Editorial Commentary

Video-assisted thoracoscopic surgery in lung metastasectomy—what is new in lung metastasectomy: an over-view

Jorge Hernández[1]^, Juan J. Fibla[1], Laureano Molins[1,2]

[1]Service of Thoracic Surgery, Hospital Universitari del Sagrat Cor, Barcelona, Spain; [2]Service of Thoracic Surgery, Hospital Clínic, Universitat de Barcelona, Barcelona, Spain

Correspondence to: Jorge Hernández, MD, Service of Thoracic Surgery, Hospital Universitari del Sagrat Cor, C/ Viladomat 288, E-08029 Barcelona, Spain. Email: jhes.82@gmail.com.

Received: 06 July 2020. Accepted: 03 August 2020; Published: 15 December 2020.
doi: 10.21037/vats-2020-lm-07
View this article at: http://dx.doi.org/10.21037/vats-2020-lm-07

After the publication of the results of the International Registry of Lung Metastases (1), there was a great impact on the clinical practice of metastatic lung disease and its surgical management. According to these results, the accuracy of the CT to detect the exact number of lung nodules was 61%. With these findings, they concluded that manual bilateral palpation was required for correct final staging by performing a complete resection of all lung metastases (M1). The importance of complete resection was already a criterion that had been established during forty years as one of the classic criteria in the selection of patients to undergo surgery (2). This impact has been reflected in the increase in publications related to this topic in subsequent years.

The classic defense of the open approach is justified by the frequent discrepancy between the number of lesions seen in the preoperative imaging tests and the final number of resected metastases. This discrepancy has been evident since the 80's but has been maintained over the years (3-5). Thus, an open approach would allow a better lung palpation and detection of possible hidden metastases in the preoperative study, offering a theoretical complete lung resection.

The discrepancy rate between the latest generation helical CT and the pathological findings after the open surgical approach, vary between 15% and 25% (6-8). Several clinical and histological factors have been related to a greater or lesser rate of discrepancies between the CT and the final pathological findings. The most frequently reported were the number of suspicious lesions on CT, bilateral or not of the lesions, disease-free interval, tumor doubling time and certain histological types such as soft tissue sarcomas and osteosarcomas (7,9,10).

A study published in 2011 (11) concluded that CT sensitivity in patients with single pulmonary M1 of colorectal origin was 95.5%. Another study was published in 2013 (12) based on 183 patients, on whom a lung metastasectomy was performed using a thoracotomy. Patients older than 60 years, with one or two M1 of colorectal origin or a single M1 of any other origin were considered as the group with a low probability of resecting more metastases than those observed in the preoperative CT. In this defined group of patients, there was not only an additional M1 in 4.4% of patients in this defined group.

In 1986, a study was published showing the results of performing metastasectomy using median sternotomy in patients with a history of soft tissue osteosarcoma and evidence of unilateral disease on preoperative CT (5). After two-lung examination, it was shown that 38% of the patients had involvement of both lungs. However, this bilateral involvement did not affect a worse cancer prognosis. This work showed that potential hidden metastases can be addressed in a second or successive surgical procedure without compromising the patient's prognosis.

One of the first studies comparing both techniques (Thoracotomy & VATS) in prognostic terms was carried out in 2002 (13). It included patients with a single lung lesion suspected of being metastatic on CT, less than

^ ORCID: 0000-0003-4876-2402.

3 cm. and of peripheral location. The disease-free survival (DFS) at 2 years (VATS 50% *vs.* thoracotomy 42%) and the overall survival (OS) at 2 years (VATS 67% *vs.* thoracotomy 70%) were similar in both groups. Due to the absence of significant prognostic differences, they concluded in favor of video thoracoscopy.

In a subsequent study in 2008 (14), with patients with pulmonary metastases of colorectal origin, both approaches were compared. In the bivariate analysis, between the surgical approach used and the 5-year DFS and OS, the differences pointed to a possible beneficial effect of the thoracoscopic approach (5-year DFS of 34% for VATS *vs.* 21% for thoracotomy, P=0.064; and a 5-year OS of 49% for VATS *vs.* 39% for thoracotomy, P=0.047). In the multivariate analysis, the prognostic factors related to 5-year DFS were the presence of multiple metastases (OR 1.8; 95% CI, 1.11–2.92), hilar and/or mediastinal lymph node involvement (OR 3.48; 95% CI, 1.32–9.17), while for OS, the most influential negative prognostic factors were, the size of the metastasis as a quantitative variable in millimeters (OR 1,049; 95% CI, 1,024–1,046) and the performance of a lesser resection (OR 4.24; 95% CI, 1.19–15.1).

Another study published in 2009 (15) compared the open and thoracoscopic approach in patients with metastases of sarcomatous origin, a disease often banned from video-assisted thoracoscopic surgery (VATS). The inclusion criteria considered the potential resectability according to the number and location of the suspect nodules (two or less nodules). The results were a 3-year DFS of 26% VATS *vs.* 24% thoracotomy (P=0.54) and a 5-year OS of 52% VATS *vs.* 34% thoracotomy (P=0.20).

Over time, different studies have appeared to compared the two types of approach; most of them in selected patients, have not found any differences, and therefore conclude in favor of the video-thoracoscopic approach (16-19). With the progressive improvement of radiological technology (especially CT) in the preoperative study of metastatic disease, much more reliable progress has been made in detecting suspected lung nodules (20-25). This technological boost, together with the postoperative benefits demonstrated by minimally invasive surgery (26-29) at the expense of less pain, faster recovery, less immunological impact, better tolerance to adjuvant cancer treatments, less technical difficulty in the case of remetastasectomy... has been reflected in greater reliability in the use of the videothoracoscopic approach.

Although VATS surgery is one of the pillars of resection of the pulmonary nodule with diagnostic tool and/or curative intention, sometimes the main problem that the surgeon may encounter is locating these nodules, either due to their small size or their location (30). For this reason, different preoperative location methods have been developed. These localization techniques can be categorized into 5 groups according to the materials used; simple digital palpation through the assistance toracotomy; localization with metallic materials: hook-wire (31-34), microcoil (35,36), or spiral coil; localization with dye: methylene blue (37-39), India ink (40) or indigo carmine (41,42); localization with contrast agents: lipiodol (41-43), barium (44), or (45); radioguided occult lesion localization (ROLL) with radiotracers (46-49). Other systems used are: image-guided video-assisted thoracoscopic surgery (iVATS) (50,51) and virtual-assisted lung mapping (VAL-MAP) has evolved from bronchoscopic dye localization (52-54).

An optimal method of preoperative localization for this type of pulmonary nodules has not yet been established. A systematic review of three methods of localizing lung nodules for VATS was recently conducted (55): wire-hook localization, microcoil localization, and with lipiodol. The resulting meta-analysis aimed to compare the success rates and complications associated with these three different localization methods. The success rates between the different localization methods were similar. However, the location by wire-hook posed the problem of migration or displacement of the device, although it is true that many times the insertion area could be "marked" by the bruise produced by the harpoon. The localization method based on Lipiodol obtained the highest overall success rate: hook-wire 0.94 (95% CI, 0.91–0.96), microcoil 0.97 (95% CI, 0.95–0.98), and lipiodol 0.99 (95% CI, 0.98–1.00). The microcoil localization method found the lowest complication rates. The pneumothorax rate produced by the microcoil was 0.16 (95% CI, 0.07–0.34), by the wire hook was 0.35 (95% CI, 0.28–0.43) and by the lipiodol was 0.31 (95% CI, 0.20–0.46). The pulmonary hemorrhage rate was 0.06 (95% CI, 0.03–0.11), 0.16 (95% CI, 0.11–0.23) and 0.12 (95% CI, 0.05–0.23), respectively.

One study, based on a meta-analysis of preoperative bronchoscopic marking for lung nodules (56), included 25 studies (15 studies on dye marking under electromagnetic bronchoscopic navigation, 4 studies on assisted virtual lung mapping, and 7 others using other marking methods). The complete resection rate was 1.00 (95% CI, 1.00–1.00) while the successful marking rate was 0.97 (95% CI, 0.95–0.99). The overall rates of pleural injury were 0.02 (95% CI, 0.01–0.05) and lung parenchymal hemorrhage 0.00 (95%

CI, 0.00–0.00).

The presence of metastatic involved lymph nodes discovered during pulmonary metastasectomy has been found to negatively affect survival in patients sometimes undergoing curative intent pulmonary surgery. Therefore, a complete mediastinal lymphadenectomy, or at least lymph node sampling of various lymph node stations, is recommended at the time of pulmonary metastasectomy to complete the surgery and help define the patient's prognosis and propose future adjuvant treatment (57-62).

Classically, in a lung metastasectomy, surgeons should detect complete resection of lung lesions with negative margins, but should minimize the resection of functional lung tissue as much as possible, because of possible current or future lesions (63). They should be resected while leaving patients with adequate lung function. However, local recurrence at the surgical margin is a problem with limited wedge resections.

More than 50% of patients who undergo pulmonary metastasectomy will have a recurrence locally. This recurrence will appear 28% of the time on the surgical margin. These high percentages occur despite the fact that a complete resection has been histologically confirmed in 95% of the cases, which means that the surgical margin was free of disease (64). Pathologically, there is an increased risk of local recurrence in those patients who, although they present a disease-free surgical margin, 10 or more aerogenic diseases were observed with groups of floating cancer cells around the main tumor (P=0.02). Of course, the risk of local recurrence increased in those patients who presented a positive malignant surgical margin (P=0.04).

The existence of metastatic cells around metastases of colorectal origin is known. These satellite tumor cells represent a potential source of recurrence at the local level. For this reason, efforts should be made to maintain a distance of at least 3 mm in small nodules and at least 8-10 mm in larger sizes in order to prevent future local recurrence (65).

In another published study (66), it was shown that in surgically removed colorectal lung metastases, technical factors related to margin length and tumor size are associated with an increased risk of local recurrence. The risk of local recurrence at 2 and 5 years was 11.8% (95% CI, 8.9–14.6%) and 20.6% (95% CI, 16.2–24.8%), respectively, for each resected nodule. A greater margin of surgical resection represented a lower risk of local recurrence (HR 0.434 for each additional cm; P=0.015). However, a larger size in the metastasis was resected, representing a higher risk of local recurrence (HR 1.520 for each cm of size). Thus, the risk of local recurrence was decreased in larger tumors the greater the margin of surgical resection. The tumor grade or the presence of KRAS did not represent an increased risk of recurrence locally.

Other study published in 2020 (67) where the patients were divided into three groups according to the resection margin distance from the tumor: (I) ≥2 cm; (II) <2 and ≥1 cm; (III) <1 cm. The OS was significantly different between the three groups (P=0.020). Univariate and multivariate analyses showed that a narrow resection margin was an independent prognostic factor of worse survival (P=0.006 and HR 3.4, P=0.009).

In a study published in 2009 (68), patients who did not undergo anatomic lung resection show worse survival, the argument made seems to be related to a more anatomical resection, combined with a hilar lymphadenectomy, which is capable of eliminating the spread of hidden hematogenous of colorectal cancer in the same lobe. Another study demonstrated that the morphological characteristics of the aerogenic spread with groups of floating cancer cells, associated with a vascular invasion at the metastatic site, are two prognostic factors in patients who have undergone a metastasectomy for lung disease of colorectal origin (69). Another study showed that patients whose recurrent sites extended downstream from the lung via hematogenous colorectal cancer spread, pulmonary tumor size was significantly larger than in those with recurrent sites confined to the lung and regions upstream from the lung (70). In our study published in 2016 (71), major anatomic resection was associated with a significant differences in DSS in favor of major resection *vs.* lesser resection (DSS median not reached *vs.* 52.2 months, 95% CI, 45.9–58.5, P=0.03) (figure 2). Also, differences in DFS were statistically significant in favor of the major resection group (DFS median not reached *vs.* 23.9 months, 95% CI, 19.2–28.6, P<0.001). The surgical approach (VATS versus open surgical resection) had no effect on outcome.

The evidence for pulmonary metastasectomy does not include randomized trials, the survival benefit obtained is only based on case series with selected patients. In March 2010, a randomized trial called Colorectal Cancer Lung Metastasectomy (PulMiCC) was performed. The aims of the PulMiCC study are to examine whether surgical resection of lung metastases from colorectal cancer prolonged survival and to systematically record the harm and benefits of such surgery and quality of life (72). The study was stopped due to low recruitment (65 patients). The small number of trial

participants prevents a conclusive answer to the research question. The estimated survival in this study was 38% (23–62%) for patients with metastasectomy and 29% (16–52%) in well matched controls (73).

Currently, lung metastasectomy is a widely established surgical practice in a Thoracic Surgery Department. The latest studies show a similar survival prognosis between open- and video-assisted thoracoscopic approach in selected cases, which is why the latter may have a preference given the immediate advantages of a less invasive approach (74). Despite the fact that sparing parenchymal surgery is widely established, randomized studies should define the role of anatomical resections (anatomical segmentectomy and lobectomy) in this type of pathology nowadays. There are less doubts in the role of lymph node involvement as a prognostic factor, and therefore, the need to perform a lymphadenectomy that provides us with this histopathological information. There are numerous techniques to help in the correct location and subsequent resection of suspicious lung nodules that appeared in the preoperative study and that should be resected.

Acknowledgments

Funding: None.

Footnote

Provenance and Peer Review: This article was commissioned by the Guest Editors (Marcello Migliore and Michel Gonzalez) for the series "VATS in Lung Metastasectomy" published in *Video-Assisted Thoracic Surgery*. The article did not undergo external peer review.

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form, available at: http://dx.doi.org/10.21037/vats-2020-lm-07. The series "VATS in Lung Metastasectomy" was commissioned by the editorial office without any funding or sponsorship. The authors have no other conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

References

1. Pastorino U, Buyse M, Friedel G, et al. Long-term results of lung metastasectomy: prognostic analyses based on 5206 cases. J Thorac Cardiovasc Surg 1997;113:37-49.
2. Alexander J, Haight C. Pulmonary resection for solitary metastatic sarcomas and carcinomas. Surg Gynecol Obstet 1947;85:129-46.
3. McCormack PM, Bains MS, Begg CB, et al. Role of video-assisted thoracic surgery in the treatment of pulmonary metastases: results of a prospective trial. Ann Thorac Surg 1996;62:213-6; discussion 216-7.
4. McCormack PM, Ginsberg KB, Bains MS, et al. Accuracy of lung imaging in metastases with implications for the role of thoracoscopy. Ann Thorac Surg 1993;56:863-5; discussion 865-6.
5. Roth JA, Pass HI, Wesley MN, et al. Comparison of median sternotomy and thoracotomy for resection of pulmonary metastases in patients with adult soft-tissue sarcomas. Ann Thorac Surg 1986;42:134-8.
6. Cerfolio RJ, Bryant AS, McCarty TP, et al. A prospective study to determine the incidence of non-imaged malignant pulmonary nodules in patients who undergo metastasectomy by thoracotomy with lung palpation. Ann Thorac Surg 2011;91:1696-700; discussion 1700-1.
7. Cerfolio RJ, McCarty T, Bryant AS. Non-imaged pulmonary nodules discovered during thoracotomy for metastasectomy by lung palpation. Eur J Cardiothorac Surg 2009;35:786-91; discussion 791.
8. Parsons AM, Detterbeck FC, Parker LA. Accuracy of helical CT in the detection of pulmonary metastases: is intraoperative palpation still necessary? Ann Thorac Surg 2004;78:1910-6; discussion 1916-8.
9. Parsons AM, Ennis EK, Yankaskas BC, et al. Helical computed tomography inaccuracy in the detection of pulmonary metastases: can it be improved? Ann Thorac Surg 2007;84:1830-6.
10. Kayton ML, Huvos AG, Casher J, et al. Computed tomographic scan of the chest underestimates the number of metastatic lesions in osteosarcoma. J Pediatr Surg

2006;41:200-6; discussion 206.
11. Chung CC, Hsieh CC, Lee HC, et al. Accuracy of helical computed tomography in the detection of pulmonary colorectal metastases. J Thorac Cardiovasc Surg 2011;141:1207-12.
12. Zabaleta J, Aguinagalde B, Izquierdo JM, et al. Determination of a low risk group for having metastatic nodules not detected by computed tomography scan in lung metastases surgery. Arch Bronconeumol 2013;49:518-22.
13. Mutsaerts EL, Zoetmulder FA, Meijer S, et al. Long term survival of thoracoscopic metastasectomy vs metastasectomy by thoracotomy in patients with a solitary pulmonary lesion. Eur J Surg Oncol 2002;28:864-8.
14. Nakajima J, Murakawa T, Fukami T, et al. Is thoracoscopic surgery justified to treat pulmonary metastasis from colorectal cancer? Interact Cardiovasc Thorac Surg 2008;7:212-6; discussion 216-7.
15. Gossot D, Radu C, Girard P, et al. Resection of pulmonary metastases from sarcoma: can some patients benefit from a less invasive approach? Ann Thorac Surg 2009;87:238-43.
16. Watanabe M, Deguchi H, Sato M, et al. Midterm results of thoracoscopic surgery for pulmonary metastases especially from colorectal cancers. J Laparoendosc Adv Surg Tech A 1998;8:195-200.
17. De Giacomo T, Rendina EA, Venuta F, et al. Thoracoscopic resection of solitary lung metastases from colorectal cancer is a viable therapeutic option. Chest 1999;115:1441-3.
18. Prenafeta Claramunt N, Hwang D, de Perrot M, et al. Incidence of Ipsilateral Side Recurrence After Open or VATS Resection of Colorectal Lung Metastases. Ann Thorac Surg 2020;109:1591-7.
19. Meng D, Fu L, Wang L, et al. Video-assisted thoracoscopic surgery versus open thoracotomy in pulmonary metastasectomy: a meta-analysis of observational studies. Interact Cardiovasc Thorac Surg 2016;22:200-6.
20. Nakajima J, Takamoto S, Tanaka M, et al. Thoracoscopic surgery and conventional open thoracotomy in metastatic lung cancer. Surg Endosc 2001;15:849-53.
21. Nakajima J, Murakawa T, Fukami T, et al. Is finger palpation at operation indispensable for pulmonary metastasectomy in colorectal cancer? Ann Thorac Surg 2007;84:1680-4.
22. Kang MC, Kang CH, Lee HJ, et al. Accuracy of 16-channel multi-detector row chest computed tomography with thin sections in the detection of metastatic pulmonary nodules. Eur J Cardiothorac Surg 2008;33:473-9.
23. Perentes JY, Krueger T, Lovis A, et al. Thoracoscopic resection of pulmonary metastasis: current practice and results. Crit Rev Oncol Hematol 2015;95:105-13.
24. Cheang MY, Herle P, Pradhan N, et al. Video-assisted thoracoscopic surgery versus open thoracotomy for pulmonary metastasectomy: a systematic review. ANZ J Surg 2015;85:408-13.
25. Eckardt J, Licht PB. Thoracoscopic versus open pulmonary metastasectomy: a prospective, sequentially controlled study. Chest 2012;142:1598-602.
26. Burt BM, Kosinski AS, Shrager JB, et al. Thoracoscopic lobectomy is associated with acceptable morbidity and mortality in patients with predicted postoperative forced expiratory volume in 1 second or diffusing capacity for carbon monoxide less than 40% of normal. J Thorac Cardiovasc Surg 2014;148:19-28, dicussion 28-29.e1.
27. Paul S, Altorki NK, Sheng S, et al. Thoracoscopic lobectomy is associated with lower morbidity than open lobectomy: a propensity-matched analysis from the STS database. J Thorac Cardiovasc Surg 2010;139:366-78.
28. Kondo R, Hamanaka K, Kawakami S, et al. Benefits of video-assisted thoracic surgery for repeated pulmonary metastasectomy. Gen Thorac Cardiovasc Surg 2010;58:516-23.
29. Abdelnour-Berchtold E, Perentes JY, Ris HB, et al. Survival and Local Recurrence After Video-Assisted Thoracoscopic Lung Metastasectomy. World J Surg 2016;40:373-9.
30. Shan L, Hu J, Li M, et al. [Applications of video-assisted thoracic surgery for the diagnosis and treatment of patients with small pulmonary nodules]. Zhongguo Fei Ai Za Zhi 2013;16:369-72.
31. Fujikawa R, Otsuki Y, Nakamura H, et al. Marking method for peripheral non-palpable pulmonary nodules using a mobile computed tomography scanner with a navigation system. Gen Thorac Cardiovasc Surg 2020;68:1220-3.
32. Kastl S, Langwieler TE, Krupski-Berdien G, et al. Percutaneous localization of pulmonary nodules prior to thoracoscopic surgery by CT-guided hook-wire. Anticancer Res 2006;26:3123-6.
33. Park CH, Im DJ, Lee SM, et al. LOGIS (LOcalization of Ground-glass-opacity and pulmonary lesions for mInimal Surgery) registry: Design and Rationale. Contemp Clin Trials Commun 2017;9:60-3.
34. Molins L, Mauri E, Sanchez M, et al. [Locating pulmonary nodules with a computed axial tomography-guided harpoon prior to videothoracoscopic resection. Experience with 52 cases]. Cir Esp 2013;91:184-8.

35. Xu Y, Ma L, Sun H, et al. CT-guided microcoil localization for pulmonary nodules before VATS: a retrospective evaluation of risk factors for pleural marking failure. Eur Radiol 2020;30:5674-83.
36. Rodrigues JCL, Pierre AF, Hanneman K, et al. CT-guided Microcoil Pulmonary Nodule Localization prior to Video-assisted Thoracoscopic Surgery: Diagnostic Utility and Recurrence-Free Survival. Radiology 2019;291:214-22.
37. Sun S, Liu K, Gao X, et al. Application of Modified Tailed Microcoil in Preoperative Localization of Small Pulmonary Nodules: A Retrospective Study. Thorac Cardiovasc Surg 2020;68:533-9.
38. Zhang ZD, Wang HL, Liu XY, et al. Methylene Blue versus Coil-Based Computed Tomography-Guided Localization of Lung Nodules. Thorac Cardiovasc Surg 2020;68:540-4.
39. Jiang T, Lin M, Zhao M, et al. Preoperative Computed Tomography-Guided Localization for Pulmonary Nodules with Glue and Dye. Thorac Cardiovasc Surg 2020;68:525-32.
40. Magistrelli P, D'Ambra L, Berti S et al. Use of India ink during preoperative computed tomography localization of small peripheral undiagnosed pulmonary nodules for thoracoscopic resection. World J Surg 2009;33:1421-4.
41. Seol HY, Ahn HY, Chung HS, et al. Appropriate amounts proportions of lidocaine gel, indigo carmine and lipiodol mixture for preoperative marking in video-assisted thoracic surgery. Gen Thorac Cardiovasc Surg 2020;68:87-90.
42. Kim KS, Beck KS, Lee KY, et al. CT localization for a patient with a ground-glass opacity pulmonary nodule expecting thoracoscopy: a mixture of lipiodol and India ink. J Thorac Dis 2017;9:E349-53.
43. Kim Y, Rho J, Quan YH, et al. Simultaneous visualization of pulmonary nodules and intersegmental planes on fluorescent images in pulmonary segmentectomy. Eur J Cardiothorac Surg 2020;58:i77-i84.
44. Lee NK, Park CM, Kang CH, et al. CT-guided percutaneous transthoracic localization of pulmonary nodules prior to video-assisted thoracoscopic surgery using barium suspension. Korean J Radiol 2012;13:694-701.
45. Lee JW, Park CH, Lee SM, et al. Planting Seeds into the Lung: Image-Guided Percutaneous Localization to Guide Minimally Invasive Thoracic Surgery. Korean J Radiol 2019;20:1498-514.
46. Galetta D, Rampinelli C, Funicelli L, et al. Computed Tomography-Guided Percutaneous Radiotracer Localization and Resection of Indistinct/Small Pulmonary Lesions. Ann Thorac Surg 2019;108:852-8.
47. Dailey WA, Frey GT, McKinney JM, et al. Percutaneous Computed Tomography-Guided Radiotracer-Assisted Localization of Difficult Pulmonary Nodules in Uniportal Video-Assisted Thoracic Surgery. J Laparoendosc Adv Surg Tech A 2018;28:1451-7.
48. Starnes SL, Wolujewicz M, Guitron J, et al. Radiotracer localization of nonpalpable pulmonary nodules: A single-center experience. J Thorac Cardiovasc Surg 2018;156:1986-92.
49. Manca G, Mazzarri S, Rubello D, et al. Radioguided Occult Lesion Localization: Technical Procedures and Clinical Applications. Clin Nucl Med 2017;42:e498-503.
50. Gill RR, Barlow J, Jaklitsch MT, et al. Image-guided video-assisted thoracoscopic resection (iVATS): Translation to clinical practice-real-world experience. J Surg Oncol 2020;121:1225-32.
51. Chao YK, Leow OQY, Wen CT, et al. Image-guided thoracoscopic lung resection using a dual-marker localization technique in a hybrid operating room. Surg Endosc 2019;33:3858-63.
52. Sato M. Precise sublobar lung resection for small pulmonary nodules: localization and beyond. Gen Thorac Cardiovasc Surg 2020;68:684-91.
53. Ueda K, Uemura Y, Sato M. Protocol for the VAL-MAP 2.0 trial: a multicentre, single-arm, phase III trial to evaluate the effectiveness of virtual-assisted lung mapping by bronchoscopic dye injection and microcoil implementation in patients with small pulmonary nodules in Japan. BMJ Open 2019;9:e028018.
54. Sato M, Kuwata T, Yamanashi K, et al. Safety and reproducibility of virtual-assisted lung mapping: a multicentre study in Japan. Eur J Cardiothorac Surg 2017;51:861-8.
55. Park CH, Han K, Hur J, et al. Comparative Effectiveness and Safety of Preoperative Lung Localization for Pulmonary Nodules: A Systematic Review and Meta-analysis. Chest 2017;151:316-28.
56. Yanagiya M, Kawahara T, Ueda K, et al. A meta-analysis of preoperative bronchoscopic marking for pulmonary nodules. Eur J Cardiothorac Surg 2020;58:40-50.
57. Call S, Rami-Porta R, Embun R, et al. Impact of inappropriate lymphadenectomy on lung metastasectomy for patients with metastatic colorectal cancer. Surg Today 2016;46:471-8.
58. Dominguez-Ventura A, Nichols FC 3rd. Lymphadenectomy in metastasectomy. Thorac Surg Clin 2006;16:139-43.
59. Bölükbas S, Sponholz S, Kudelin N, et al. Risk factors for

lymph node metastases and prognosticators of survival in patients undergoing pulmonary metastasectomy for colorectal cancer. Ann Thorac Surg 2014;97:1926-32.
60. Hamaji M, Cassivi SD, Shen KR, et al. Is lymph node dissection required in pulmonary metastasectomy for colorectal adenocarcinoma? Ann Thorac Surg 2012;94:1796-800.
61. Renaud S, Alifano M, Falcoz PE, et al. Does nodal status influence survival? Results of a 19-year systematic lymphadenectomy experience during lung metastasectomy of colorectal cancer. Interact Cardiovasc Thorac Surg 2014;18:482-7.
62. Seebacher G, Decker S, Fischer JR, et al. Unexpected lymph node disease in resections for pulmonary metastases. Ann Thorac Surg 2015;99:231-6.
63. Vogelsang H, Haas S, Hierholzer C, et al. Factors influencing survival after resection of pulmonary metastases from colorectal cancer. Br J Surg 2004;91:1066-71.
64. Shiono S, Ishii G, Nagai K, et al. Predictive factors for local recurrence of resected colorectal lung metastases. Ann Thorac Surg 2005;80:1040-5.
65. Welter S, Theegarten D, Trarbach T, et al. Safety distance in the resection of colorectal lung metastases: a prospective evaluation of satellite tumor cells with immunohistochemistry. J Thorac Cardiovasc Surg 2011;141:1218-22.
66. Nelson DB, Tayob N, Mitchell KG, et al. Surgical margins and risk of local recurrence after wedge resection of colorectal pulmonary metastases. J Thorac Cardiovasc Surg 2019;157:1648-55.
67. Davini F, Ricciardi S, Zirafa CC, et al. Lung metastasectomy after colorectal cancer: prognostic impact of resection margin on long term survival, a retrospective cohort study. Int J Colorectal Dis 2020;35:9-18.
68. Lin BR, Chang TC, Lee YC, et al. Pulmonary resection for colorectal cancer metastases: duration between cancer onset and lung metastasis as an important prognostic factor. Ann Surg Oncol 2009;16:1026-32.
69. Shiono S, Ishii G, Nagai K, et al. Histopathologic prognostic factors in resected colorectal lung metastases. Ann Thorac Surg 2005;79:278-82; discussion 283.
70. Iida T, Nomori H, Shiba M, et al. Prognostic factors after pulmonary metastasectomy for colorectal cancer and rationale for determining surgical indications: a retrospective analysis. Ann Surg 2013;257:1059-64.
71. Hernández J, Molins L, Fibla JJ, et al. Role of major resection in pulmonary metastasectomy for colorectal cancer in the Spanish prospective multicenter study (GECMP-CCR). Ann Oncol 2016;27:850-5.
72. Treasure T, Fallowfield L, Lees B, et al. Pulmonary metastasectomy in colorectal cancer: the PulMiCC trial. Thorax 2012;67:185-7.
73. Treasure T, Farewell V, Macbeth F, et al. Pulmonary Metastasectomy versus Continued Active Monitoring in Colorectal Cancer (PulMiCC): a multicentre randomised clinical trial. Trials 2019;20:718.
74. Gonzalez M, Zellweger M, Nardini M, et al. Precision surgery in lung metastasectomy. Future Oncol 2020;16:7-13.

doi: 10.21037/vats-2020-lm-07
Cite this article as: Hernández J, Fibla JJ, Molins L. Video-assisted thoracoscopic surgery in lung metastasectomy—what is new in lung metastasectomy: an over-view. Video-assist Thorac Surg 2020;5:40.

