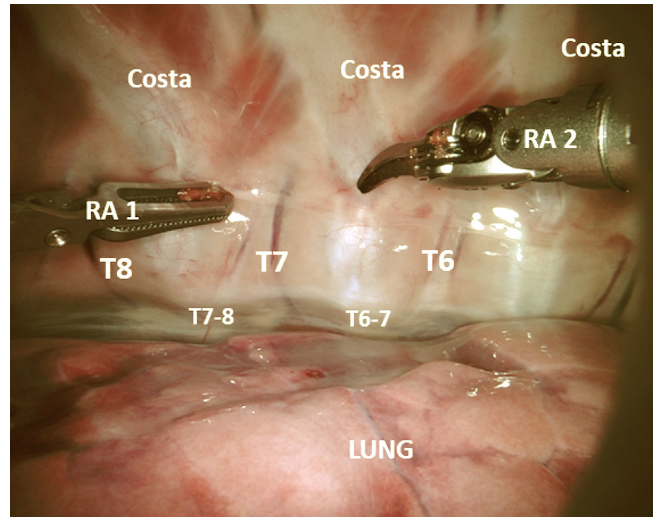

Fig. 2. Toracal vertebral body; The toracal vertebral body under the anterior longitudinal ligament is observed medial to the costa and posterior the rigt lung. RA 1 = Robotic Arm 1 (Fenestrated Bipolar Forceps), RA 2 = Robotic Arm 2 (Curved Bipolar Dissector).

4. Discussion

Robotic surgery has begun to be used in practical applications in some branches, but it is still limited in daily spine practice. In our study, the Da vinci robotic system was used. This system has 3D and high image quality with filtering surgeon's handshake, surgeon's working cabinet, dual camera set, and numerous operating arms [6]. One of the disadvantages of the systen was the need for a large working space necessary to put the robot in the operation room [7]. The swine model was used in our study because of the tissue similarity of vertebrae to the ones of human [8]. However, in the swine model, the disc distances are narrower, and the thoracic vertebral kyphotic angle is different from the human spine angle [9].

Minimally invasive spine surgeries using endoscopic instruments have become convenient in the last two decades. In thoracic spine stenosis, endoscopic approaches can be difficult and inadequate except anterior approaches. It has also been stated that

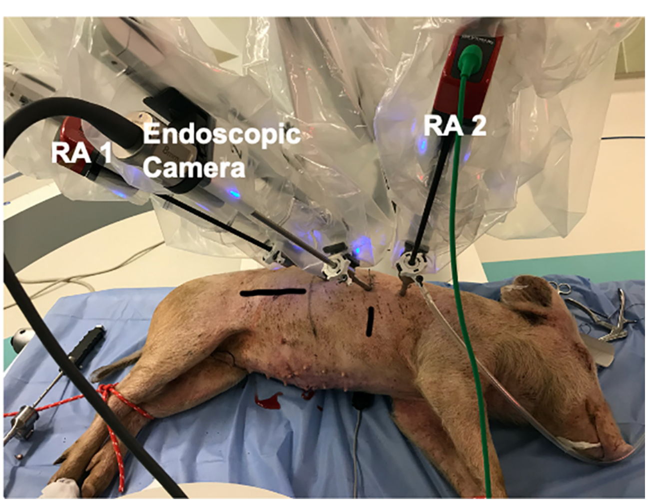

Fig. 1. Thoracal procedure; The placement of the ports and robotic arms in thoracal procedure. RA 1 = Robotic Arm 1 (Fenestrated Bipolar Forceps), RA 2 = Robotic Arm 2 (Curved Bipolar Dissector).

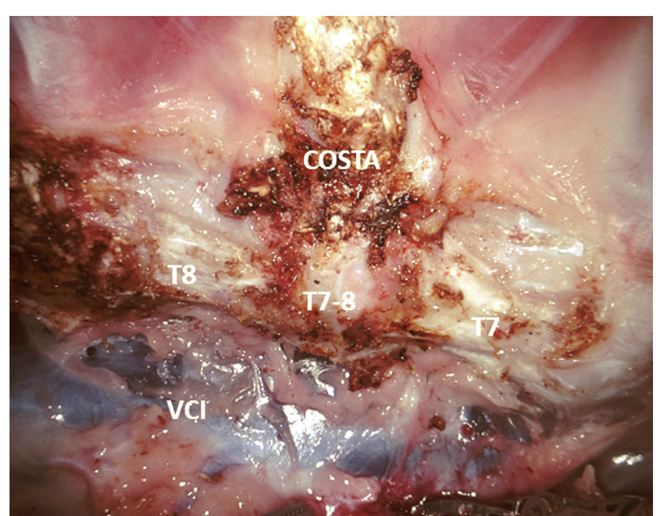

Fig. 3. The revealing of T7-8 disc ; After dissection and cauterization of the anterior longitudinal ligament reveals the T7 and 8 vertebral bodies and the T7-8 disc.

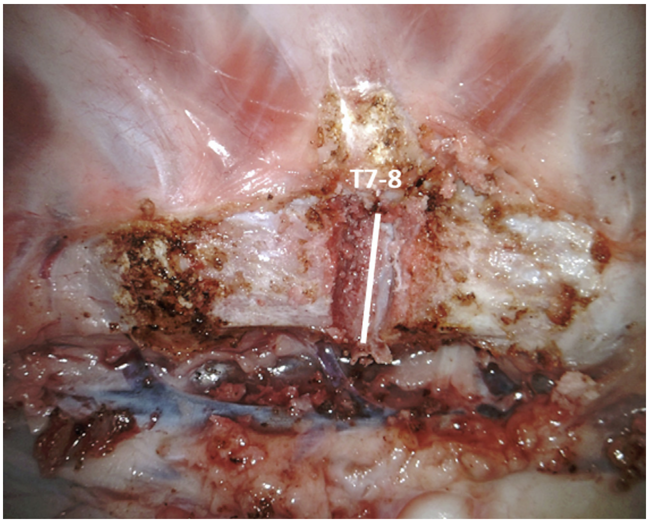

Fig. 4. T7-8 discectomy; The T7-8 discectomy is performed by robotic instruments with preserving VCI and lung.

instability may develop after posterior approaches[10]. Fort his reason anterior approach to thoracic spine via endoscopes has been turning to be state of art. It has been found that endoscopic thoracic discectomy can be technically challenging in the surgical treatment of upper and middle thoracic disc hernias due to the complexity of neural and vascular structures[11]. Using RS could overcome the disadvantages that have been seen during conventional endoscopic spine produres in thoracic spine.

Robotic surgeries have increased surgical success rates in minimal invasive attempts and optimized the surgeon's performance besides reducing complication rates. Robotic procedures have been developed for spinal surgeries, especially for spinal instrumentation operations [12]. Fluoroscopy is widely used as a guide in spine surgeries with instrumentation. Therefore, doctors, nurses, and other healthcare professionals are exposed to excessive amounts of radiation. With the help of robotic surgery, the amount of radiation exposed by fluoroscopy has declined with less demand during procedures [13]. In the present study, much less fluoroscopy was necessary for cage application to the thoracic vertebra by the anterior route than freehand surgery. It has been shown that

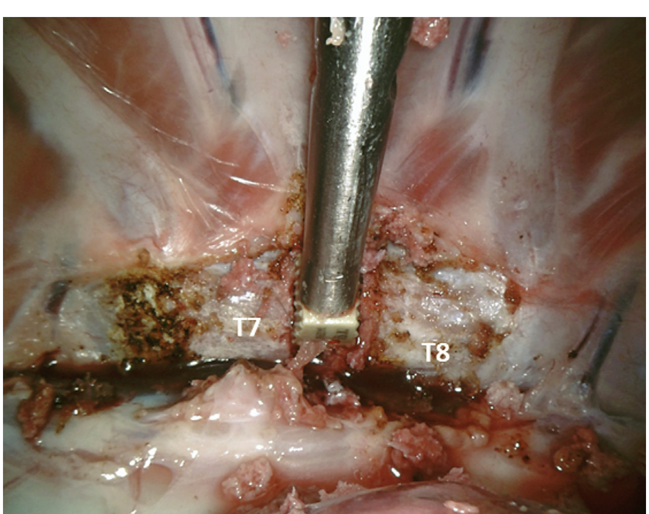

Fig. 5. T7-8 cage placement; After discectomy the cage is placed the T7-8 disc space.

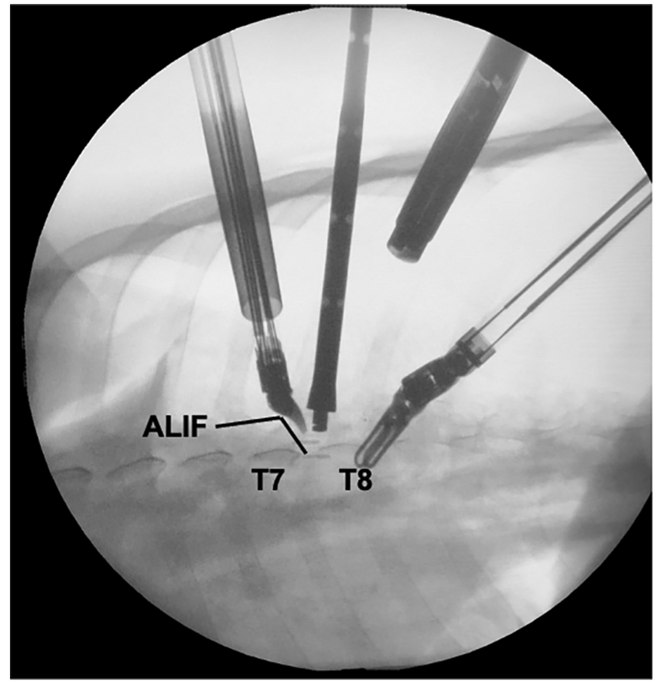

Fig. 6. Control with the C arm X-Ray machine; The level and cage position is control by C-arm. The cage is observed in the T7-8 disc level.

the cage could be inserted with correct angle with the RS compared to conventional surgeries. Likewise, when the misplacement rates for cage insertion were analyzed, rate of failure was less in the robotic group [14]. In our study, the cage was placed in the thoracic vertebra at the correct place and angle. In the Da Vinci robotic system, the small size of the incision allows freedom of movement at a certain angle and allows the surgeon to filter hand tremor.

Minimally invasive procedures can be accomplished easily with robotic systems. Minimally invasive methods provide many advantages over open surgeries. It has advantages such as less bleeding during the operation and less postoperative pain [15]. Minimally invasive procedures do not damage paraspinal muscles and facet joints hence decreasing the rate of adjacent segment disease [16]. Thus RS have been shown to reduce the rate of revision surgeries [17]. In a study conducted by Menger et al., they stated that minimally invasive methods with RS reduced the operation time and the patient hospitalization time. In addition, it has been shown that the infection rates were lower with robotic systems compared to open surgical methods [18]. One disadvantage of the Da Vinci system is the lack of tactile feedback, which is essential for preserving vascular and neural structures. In addition, there is no suitable instrument for interventions in bone structures [19]. Recent studies have shown that tactile feedback and natural hand movements can be achieved using sensor gloves [20]. Another disadvantage of RS is high cost rates for installation and maintenance of the robots [21]. However, in the procedures performed with RS, savings are made compared to open surgical methods due to the low hospital stay, low revision rates, low infection rates and low complication rates. For this reason, we propose an evaluation of costs with more surgical procedures would be more accurate in order to make detailed and accurate cost evaluation for RS.

When conventional and robotic endoscopic procedures are compared, there is an obvious disadvantage for conventional endoscopic approach: long learning curve to master the technique[22]. Contrary, a certain training period and money are needed for taining of surgeons and operating room staff who will use RS [23]. Rather than a constant learning curve unlike conventional endoscopic approaches, robotic assisted systems could be adapted faster and they could be updated with software. Artificial intelligence could be in place for RS in future. One other disadvantage of conventional endoscopic procedures is that wide-based, large intervertebral disc herniations and spine instability are contraindications fort he procedures[24]. In the present study, we showed that interbody fusion and thoracic discectomy with robotic assisted systems could be accomplied successfully with RS. The next step in our research would be applying what we have learned from this study into human cadaveric model for futher approaching in using RS in daily spine practice.

5. Limitations

The most important limitation of our study is the lack of comparison groups for the conventional approach, endoscopic approach and robotic approach. This study was done in a swine model, which is similar to human model; but not same. So, further studies are needed to be done in human cadavers to understand the feasibility of robotic assisted systems in spine surgeries.

6. Conclusion

Anterior thoracic cage insertion with fusion could be successfully accomplished with RS. Reducing costs of RS would enhance more convenient use of RS in routine spine surgeries with enhancement of tactile feedback and artificial intelligence, specifically long-lasting demanding spine surgeries such as in oncological cases.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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