Editorial

Profiles of intraoperative complications in robot-assisted anatomical pulmonary resection for lung cancer

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It is estimated that lung cancer will be the leading cause of cancer-related deaths in 2021 (1). Lobectomy with lymph node dissection remains the gold standard treatment for early-stage lung cancer. Traditionally, lung cancer was surgically resected by thoracotomy, but recently, video-assisted thoracoscopic surgery (VATS) for lung cancer has become popular and widely adopted. This method yields oncological results that are not inferior to those of thoracotomy. Furthermore, VATS successfully reduces the incidence and magnitude of the most common drawbacks of open chest surgery, such as pain, infection, and slow postoperative recovery (2). Additionally, robot-assisted pulmonary lobectomy offers a new approach to the surgical treatment of lung tumors since this technology was first approved in 2000 by the US Food and Drug Administration. Robot-assisted surgery is associated with improved clinical outcomes compared with open thoracotomy (3), with some authors even stating that robot-assisted surgery has improved outcomes over the VATS approach (4-6). Moreover, an additional advantage is that robotic surgery has been reported to have a shorter learning curve than that with conventional minimally invasive surgery (7). With this background, many medical institutions are planning to introduce robot-assisted pulmonary lobectomy. A concern when introducing a new technology is that complications specific to that technology may occur. Therefore, the profile of potential complications that may be encountered at the installation is very important. This is because if we know in advance what may happen, we can prepare accordingly. Especially in the field of respiratory surgery, a small complication can develop into a fatal problem because even a small vascular injury can easily lead to major bleeding.

Takase *et al.* reported 134 cases of intraoperative complications in robot-assisted anatomic pulmonary resections (8). It is particularly noteworthy that the report focused on complications that occurred in the first 30 cases after the installation of robot-assisted surgery. As mentioned previously, information on complications that may occur during the introduction of robot-assisted surgery is very valuable.

We would like to discuss intraoperative bleeding and conversion to thoracotomy. In the paper by Takase *et al.*, 7 of the 17 reported complications were pulmonary artery injuries. Laceration of the pulmonary artery is a common cause of intraoperative hemorrhage, which is difficult to address (9,10). Given the concordance of the results, this injury is probably a common feature in respiratory surgery. In response to hemorrhagic complications, the authors of the article stated that these were controlled by compression, applying fibrin sealant to the bleeding site, and stapling proximal to the injury site. Because many medical professionals have expressed concern about how to deal with intraoperative bleeding, an expert consensus was compiled (11). This consensus clarified the following points: first, if there is bleeding, it is important to deal with it calmly, and the first step is compression. Second, the

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decision should be made to proceed to thoracotomy if the laceration is large, if bleeding is not well controlled, if an endoscopic view cannot be obtained, or if the laceration spreads during repair. Therefore, the authors' approach to complications is consistent with expert opinion.

We propose that the additional application of increased positive intrapleural pressure with carbon dioxide (CO_2) insufflation leads to temporary suppression of bleeding, making it easier to control bleeding by compression and to perform thoracoscopic repair of the laceration. First, because many robot-assisted surgeries already involve CO_2 insufflation, there appears to be little impediment to its use. Second, as previously reported, the use of positive intrapleural pressure with CO_2 insufflation during such a bleeding event could temporarily control the bleeding speed (12,13). In both *ex-vivo* and *in-vivo* models, regardless of whether the bleeding point originates from the pulmonary artery, pulmonary vein, or vena cava, >15 mmHg of positive intrapleural pressure could sharply decrease the amount of bleeding. This is because the average blood pressure in the pulmonary artery is 10–18 mmHg; thus, compression is at least partially provided by a positive intrathoracic pressure of 15 mmHg. Furthermore, blood pressures in the pulmonary vein and vena cava are much lower than that in the pulmonary artery; therefore, there is no question that a positive intrathoracic pressure of 15 mmHg is effective. Third, previous reports stated that insufflation can be safely managed with a setting of up to 15 mmHg during surgery (14,15). It is true that, regarding air embolism, there are no clear reports of air embolism caused by thoracic CO_2 insufflation. However, based on the accumulation of sufficient safety data from abdominal surgery, we believe that symptomatic air embolism is unlikely to occur when CO_2 is used for insufflation, thanks to the high solubility of CO_2 in water.

We would also like to discuss conversion to thoracotomy as a safety measure as a premise for developing the hemostatic procedure that we have described to this point. In the paper by Takase *et al.*, all operations were completed with a robot; in other words, without conversion to thoracotomy, despite the large blood loss volume and wasted long console time in some cases. The decision to convert to thoracotomy may be stressful for the surgeon, as the patient may expect the surgery to be completed using the robot. However, we believe that conversion is neither a surgical failure, nor a surgeon's fault. In fact, it is difficult to predict adhesions and lymph node involvement surrounding the pulmonary artery accurately before surgery, which can be obstacles to robot-assisted surgeries. For this reason, the difficulty of the surgery is often unknown until surgery is actually performed. Therefore, the decision to convert should be made early, and the threshold for conversion should be set at a sufficiently low level because safe completion of the surgery is the priority. When the decision for conversion is made after bleeding becomes uncontrollable, it is difficult to stop the bleeding, which may be potentially fatal. In contrast, even if the operation time exceeds the scheduled time, or if the bleeding is within the controllable range, a conversion decision can be made, and the operation can be completed without major problems. We believe that "panic conversion", in which emergency thoracotomy is performed after a large amount of bleeding, should be avoided as much as possible because the surgeon may feel rushed, and errors may occur. Instead, "cool conversion", in which thoracotomy is performed after a small amount of bleeding is detected, avoids worsening the bleeding. This approach is particularly recommended for crisis management during the introduction of robotic surgery because cool conversion allows the surgeon to respond calmly. In this regard, setting and following appropriate conversion criteria is crucial for safe robot-assisted surgery.

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