



Advantages and disadvantages of robotic and uniportal video-assisted thoracoscopic surgery

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Abstract: Robotic-assisted thoracoscopic surgery (RATS), which aims to increase accuracy, and uniportal video-assisted thoracoscopic surgery (U-VATS), which aims to decrease invasiveness, have been reported as new surgical methods for pulmonary resection. The advantages of robotic-assisted surgery include a three-dimensional surgical view, elimination of physiological tremors, and enabling surgical manipulation in a natural orientation because of the presence of forceps that move in the same manner as human wrist joints. Therefore, it allows some surgeries that are not feasible with the manual thoracoscopic techniques performed by human hands available currently. Its disadvantages include the lack of tactile sensation, an increased number of ports, the high cost, and unproven commensurate patient benefits. The advantages of uniportal surgery include a lower level of postoperative pain and faster patient recovery because of the single incision, whereas the fact that all surgical instruments are inserted via a single incision, thereby limiting surgical manipulation and decreasing surgical safety and accuracy, represents a disadvantage of this technique. Although many reports have indicated that both robotic-assisted surgery and uniportal surgery are more useful than conventional thoracoscopic surgery, sufficient demonstration based on a high level of evidence remains to be achieved. In the future, the safety, level of invasion, and oncological long-term results of these new surgical methods should be compared with those of conventional surgical methods and investigated regarding their utility.

Keywords: Surgery; minimally invasive surgery; robotic-assisted thoracoscopic surgery (RATS); uniportal video-assisted thoracoscopic surgery (U-VATS)

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Introduction

Two hundred years have passed since the advent of pulmonary resection, which was first performed in 1821. Video-assisted thoracoscopic surgery (VATS), which was previously performed as an open surgery prior to being performed endoscopically, has now become the mainstay for surgical pulmonary resection. In recent years, robotic-assisted thoracoscopic surgery (RATS) and uniportal video-assisted thoracoscopic surgery (U-VATS) have been reported as new surgical approaches. RATS, which is an

endoscopic procedure that uses robotic systems, was first described by Melfi *et al.* in 2002 and is now widely used worldwide (1). The robotic system used most commonly at present is the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA). The advantages associated with robotic-assisted surgery using the da Vinci surgical system include a three-dimensional surgical view, the elimination of physiological tremors, and the ability to perform surgical manipulation in a natural orientation because of the presence of forceps that move in the same manner as human wrist joints. Its disadvantage is the absence of tactile

sensation. As a new surgical approach, U-VATS has been used more widely, together with robotic surgery, mainly in Asia and Europe. Unlike multiportal VATS, which is performed by inserting ports into three to four incisions, U-VATS is a surgical procedure that is performed using only one incision of 4 cm or less (2). U-VATS was reported as a partial pulmonary resection procedure by Rocco *et al.* in 2004 (3). After the first U-VATS lobectomy was reported by Gonzalez *et al.* in 2011, the procedure has been used worldwide (4). The advantages associated with U-VATS include the expectations of a lower level of postoperative pain because of the single incision and a faster recovery. Its disadvantage is that all surgical instruments are inserted via a single incision, which may limit surgical manipulation and reduce surgical safety and accuracy.

In this article, reports of RATS and U-VATS are reviewed and the advantages and disadvantages associated with the two surgical techniques and their respective uses are discussed. Only the study by Yang *et al.* (5) has directly compared RATS with U-VATS. Thus, we reviewed RATS and UVATS based on studies in which RATS and VATS and U-VATS and VATS were compared.

Current status of RATS

Because RATS is a novel surgical technique, various port placements have been reported; however, in general, three to five ports are prepared for the procedure (6-8). One of the disadvantages of RATS is that the number of ports is high, even compared with multiportal VATS, which is performed manually by human hands. Reports of comparisons of RATS to open thoracotomy indicate that the former can be performed safely; is associated with lower morbidity and mortality; and affords a reduction in postoperative hospital stay, a greater number of lymphadenectomies, and improved postoperative quality of life (7); however, RATS has been reported to have longer operative times (9).

To date, no prospective studies have compared RATS and VATS, and mixed results have been reported for the comparisons of these two techniques. The advantages associated with RATS *vs.* VATS reportedly include a higher number of lymphadenectomies, its similarity to open thoracotomy, less complications, less blood loss, a shorter hospital stay, use of fewer analgesics, and an earlier return to daily activities (10-19). Conversely, the disadvantages associated with RATS compared with VATS reportedly include longer operative times, higher costs, greater

postoperative pain, and a higher incidence of postoperative pulmonary leaks (14-19). In terms of operative times, the specific action of docking the patient cart in RATS may prolong its operative time (15), which may be one of its drawbacks in terms of effective utilization of operating rooms, as it will increase their occupancy time. Regarding the incidence of postoperative complications, we reported previously that RATS had a significantly lower rate of complications compared with VATS (20); however, several studies have reported that RATS is associated with more intraoperative blood loss and more postoperative pulmonary leaks (19). Regarding vascular injuries, Cerfolio *et al.* reported these injuries in 15 (2.4%) out of 632 patients undergoing robotic-assisted procedures in 2016, and concluded that vascular injuries can be safely managed even with robotic procedures (21). In terms of pain, although the presence of a forceps joint was expected to reduce compression on the intercostal nerves and decrease pain in RATS, an increased level of pain has been reported (18). The costs of performing RATS were reportedly higher than the costs of performing VATS (16,17). This cost increase is likely attributable to the robot-specific consumables used in RATS (10). Regarding long-term results, in 2012, Park *et al.* reported a multicenter study involving 325 patients in which the 5-year survival rate was 80% (91% for Stage IA, 83% for Stage IB, and 49% for Stage II), showing a favorable outcome. Data reportedly showed that RATS was safe and efficient and was associated with a similar survival rate (22). In 2017, Yang *et al.* compared the long-term results of open thoracotomy, VATS, and robotic surgery and found that minimally invasive approaches to lobectomy for clinical stage I non-small lung cancer resulted in similar long-term survival compared with thoracotomy. The use of VATS and robotics was also reportedly associated with a shorter length of hospital stay, and the robotic approach resulted in greater lymph node assessment (11). In 2018, Cerfolio *et al.* reported a large study of long-term survival after RATS, with 5-year survival results according to stage being reportedly comparable to those of conventional techniques, with 83% 5-year survival rates for Stage IA disease, 77% for Stage IB, 68% for Stage IIA, 70% for Stage IIB, 62% for Stage IIIA, and 31% for Stage IIIB (23) (Table 1).

Issues pertaining to the evaluation of robotic-assisted surgery at this point in time include the high number of ports, the inefficiency in utilizing medical resources because of the prolonged operative time and consequent prolongation of operating room occupancy time, the high cost, and the insufficient demonstration of utility for the

Table 1 RATS versus VATS

Study	Year	Operative times	Blood loss	Lymphadenectomy	Postoperative hospital stay	Postoperative complication	Postoperative pain	Cost
Novellis P, <i>et al.</i> (10)	2018	RATS > VATS	N	RATS > VATS	RATS > VATS	RATS = VATS	N	RATS < VATS
Yang HX, <i>et al.</i> (11)	2017	N	N	RATS > VATS	RATS > VATS	RATS = VATS	N	N
Jang HJ, <i>et al.</i> (12)	2011	RATS < VATS	N	N	N	RATS = VATS	N	N
Louie BE, <i>et al.</i> (13)	2012	RATS = VATS	RATS = VATS	RATS = VATS	RATS = VATS	N	RATS > VATS	N
Deen SA, <i>et al.</i> (14)	2014	RATS < VATS	N	N	RATS = VATS	RATS = VATS	N	RATS > VATS
Louie BE, <i>et al.</i> (15)	2016	RATS < VATS	N	RATS = VATS	RATS = VATS	RATS = VATS	N	N
Bao F, <i>et al.</i> (16)	2016	RATS < VATS	RATS = VATS	RATS = VATS	RATS < VATS	RATS = VATS	N	RATS < VATS
Swanson SJ, <i>et al.</i> (17)	2014	RATS = VATS	N	N	RATS = VATS	N	N	RATS < VATS
Duclos G, <i>et al.</i> (18)	2018	RATS < VATS	N	N	N	N	RATS < VATS	N
Huang L, <i>et al.</i> (19)	2019	N	N	RATS = VATS	RATS < VATS	RATS < VATS	N	N

RATS, robotic-assisted thoracoscopic surgery; U-VATS, uniportal video-assisted thoracoscopic surgery.

patient commensurate with the higher costs.

A randomized trial is currently underway to compare the early results of robotic-assisted surgery with those of VATS for Stage I and II lung cancer (24). Future evaluations of the utility of robotic surgeries via additional multicenter randomized controlled studies are warranted. Robotic systems are being improved constantly, and uniportal robotic systems are also currently being developed. There is a need to investigate further the utility of robotic systems using the latest models and instruments, including assessments of safety and pain associated with robotic surgery, complication rates, accurate diagnosis of lymph nodes, and long-term results.

Current status of U-VATS

U-VATS is a surgical method that uses a single incision of 4 cm or less. The history of uniportal surgery begins with a report of the use of a single incision for thoracic sympathectomy performed for palmar hyperhidrosis between 1990 and 1992 (25). Since the report by Gonzalez-Rivas *et al.* of a U-VATS lobectomy from a single incision in 2011, this technique has spread mainly in Asia and Europe and, in recent years, has also been applied during more sophisticated surgical techniques, such as sleeve resection, segmental resection, and carinoplasty (26–28). Currently, this method appears to be the most minimally invasive

surgical approach for lung cancer. If the method does not differ from conventional thoracoscopic surgery, uniportal surgery may be a quite useful procedure for patients, because of its minimal invasiveness and cosmetic nature.

Comparisons between U-VATS and VATS have revealed that uniportal surgery results in less intraoperative blood loss (29). U-VATS has also been reported to cause less postoperative pain, although there are some reports of an absence of differences in postoperative pain between these techniques (30). U-VATS has also been reported to be superior to VATS in terms of the incidence of post-thoracotomy pain syndrome (31). As only one incision is used in U-VATS, this procedure imparts less damage than does VATS, which requires multiple incisions. Thus, reduced intraoperative blood loss and postoperative pain are to be expected. A disadvantage reportedly associated with U-VATS compared with VATS is the longer duration of lymphadenectomy (32). However, according to a study, with U-VATS, results for the extent of lymph node dissection and the number of dissected lymph nodes were equal to or better than those with VATS (29,33–39). In addition, Ismail *et al.* reported that U-VATS allows for safe and effective radical lymphadenectomy comparable to other minimally invasive techniques (33). Because U-VATS is a novel surgical technique, few studies have reported its long-term outcomes. Uniportal surgery can be accomplished within a similar duration as multiportal VATS if the surgeon

Table 2 UVATS versus VATS

	Year	Operative times	Blood loss	Lymphadenectomy	Postoperative hospital stay	Postoperative complication	Postoperative pain
Wang BY, <i>et al.</i> (29)	2015	U-VATS > VATS	U-VATS > VATS	U-VATS > VATS	U-VATS = VATS	U-VATS = VATS	N
McElnay PJ, <i>et al.</i> (30)	2015	N	N	N	U-VATS = VATS	N	U-VATS = VATS
Hirai K, <i>et al.</i> (31)	2019	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	N	U-VATS > VATS
Shen Y, <i>et al.</i> (32)	2015	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	N	N
Wu HR, <i>et al.</i> (34)	2019	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	N
Fan J, <i>et al.</i> (35)	2016	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	N
Ji C, <i>et al.</i> (36)	2017	U-VATS < VATS	U-VATS > VATS	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	U-VATS > VATS
Mu JW, <i>et al.</i> (37)	2016	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	N
Ye Z, <i>et al.</i> (38)	2019	U-VATS > VATS	U-VATS > VATS	U-VATS = VATS	U-VATS > VATS	N	U-VATS > VATS
Dai F, <i>et al.</i> (39)	2016	U-VATS = VATS	U-VATS > VATS	U-VATS = VATS	U-VATS = VATS	U-VATS = VATS	U-VATS > VATS

U-VATS, uniportal video-assisted thoracoscopic surgery.

is familiar with the procedure; for patients, it is thus reasonable to expect that, as the damage to the intercostal space is limited to one location, postoperative pain, the extent of intercostal nerve injury, and the incidence of post-thoracotomy pain would be reduced in the case of uniportal surgery. The proof of the utility of uniportal surgery is not sufficient at present; thus, its utility compared with VATS is required to be demonstrated in a multicenter randomized control study in the future (Table 2).

Discussion

Few reports have compared directly uniportal resection with robotic-assisted pulmonary resection. In the study reported by Yang *et al.*, the superiority of RATS *vs.* U-VATS was observed based on less intraoperative blood loss and more lymphadenectomy sites; conversely, the superiority of U-VATS *vs.* RATS was observed based on the shorter period of chest drain placement. Yang *et al.* reported an absence of differences in operative time, period of hospital stay, postoperative analgesic use, and incidence of complications (5). RATS may be superior to U-VATS in cases that require more challenging surgical manipulation, because of its superior maneuverability. In lung cancer surgery, the presence of a joint that moves as well as the human wrist joint in lymphadenectomy, which requires manipulation in deep sites, allows the performance of the procedure in the same manner as open surgery. This is an advantage over uniportal surgery, which

is associated with limited maneuverability. Moreover, limitations in suture manipulation have arisen during uniportal surgery. Uniportal bronchoplasty and angioplasty have been reported; however, uniportal procedures that limit the orientation of the instruments result in very difficult procedures. According to Veronesi *et al.*, robotic-assisted surgery for advanced lung cancer facilitates lymph node resection, and precise lymph node resection can lead to accurate diagnoses of patients requiring adjuvant chemotherapy, thus allowing rapid prognostic improvement in these patients (40). We also performed robotic-assisted graft replacement of innominate veins, which is not considered feasible via manual VATS using human hands, in surgeries for thymic carcinoma (41). Robotic-assisted surgery is a minimally invasive surgical technique in which highly challenging procedures can be achieved that are not feasible with manual VATS using human hands, which may be of clear benefit for some patients.

Conversely, there is no doubt that U-VATS is associated with a lower burden on patients as the surgery is performed using only one incision. RATS is also a minimally invasive procedure compared with open thoracotomy; however, currently, more port insertions are required (similar to, or more than, those required for VATS) and the burden on patients may be comparable to that of VATS (31). If uniportal surgery is safe and can be performed with adequate accuracy, including for lymph node resection, this surgical technique can be useful for patients. Thus, at present, uniportal surgery may be a beneficial surgical

procedure for patients as a minimally invasive procedure in those for whom the required procedure is not associated with high difficulty, provided that the surgeon has adequate skill, while robotic surgery may be useful for more challenging surgical procedures. In the future, the safety, degree of invasiveness, and oncological long-term results of these new surgical methods should be investigated and compared with those of conventional surgical methods, to assess their benefits.

In recent years, a variety of new systems have been developed for robotic surgical systems. Uniportal robotic surgical systems and robotic systems with tactile sensation are also being developed (42,43). Procedures performed manually with human hands have limitations; however, robotics will continuously be developed in the future. Robotic surgery, aimed at high accuracy, and uniportal surgery, aimed at minimally invasive surgery, will likely eventually be fused.

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