Curr Surg Rep (2017) 5:27
DOI 10.1007/s40137-017-0192-3

THORACIC SURGERY (G. ROCCO AND M. SCARCI, SECTION EDITORS)

Robot-Assisted Thoracoscopic Surgery: Pros and Cons

Tugba Cosgun[1] · Erkan Kaba[1] · Kemal Ayalp[2] · Mezen Rasmi Alomari[2] · Alper Toker[2]

Published online: 1 September 2017

Abstract
Purpose of Review In the last two decades, minimally invasive approaches for thoracic surgery have become the major challenge in the field of thoracic surgery. These techniques became preferable over open surgery (thoracotomy) in terms of reducing pain and having aesthetic advantages. However, patient selection is one of the most important factors for minimally invasive surgery because of related limitations and insufficiency of video-assisted thoracoscopic surgery (VATS).
Recent Findings Robot-assisted thoracoscopic surgery (RATS) has been developed to overcome the limitations of VATS. Better flexibility and transmission the surgeon's convenient manoeuvrability in the thoracic cavity are some of the advantages of robotic surgery.
Summary This paper focuses on the advantages and disadvantages of RATS in comparison to that of VATS and thoracotomy.

Keywords Video-assisted thoracoscopic surgery · Robot-assisted thoracoscopic surgery · Thoracotomy

This article is part of the Topical collection on *Thoracic Surgery*.

✉ Tugba Cosgun
tugba_cosgun@hotmail.com

[1] Thoracic Surgery Department, Istanbul Bilim University, Abide-i Hurriyet Cd, No:166, Sisli, 34381 Istanbul, Turkey

[2] Thoracic Surgery Department, Istanbul Florence Nightingale Hospital, Istanbul, Turkey

Introduction

Video-assisted thoracoscopic surgery (VATS) has become an essential surgical technique for thoracic surgery, and it is performed in almost all thoracic surgical indications. VATS-based lobectomy series for lung cancer have been reported many times in the last decade [1], and it has been shown to have several advantages over open surgery (thoracotomy). These include shorter postoperative stay, fewer complications, such as decrease incidence of pneumonia and atrial fibrillation, early return to work and increased compliance rate of adjuvant chemotherapy treatment [2, 3]. However, VATS has some disadvantages, such as rigid instruments and two-dimensional (2D) visualization. Currently, VATS techniques (uniportal, biportal and three-portal technique) have been adopted universally. Instrumentations have been developed for uniportal VATS. Several organizations have helped in the worldwide distribution of knowledge. Robot-assisted thoracoscopic surgery (RATS) has been developed to overcome the limitations of VATS. Better flexibility due to endo-wrist instruments, more intuitive movements and high-definition three-dimensional (3D) visualization are some of the advantages of robotic surgery [4•]. Initially, robotic surgeons have benefitted from their vast experience of performing VATS believing that this minimal invasive modality should provide similar results. However, with increasing experiences, outcomes of RATS have been presented. These results demonstrated that they are not similar, and both surgical techniques may have superiorities over each other. In this paper, we aimed to discuss the pros and cons of RATS, VATS and thoracotomy.

Indications

Thymectomy and Mediastinal Mass

Optimum exposure and availability of complete mediastinal fatty tissue and thymus resection are the primary requirements of thymectomy. A transsternal approach has been claimed to provide both requirements appropriately. However, this technique has major disadvantages, such as splitting of the sternum and longer postoperative stay. Transcervical thymectomy is one of the most applied minimally invasive techniques for thymectomy. This technique has been attributed to result in incomplete thymectomy due to crowding of instruments from the neck incision. VATS thymectomy gained its popularity in the last 15 years. It can be performed from the left, right and/or bilateral thoracic cavity or subxiphoid incision or even in combinations with neck incision. The aim was to resect the maximum amount of mediastinal fatty tissue and thymus as possible. The development of minimally invasive surgery (MIS) has increased the acceptance of thymectomy [5].

Recently, RATS becomes an important alternative to VATS. Rueckert et al. presented that patients who underwent robotic surgery showed a trend toward better cumulative complete remission rate than patients who underwent non-robotic surgery with respect to those who had myasthenia gravis and underwent thymectomy ($p = 0.01$) [6].

RATS-based thymectomy for early-stage (stages 1 and 2) thymoma has been shown to be a reliable and safe procedure with a low complication rate and shorter hospital stay [7]. Pfister claimed that RATS could overcome larger and more complex thymomas in comparison to VATS [8]. Robotic thymectomy has been demonstrated to have better early outcomes, and long-term results were similar to that of the transsternal thymectomy in patients with myasthenia gravis in Kang's study [9]. Other anterior mediastinal masses and mediastinal parathyroid adenoma have also become indications for robotic surgery because of the better visualization of the operating field and manoeuvrability of endo-wrist instruments during robotic surgery [10].

Robotic surgery has become a preferred technique not only for anterior and middle mediastinal masses but also for posterior mediastinal masses. Kajiwara et al. reported that patients who underwent robotic surgical treatment of posterior mediastinal tumours located adjacent to the vertebrae and aorta are not ideal candidates for VATS resection [11]. A study advocated that treatment of tumours located in the posterior mediastinum became feasible with RATS; these tumours are very difficult to reach with conventional VATS [11]. A robotic system using wristed instruments with multiple degrees allows dissection and cauterizing of the occasional vascularized attachments to the posterior mediastinal lesions [12].

In our mediastinal robotic surgery experience, VATS thymectomy is a cheap, safe and effective method for surgeons who have developed the required endosurgical capabilities. Certainly, robotic thymectomy is a high-quality approach, which can reach the shallow parts of the mediastinum, including the area known as the suprainnominate vein region. However, we must agree that VATS thymectomy is a short surgery because it lacks the docking procedures that are present in robotic surgery, which affects the postoperative outcome of in patients with myasthenia gravis. Cystic lesions located at the middle mediastinum are the ideal cases for robotic surgery. Complete resection is an essential part of surgery in bronchogenic cysts. These cysts may have tight adhesions, and precise dissection is necessary to avoid major injury to the bronchus or pulmonary vessels. According to our experiences, we strongly believe that masses ideal for resection are neurogenic tumours located at the posterior part of the thoracic cavity. These tumours are connected to the nerves, intervertebral foramen and subclavian vein, and robotic surgery may provide better capabilities without causing injury.

Oesophagectomy

Oesophagectomy is the primary treatment in selected patients with resectable oesophageal malignancies. Over the past 20 years, minimally invasive oesophagectomy is the preferred method to reduce potential perioperative complications, especially pulmonary complications. More recently, robotic-assisted approaches have been increasingly accepted by several centres [13]. Early experiences in robotic-assisted minimally invasive oesophagectomy (RAMIE) resections did not show any superiority in terms of morbidity and mortality. However, initial experience demonstrated reduced blood loss, shorter intensive care unit stay and less cardiopulmonary morbidity. Hillegersberg described that the operative technique of thoraco-laparoscopic oesophagectomy included better thoracic lymphadenectomy, which involves the right paratracheal, lower paratracheal (station 4), aortopulmonary window, subcarinal and perioesophageal lymph nodes. The authors claimed that RAMIE is safe and feasible and may have possible advantages in the number of dissected lymph nodes that may be comparable with those of open transthoracic oesophagectomies [14]. The recurrence rate was also reported to be comparable to thoracotomy [14].

Anatomical Lung Resection

Lobectomy is the most common indication in robotic thoracic surgery. Several papers report that RATS is safe and feasible [4, 15•]. Early experience of RATS has been shown to have similar outcomes as that of VATS [16]. Long-term stage-specific survival is also acceptable and comparable with previous results for VATS and thoracotomy [17]. According to our experience, the major benefit of RATS in resections for lung cancer is the capability of lymph node dissection and resection. The lymph nodes are removed without rupturing the capsule, bleeding and causing major complications. Nodal upstaging is one of the quality predictors of lung cancer surgery. Several studies have focused on nodal upstaging in RATS. Louie reported that nodal upstaging was similar to that in VATS. The rate of nodal upstaging was higher in VATS but similar in thoracotomy according to a study by Wilson et al. [18•, 19].

Higher upstaging rates maybe associated to RATS because more lymph node dissection (especially N1 lymph nodes) than that of thoracotomy and VATS [20••] is allowed. However, RATS is limited because of its high costs in lung surgery [21•].

Robotic anatomic lung segmentectomy has been demonstrated to be a feasible and safe procedure [22]. RATS-based segmentectomy has been reported to be highly advantageous because it enables better dissection capabilities around smaller vessels and lymph node dissection around lobar and segmentary bronchi. For RATS-based segmentectomy, surgeons must have experiences in proper patient selection and should be able to perform correct docking [23].

However, both RATS- and VATS-based pulmonary segmentectomies have been demonstrated to have similar morbidity and mortality rates. RATS may require longer duration of operation than VATS; however, it may also have a tendency towards a shorter hospital stay [24].

In our early robotic thoracic surgery experience, most of the lung resections were performed on patients with stage 1a segmentectomy. We believe that RATS-based segmentectomies, especially lower lobe superior segmentectomy, lower lobe common basal segmentectomy and lingulectomy, are ideal operations to develop surgeons' capabilities. These segmentectomies are technically easy to perform.

Robotic sleeve resections are reported rarely in recent years. VATS-based sleeve resection had been presented since 2008 [25], but we believe that sleeve resection did not gain popularity because of technical difficulties. However, robotic surgery enabled easier technical adoptability for sleeve resections [26].

We have performed five sleeve lobectomies. Suturing using robotic arm certainly provides optimum environment for the anastomosis. We are performing both VATS and RATS, and we believe that RATS-based sleeve operation is technically easier and safer.

Outcomes

In this section, we will discuss the outcomes of RATS.

Pain

Pain is the most important postoperative problem after thoracic surgery. Multimodal analgesic approach which includes systemic analgesics and local anaesthetics/nerve blocks, and epidural analgesia are used to treat postoperative pain. Controlling post-thoracotomy pain decreases the rate of respiratory complications. Minimally invasive techniques aim to minimize postoperative pain and complications associated with it. Minimizing the operative trauma and associated inflammatory reactions enable faster convalescence after surgery [27]. After thoracic surgery, patients not only suffer from chronic and acute pain but also chronic numbness [28], especially in the upper quadrant of the operated side of the abdomen. Studies have demonstrated a decrease in pain after MIS, but reports for chronic numbness has not been clearly presented.

Minimally invasive techniques have been reported to provide less pain. Lacroix et al. stated that persistent postoperative pain after robotic surgery is mild and non-neuropathic-like, with less effect on daily activities. Studies have also presented that quality of life (QOL) seems not optimum after a minimally invasive operation, but is better than that associated with thoracotomy-related pain [29].

No significant difference in acute and chronic pain between RATS and VATS was found in the clinical trial by Kwon et al. [28]. However, pain after MIS was significantly lower than after a thoracotomy in the same study. Chronic numbness was significantly higher after open resection, but chronic pain was comparable between MIS and thoracotomy [28].

Some authors reported a reduction in postoperative pain and shortened postoperative stay in hospital with uniportal VATS-based lobectomy because of one intercostal space incision. In addition, earlier postoperative administration of adjuvant therapy is possible, and better aesthetic results could be obtained [30].

Hospitalization

In both VATS and RATS, the length of postoperative stay is shorter than open lobectomies [31]. Paul et al. demonstrated that shorter postoperative stay maybe the consequence of earlier chest tube removal [32]. Less pain in early postoperative period maybe another cause of earlier discharge. Cerfolio et al. compared patients who underwent robotic lobectomy and who had open rib and nerve-sparing lobectomy using propensity score matching. However, the operating time was significantly longer with the robotic approach (2.2 vs.1.5 h). The robotic group had significantly better mental QOL and significantly shorter hospital stay (2.0 vs. 4.0 days) [33••].

Patients who underwent VATS have less surgical trauma and quicker recovery; thus, earlier adjuvant chemotherapy application maybe possible [34]. Patients in both (MIS and thoracotomy) groups started postoperative chemotherapy after about postoperative day 30. Moreover, patients who underwent VATS had better compliance to adjuvant chemotherapy than patients who underwent thoracotomy in the same study [34].

Nasir et al. pointed out that robotic anatomic lobectomy is a safe surgical technique. Their study included 862 patients who underwent robotic surgery. They claimed that R0 resection is possible even if the tumour size is 7 cm. Additionally, they claimed that more patients may be candidates for robotic surgery with this technique. They also showed superiority in mediastinal and hilar lymph node dissection (with median number 17) [35•].

Costs

High capital cost is one of the major disadvantages of robotic surgery. Deen et al. compared the costs of VATS, RATS and thoracotomy. However, only the costs between VATS and RATS were found to be significant [36]. VATS were found to be the cheapest technique. According to Park et al. the higher costs of RATS-based lobectomy were due to the increased costs on the first operative day. The increased costs in thoracotomy are related to the longer postoperative stay in the hospital [15•].

Perioperative Characteristics

Rinieri et al. reported 51 patients who underwent VATS- and RATS-based segmentectomies. Conversion to thoracotomy, conversion to lobectomy and operative time were similar. However, the estimated blood loss was significantly higher in the VATS group [37].

Augustin et al. presented that in addition to less blood loss and cheaper costs for VATS group, the operation times are shorter in comparison to the RATS group [38]. Therefore, Augustin et al. favoured VATS in comparison to RATS.

The most important reason for high costs of robotic surgery is longer operation times. Baste et al. analysed RATS and described that the mean docking time was 30 min [39]. Veronessi et al. specified that the duration of operation was higher in the muscle-sparing thoracotomy group, but for robotic resections, specifically after the first period on a series of operations, operation time was reduced significantly. A study reported that the mean operating time was shortened from 260 (152–513) to 235 (146–304) min [40••]. Moreover, a series from Canada showed that the total operation time decreased by 8.04 ± 1.78 min/case until case 20 ($p < 0.001$), and the console time decreased by 6.64 ± 1.84 min/case in the first 20 cases ($p = 0.001$) in their first tertile when they analysed the data [41••]. Toker et al. showed that a sharp change in the slope of the regression trendline correlated with case 14 ($R^2 = 0.72$) in the learning curve at docking. The console time changed in the slope of the regression trendline in the learning curve of 13 patients ($R^2 = 0.41$) at the console. In addition, the total operating time decreased in 14 patients ($R^2 = 0.57$) in the aforementioned study [42••].

Nodal Upstaging

The number of dissected lymph nodes is used as an indicator of quality and radical surgery [4•]. RATS allows adequate assessment of mediastinal lymph nodes [43, 44]. Veronesi et al. claimed that the number of lymph nodes removed with RATS is comparable with thoracotomy [40••]. Several studies compared the numbers of dissected mediastinal lymph nodes during VATS- and RATS-based lobectomies; RATS was found to be associated with higher lymph node resections [45]. Other studies reported similar number of sampled lymph nodes in VATS- and RATS-based lobectomy groups [46]. However, in our previous study, we described that more lymph nodes were dissected with RATS than thoracotomy and VATS. The difference was significant when the total lymph nodes and N1 lymph nodes (levels 11 and 12) were analysed [20••]. We believe that this difference, especially in the N1 level, is due to the higher number of robotic segmentectomies we have performed. In segmentectomy operations, the lymph nodes at station 12 are also removed to ensure proper dissection planes [20••].

Manoeuvrability

However though VATS has become a highly preferred technique in the last few decades, it has some insufficiencies, such as rigid instruments and 2D visualization. RATS brings more capabilities in manoeuvrability as a consequence of better flexibility due to endo-wrist instruments, more intuitive movements and high-definition 3D visualization [4•, 47]. These increased capabilities may enable the use of RATS-based sleeve lobectomies or bronchoplasties for locally advanced lung cancers [48].

Conclusions

Several studies have compared the long- and short-term outcomes of VATS, RATS and thoracotomy. Minimally invasive techniques (VATS and RATS) are advantageous in reducing pain and hospitalization time. RATS has become the preferred method because of surgeons' easy manoeuvrability into the thoracic cavity. However, higher cost is the major disadvantage of RATS in comparison to VATS.

Compliance with Ethics Guidelines

Conflict of interest The authors declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Yamamoto K, Ohsumi A, Kojima F, Imanishi N, Matsuoka K, Ueda M, Miyamoto Y. Long-term survival after video-assisted thoracic surgery lobectomy for primary lung cancer. Ann Thorac Surg. 2010;89(2):353–9.
2. Cai YX, Fu XN, Xu QZ, Sun W, Zhang N. Thoracoscopic lobectomy versus open lobectomy in stage I non-small cell lung cancer: a meta-analysis. PLoS ONE. 2013;8(12):e82366.
3. Swanson SJ, Batirel HF. Video-assisted thoracic surgery (VATS) resection for lung cancer. Surg Clin North Am. 2002;82(3): 541–59.
4. • Veronesi G. Robotic lobectomy and segmentectomy for lung cancer: results and operating technique. J Thorac Dis. 2015;7(Suppl 2): 122–30. *There are many educational technical details in this study.*
5. Marulli G, Schiavon M, Perissinotto E, Bugana A, Di Chiara F, Rebusso A, Rea F. Surgical and neurologic outcomes after robotic thymectomy in 100 consecutive patients with myasthenia gravis. J Thorac Cardiovasc Surg. 2013;145(3):730–5.
6. Rückert JC, Swierzy M, Ismail M. Comparison of robotic and nonrobotic thoracoscopic thymectomy: a cohort study. J Thorac Cardiovasc Surg. 2011;141(3):673–7.
7. Marulli G, Rea F, Melfi F, Schmid TA, Ismail M, Fanucchi O, Augustin F, Swierzy M, Di Chiara F, Mussi A, Rueckert JC. Robot-aided thoracoscopic thymectomy for early-stage thymoma: a Multicenter European study. J Thorac Cardiovasc Surg. 2012; 144(5):1125–30.
8. Witte Pfister A, Baste JM, Piton N, Bubenheim M, Melki J, Wurtz A, Peillon C. Thymomectomy by minimally invasive surgery. Comparative study videosurgery versus robot-assisted surgery. Rev Mal Respir. 2017;34(5):544–52.
9. Kang CH, Hwang Y, Lee HJ, Park IK, Kim YT. Robotic thymectomy in anterior mediastinal mass: propensity score matching study with transsternal thymectomy. Ann Thorac Surg. 2016;102(3):895–901.
10. Profanter C, Schmid T, Prommegger R, Bale R, Sauper T, Bodner J. Robot-assisted mediastinal parathyroidectomy. Surg Endosc. 2004;18(5):868–70.
11. Kajiwara N, Kakihana M, Usuda J, Ohira T, Kawate N, Ikeda N. Extended indications for robotic surgery for posterior mediastinal tumors. Asian Cardiovasc Thorac Ann. 2012;20(3):308–13.
12. Broussard BL, Wei B, Cerfolio RJ. Robotic surgery for posterior mediastinal pathology. Ann Cardiothorac Surg. 2016;5(1):62–4.
13. Okusanya OT, Sarkaria IS, Hess NR, Nason KS, Sanchez MV, Levy RM, Pennathur A, Luketich JD. Robotic assisted minimally invasive esophagectomy (RAMIE): the University of Pittsburgh Medical Center initial experiences. Ann Cardiothorac Surg. 2017;6(2):179–85.
14. van der Sluis PC, Ruurda JP, Verhage RJJ, van der Horst S, Haverkamp L, Siersema PD, Borel Rinkes IHM, ten Kate FJV, van Hillegersberg R. Oncologic long-term results of robot-assisted minimally invasive thoraco-laparoscopic esophagectomy with two-field lymphadenectomy for esophageal cancer. Ann Surg Oncol. 2015;22:1350–6.
15. • Park BJ, Flores RM. Cost comparison of robotic, video-assisted thoracic surgery and thoracotomy approaches to pulmonary lobectomy. Thorac Surg Clin. 2008;18(3):297–300. doi:10.1016/j.thorsurg.2008.05.003. *This study is one of the biggest and earliest study on cost effectivity.*
16. Louie BE, Farivar AS, Aye RW, Vallières E. Early experience with robotic lung resection results in similar operative outcomes and morbidity when compared with matched video-assisted thoracoscopic surgery cases. Ann Thorac Surg. 2012;93(5):1598–604; discussion 1604–05. doi:10.1016/j.athoracsur.2012.01.067.
17. Park B, Melfi F, Mussi A, Maisonneuve P, Spaggiari L, Da Silva RK, Veronesi G. Robotic lobectomy for non-small cell lung cancer (NSCLC): long-term oncologic results. J Thorac Cardiovasc Surg. 2012;143(2):383–9.
18. • Louie B, Wilson JL, Kim S, Cerfolio RJ, Park BJ, Farivar AS, Vallières E, Aye RW, Burfeind WR Jr, Block MI. Comparison of video-assisted thoracoscopic surgery and robotic approaches for clinical stage I and stage II non-small cell lung cancer using the society of thoracic surgeons database. Ann Thorac Surg. 2016;102:917–24. *This study has a big database.*
19. Wilson JL, Louie BE, Cerfolio RJ, Park BJ, Vallières E, Aye RW, Abdel-Razek A, Bryant A, Farivar AS. The prevalence of nodal upstaging during robotic lung resection in early stage non-small cell lung cancer. Ann Thorac Surg. 2014;97(6):1901–6; discussion 1906–07.
20. •• Toker A, Özyurtkan MO, Demirhan Ö, Ayalp K, Kaba E, Uyumaz E. Lymph node dissection in surgery for lung cancer:-comparison of open vs. video-assisted vs. robotic-assisted approaches. Ann Thorac Cardiovasc Surg. 2016;22(5):284–90. *This study is new and there are not more study on this issue.*
21. • Swanson SJ, Miller DL, McKenna RJ Jr, Howington J, Marshall MB, Yoo AC, Moore M, Gunnarsson CL, Meyers BF. Comparing robot-assisted thoracic surgical lobectomy with conventional video-assisted thoracic surgical lobectomy and wedge resection: results from a multihospital database (Premier). J Thorac Cardiovasc Surg. 2014;147(3):929–37. *This study has a big database.*
22. Pardolesi A, Park B, Petrella F, Borri A, Gasparri R, Veronesi G. Robotic anatomic segmentectomy of the lung: technical aspects and initial results. Ann Thorac Surg. 2012;94(3):929–34.
23. Toker A, Ayalp K, Uyumaz E, Kaba E, Demirhan O, Erus S. Robotic lung segmentectomy for malignant and benign lesions. J Thorac Dis. 2014;6(7):937–42.
24. Demir A, Ayalp K, Ozkan B, Kaba E, Toker A. Robotic and video-assisted thoracic surgery lung segmentectomy for malignant and benign lesions. Interact Cardiovasc Thorac Surg. 2015;20(3):304–9.

25. Mahtabifard A, Fuller CB, McKenna RJ Jr. Video-assisted thoracic surgery sleeve lobectomy: a case series. Ann Thorac Surg. 2008;85(2):S729–32. doi:10.1016/j.athoracsur.2007.12.001.
26. Zhao Y, Jiao W, Ren X, Zhang L, Qiu T, Fu B, Wang L. Left lower lobe sleeve lobectomy for lung cancer using the Da Vinci surgical system. J Cardiothorac Surg. 2016;11(1):59. doi:10.1186/s13019-016-0453-8.
27. Schneiter D, Weder W. Minimal-invasive surgery for lung cancer—strategies and limits. Ther Umsch. 2012;69(7):406–10.
28. Kwon ST, Zhao L, Reddy RM, Chang AC, Orringer MB, Brummett CM, Lin J. Evaluation of acute and chronic pain outcomes after robotic, video-assisted thoracoscopic surgery, or open anatomic pulmonary resection. J Thorac Cardiovasc Surg. 2017;. doi:10.1016/j.jtcvs.2017.02.008.
29. Lacroix V, Nezhad ZM, Kahn D, Steyaert A, Poncelet A, Pieters T, Noirhomme P. Pain, quality of life, and clinical outcomes after robotic lobectomy. Thorac Cardiovasc Surg. 2016;65:344–50.
30. Ismail M, Swierzy M, Nachira D, Rückert JC, Gonzalez-Rivas D. Uniportal video-assisted thoracic surgery for major lung resections: pitfalls, tips and tricks. J Thorac Dis. 2017;9(4):885–97. doi:10.21037/jtd.2017.02.04.
31. Yang HJ. Long term survival of early-stage non-small cell lung cancer patients who underwent robotic procedure: a propenity score-matched study. Chin J Cancer. 2016;35:36. doi:10.1097/SLA.0000000000001708.
32. Paul S, Altorki NK, Sheng S, Lee PC, Harpole DH, Onaitis MW, Stiles BM, Port JL, D'Amico TA. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity matched analysis from the STS database. J Thorac CardiovascSurg. 2010;139(2):366–78.
33. •• Cerfolio RJ, Bryant AS, Skylizard L, Minnich DJ. Initial consecutive experience of completely portal robotic pulmonary resection with 4 arms. J Thorac Cardiovasc Surg. 2011;142(4):740–6. doi:10.1016/j.jtcvs.2011.07.022. *There are many educational details in this study*.
34. Jiang G, Yang F, Li X, Liu J, Li J, Zhao H, Li Y, Wang J. Video-assisted thoracoscopic surgery is more favorable than thoracotomy for administration of adjuvant chemotherapy after lobectomy for non-small cell lung cancer. World J Surg Oncol. 2011;21(9):170. doi:10.1186/1477-7819-9-170.
35. • Nasir BS, Bryant AS, Minnich DJ, Wei B, Cerfolio RJ. Performing robotic lobectomy and segmentectomy: cost, profitability and outcomes. Ann Thorac Surg. 2014;98(1):203–8. doi:10.1016/j.athoracsur.2014.02.051. *This study is new, and many different outcomes are investigated*.
36. Deen SA, Wilson JL, Wilshire CL, Vallières E, Farivar AS, Aye RW, Ely RE, Louie BE. Defining the cost of care for lobectomy and segmentectomy: a comparison of open, videoassissted thoracoscopic and robotic approaches. Ann Thorac Surg. 2014;97(3):1000–7. doi:10.1016/j.athoracsur.2013.11.021.
37. Rinieri P, Peillon C, Salaün M, Mahieu J, Bubenheim M, Baste JM. Perioperative outcomes of video- and robot-assisted segmentectomies. Asian Cardiovasc Thorac Ann. 2016;24(2):145–51. doi:10.1177/0218492315627556.
38. Augustin F, Bodner J, Maier H, Schwinghammer C, Pichler B, Lucciarini P, Pratschke J, Schmid T. Robotic-assisted minimally invasive vs. thoracoscopic lung lobectomy: comparison of perioperative results in a learning curve setting. Langenbecks Arch Surg. 2013;398(6):895–901. doi:10.1007/s00423-013-1090-5.
39. Baste JM, Riviera C, Nouhaud FX, Rinieri P, Melki J, Peillon C. Implementation of a robotic video-assisted thoracoscopic surgical programme. Rev Mal Respir. 2016;33(3):207–17. doi:10.1016/j.rmr.2015.05.004.
40. •• Veronesi G, Galetta D, Maisonneuve P, Melfi F, Schmid RA, Borri A, Vannucci F, Spaggiari L. Four-arm robotic lobectomy for the treatment of early-stage lung cancer. J Thorac Cardiovasc Surg. 2010;140(1):19–25. doi:10.1016/j.jtcvs.2009.10.025. *There are many educational details in this manuscript*.
41. •• Fahim C, Hanna W, Waddell T, Shargall Y, Yasufuku K. Robotic-assisted thoracoscopic surgery for lung resection: first Canadian series. Can J Surg. 2017;60(4):5316. doi:10.1503/cjs.005316. *This study is new and many educational details in it*.
42. •• Toker A, Özyurtkan MO, Kaba E, Ayalp K, Demirhan Ö, Uyumaz E. Robotic anatomic lung resections: the initial experience and description of learning in 102 cases. Surg Endosc. 2016;30(2):676–83. doi:10.1007/s00464-015-4259-x. *There are many educational details in this study*.
43. Toosi K, Velez-Cubian FO, Glover J, Ng EP, Moodie CC, Garrett JR, Fontaine JP, Toloza EM. Upstaging and survival after robotic-assisted thoracoscopic lobectomy for non-small cell lung cancer. Surgery. 2016;160(5):1211–8. doi:10.1016/j.surg.2016.08.003.
44. Egberts JH, Schlemminger M, Schafmayer C, Dohrmann P, Becker T. Robot-assisted minimally invasive lobectomy with systematic lymphadenectomy for lung cancer. Zentralbl Chir. 2015;140(1):15–6. doi:10.1055/s-0034-1396253.
45. Mungo B, Hooker CM, Ho JS, Yang SC, Battafarano RJ, Brock MV, Molena D. Robotic versus thoracoscopic resection for lung cancer: early results of a new robotic program. J Laparoendosc Adv Surg Tech A. 2016;26(4):243–8. doi:10.1089/lap.2016.0049.
46. Liang H, Liang W, Zhao L, Chen D, Zhang J, Zhang Y, Tang S, He J. Robotic versus video-assisted lobectomy/segmentectomy for lung cancer: a meta-analysis. Ann Surg. 2017;. doi:10.1097/SLA.0000000000002346.
47. Davila HH, Storey RE, Rose MC. Robotic-assisted laparoscopic radical nephrectomy using the Da Vinci Si system: how to improve surgeon autonomy. Our step-by-step technique. J Robot Surg. 2016;10(3):285–8. doi:10.1007/s11701-016-0608-6 (Epub 7 June 2016).
48. Lin MW, Kuo SW, Yang SM, Lee JM. Robotic-assisted thoracoscopic sleeve lobectomy for locally advanced lung cancer. J Thorac Dis. 2016;8(7):1747–52. doi:10.21037/jtd.2016.06.14.