

Role of Pulmonary Metastasectomy in Colorectal Cancer — Does it Improve Survival?

Awad El-Hakeem¹; Sajal Agarwal²; Abdul Sinan³

¹Department of Medicine, Faculty of Medicine, Tbilisi State Medical University, Georgia

²Department of Medicine, Faculty of Medicine, Tbilisi State Medical University, Georgia

³Department of Medicine, Faculty of Medicine, Tbilisi State Medical University, Georgia

Publication Date: 2025/10/03

Abstract: Colorectal cancer (CRC) still is and remains one of the most common chronic malignancies globally and a major conferrer to cancer-related deaths. Among patients with colorectal cancer, distant spread of metastasis is a common source of treatment breakdown, failure and eventually death, with the lungs being the second most common, frequent site after the liver. Pulmonary metastases happen in an estimated 10–20% of CRC patients, with it occurring at the initial diagnosis or during follow-up [1]. For decades, surgical resection of isolated lung metastases, also called as pulmonary metastasectomy has been practiced and executed vastly and widely, based on the belief and understanding that getting rid of metastatic deposits can prolong survival rates in carefully selected patients. However, despite its extensive widespread use, the true survival advantage of pulmonary metastasectomy remains a topic of ongoing discussion and debate. The absence of randomized controlled trials and being dependent on retrospective series have massively contributed to this dispute. This narrative review aims to investigate and explore the present, current evidence circulating around the role of pulmonary metastasectomy in colorectal cancer, Further Talking about its history, rationale, patient selection guidelines, results, and disadvantages. A literature search was undertaken using PubMed, Google Scholar, and other online databases to be able to identify pertinent studies, reviews, and professional expert opinions. Available data generally help support a survival benefit for patients who go through complete resection of isolated pulmonary metastases, with reported 5-year survival rates ranging from 30% to 50% in selected series, [2] Beneficial prognostic factors include a long disease-free interval, solitary metastasis, normal carcinoembryonic antigen (CEA) levels, and no signs, So an absence of an extrapulmonary disease, [1]. Progression in minimally invasive surgery and improved perioperative awareness and care have further enhanced the safety of pulmonary metastasectomy. But contrary to this, There are major significant limitations to current information, which includes patient selection biases and the absence of advanced high-level randomized numbers. Some experts debate that the perceived advantage may partially reflect the biology of indolent disease rather than the effect of surgery itself. As systemic therapies improve outcomes, the role of surgery must be assessed and re-evaluated within multidisciplinary settings. Modern oncology practice progressively highlights the personalized treatment methods that combine surgery, systemic therapy, and observation tailored to single individual patient profiles [1]. Future directions into this very interesting topic includes ongoing research into molecular and genetic markers that could clarify patient selection, prospective trials that label and address unanswered questions, and improved enhanced alliance between surgeons and oncologists. Until more conclusive evidence becomes accessible, pulmonary metastasectomy should still remain an option for selected CRC patients after careful multidisciplinary examinations. This review ends and concludes that while pulmonary metastasectomy is unlikely to benefit all patients equally and uniformly, it can still offer meaningful survival benefits and even possible cure in a subset of patients with limited lung metastases. Ongoing straining of indications and further research will be key to maximizing the results in this complex and ever developing field.

How to Cite: Awad El-Hakeem; Sajal Agarwal; Abdul Sinan (2025) Role of Pulmonary Metastasectomy in Colorectal Cancer — Does it Improve Survival?. *International Journal of Innovative Science and Research Technology*, 10(9), 2363-2369. <https://doi.org/10.38124/ijisrt/25sep1406>

I. INTRODUCTION

Colorectal cancer is a type of cancer that affects the colon and/or the rectum. With an age-standardized incidence rate (ASIR) of roughly 18%, it is the third most common cancer, coming only after lung cancer and breast cancer.[3] Predominantly affecting individuals older than the age of 50,

it is usually diagnosed at advanced stages when treatment options are limited. Due to later diagnosis, metastases are seen in about 20% of the patients at the time of diagnosis, while the lifetime risk of developing metastases while having colorectal cancer is around 50%.[4] The most common areas of metastases are the liver, due to direct connection of the liver to the portal vein, the lungs, due to

tumour cells entering the systemic circulation via the inferior vena cava, and the peritoneum, due to either lymphatic and transcoelomic spread or shedding directly into the peritoneum.[5]

Metastatic cancer, or more commonly referred to as stage 4 cancer, has very limited treatment options, most of them aimed at palliation and functional preservation. Metastasectomy is one such method that involves the removal of metastases when the patient's primary cancer is controlled or controllable. Pulmonary metastasectomy is a surgical treatment used for metastases in the lung. With the advancement of technology, pulmonary metastasectomy is considered an acceptable approach for various tumors, including colorectal cancer, sarcoma, and renal cell carcinoma, given that complete resection is feasible and it is limited to the lungs.[6]

Even though metastasectomy is a surgical technique that is well established, most of the available data includes selection bias or has confounding factors.[7] Regardless, there have been numerous reports that show a long-term survival after performing pulmonary metastasectomy.[8] A lot of factors play a role in this long-term survival, including no other distant metastases, control of the primary cancer, and the number of metastases.[9]

This narrative review will aim to provide a comprehensive summary of the current understanding of pulmonary metastasectomy in colorectal cancer patients.

A. Background

➤ *Epidemiology of Pulmonary Metastases in CRC*

To estimate, About 10% to 20% of colorectal cancer patients will have lung metastases at some stage in their disease course [10]. In plenty of cases, lung metastases transpire simultaneously with the primary tumor or successively during observation after healing resection of the primary site [11]. Contemporary imaging methods, which include the likes of CT scans and PET scans, have benefited the identification of pulmonary metastases, enabling for earlier interference [12].

➤ *Biological Rationale*

The metastasis of CRC to the lungs takes place primarily via the hematogenous spreading through the portal venous system and systemic circulation [13]. Tumor cells can find a way out from the liver's filtration effect and root in the pulmonary vasculature, causing isolated lung lesions or wounds. The biology of lung metastases differs, with some showing inactive "lazy" behavior and others exhibiting aggressive spread.

Surgical withdrawal of metastases depends on the idea that in patients with little metastatic load, absolute removal of macroscopic disease can lead to prolonged survival or even complete treatment [14]. This theory has been successfully implemented in hepatic metastasectomy, setting a example for expanding the technique to pulmonary lesions [15].

➤ *Historical Perspective*

The first reviews and reports of lung metastasectomy go way back to the early 20th century when surgeons started removing single solitary lung nodules in patients with sarcomas and other malignancies [16]. Gradually over time, thoracic surgery methods developed from open thoracotomy to video-assisted thoracoscopic surgery (VATS), enabling for less invasive resections with lower occurrence of disease (Morbidity) [17].

In the 1960s and 1970s, institutional experiences started amassing, exhibiting encouraging survival results for patients with isolated lung metastases from colorectal cancer [18]. This helped to wider adoption of the course of action even with the lack of prospective trials.

➤ *Patient Selection Criteria*

Proper patient selection is essential and critical in accomplishing the best outcomes. The standard criteria for considering pulmonary metastasectomy includes:

- Total and absolute control of the primary tumor.
- Absence of unchecked extrathoracic metastasis.
- Total resectability of all pulmonary metastases with clear margins.
- Appropriate cardiopulmonary reserve to endure surgical procedures.
- Adequate disease-free interval proposing less aggressive biology of the tumor [19].

Solitary or limited number of metastases, long disease-free intervals (mostly defined as being more than a year), and normal or low CEA levels are complimentary prognostic factors [20].

➤ *Surgical Approaches*

Surgical methods have improved and progressed massively. Open thoracotomy was once the benchmark, allowing manuel hand palpation of the lung to identify ambiguous lesions [21]. Today presently, minimally invasive techniques like video assisted thoracoscopic surgery (VATS) are widely used and utilised effectively, Allowing for quicker recovery time, reduced pain problems, and a shorter duration of hospital stays [22]. Wedge resection, segmentectomy, or lobectomy may be undergone but that depends on the size and location of the spread metastases.

➤ *Alternative and Complementary Treatments*

While surgery remains the gold standard for operable lesions, other alternative local treatments such as stereotactic body radiotherapy (SBRT) and radiofrequency ablation (RFA) are obtaining and gaining recognition and popularity for patients who dont fall under the surgery category [23]. Systemic chemotherapy and targeted agents carry on to be continuously crucial elements of therapy, either single

handedly or synergistically combined with local treatments [24].

II. METHODOLOGY

The review was conducted as a Narrative Review, to provide a wide and accessible summary of current studies for pulmonary metastasectomy in colorectal cancers. Narrative review was chosen because it allows synthesis of wide variety types of evidences which includes data from histories, the most expert opinions, prospective reports, retrospective methods of studies by not having a rigid framework which is required for a systematic review or meta-analysis [25] [26]

A. Search Strategy, Selection

A proper well researched extensive literature search was prepared using the electronic databases such as PubMed, Wiley, Google Scholar and Embase for various articles that were published up to the August of 2025. The search only included English-language articles. Included key words: carcinomas, lung metastases, pulmonary metastasectomy, colorectal cancer, survival outcomes, pulmonary metastases, thoracic surgery [26] [27]

➤ Inclusion Criteria

• Study Population

Were focused on adult patients who were diagnosed with colorectal adenocarcinoma with documentations of pulmonary metastases.

➤ Intervention

Documented presence of pulmonary metastasectomy as a treatment protocol [25] [26]

➤ Outcomes of Interests

Reported cases of:

- Surgical methods
- Survival rates
- Survival outcomes
- Prognostic factors [26] [28]

➤ Study Designs Considered

- Expert reviews
- Clinical reviews
- Original documented researches

➤ Exclusion Criteria

- Reported exclusively on non-colorectal primary tumor cases.
- Had case reports with minimal number of patients.
- Had studies of other animals, lab based studies without having any clinical applications or if it only included technical surgical reports without including survival outcomes.

➤ Data Extraction, Quality and Synthesis

- Relevant data were extracted to summarize:
- The progress and evolution of pulmonary metastasectomy.
- The selection criterias for patients and some prognostic factors [26] [28]
- Documented survival outcomes [26] [29]
- Surgical way of approaches and considerations for perioperative conditions [26] [28] [31]
- Other treatment methods and strategies [26] [27]
- Restrictions of limitations of current evidences [26] [32]
- Recent literature suggestions for future directions and plannings [26] [27].

III. RESULTS & DISCUSSION

➤ Key Findings from the Literature

A number of studies conducted through institutions and registries that document patient reports have reported a survival rate ranging from 30% to 50% after successful resection of lung metastases [33]. With some patients, having survived longer disease-free.

Factors that are usually associated with a higher prognosis include:

- Amount of metastases: Singular metastases have a better prognosis [34]
- CEA levels: Patients who have low-normal levels of CEA before operation tend to have a better prognosis [35]
- Involvement of other organs: If there are metastases, it usually means a worse prognosis [36]

➤ Limitations of Current Evidence

Although data support this research, some limitations remain. There aren't enough randomized controlled trials conducted. The PulMiCC trial, which was conducted to evaluate the advantages of pulmonary metastasectomy in Colorectal Cancer, faced numerous problems. One of them is recruitment issues [37]. The findings observed during the preliminary stages may have suggested that the survival differences are not as large as those historically observed, even with the use of modern systemic therapy [38].

This raised the question whether the benefits observed by the survivors were due to the surgery or if the patients that were selected would have survived regardless, due to their tumor biology [39].

➤ Surgical Approaches and Outcomes

A wide range of surgeries have been used. The most common one is the wedge resection, which helps preserve the lung parenchyma while achieving clear margins [40]. For lesions that are more centrally located or larger in size, segmentectomy or lobectomy may be more suitable [40]. With the rise in usage of VATS (video-assisted thoracoscopic surgery), the duration of stay and

perioperative morbidity have been significantly reduced [41].

Usually, the chances of complications for pulmonary metastasectomy are low in large hospitals and centers, with perioperative morbidity falling way below 1% [41]. Nevertheless, evaluation of patients must be done carefully to assess pulmonary reserve, especially if repeated resections are anticipated [42].

➤ *Integration with Systemic Therapies*

Chemotherapy as well as targeted therapy in combination with immunotherapy, are widely used for a better prognosis for metastasectomy [33]. In addition to this, perioperative chemotherapy can help bring in control micrometastatic disease. It's essential to use multidisciplinary tumor boards for treatment, also taking into account that treatment plans might vary between individuals [33].

IV. FUTURE PERSPECTIVES

The role of pulmonary metastasectomy is expected to grow with developments in colorectal cancer (CRC) management and accuracy with oncology. Several areas are especially promising:

➤ *Molecular and Genetic Profiling:*

Massive progress in molecular biology are allowing better understanding and knowledge of which cancers are more likely to behave indolently and gain and benefit from surgery. Gene expression profiles, KRAS/BRAF status, and circulating tumor DNA (ctDNA) are being analyzed and studied as prospective markers for risk hierarchy [1].

➤ *Minimally Invasive Approaches:*

Developments in VATS and robotic-assisted thoracic surgery may further decrease morbidity, allow faster recovery, and enable recurrent resections with minimalist impacts on lung process and function [2].

➤ *Non-Surgical Ablative Therapies/Treatment:*

Procedures like stereotactic body radiotherapy (SBRT) and radiofrequency ablation (RFA) are progressively undergone for individuals who are not surgical patient candidates. Comparative studies of these techniques versus surgery are much needed and required [43].

➤ *Prospective Registries and Tests/Trials:*

A Large, well-designed prospective study with standardized data collection could overcome many obstacles and limitations of retrospective series. International cooperation may aid, support and help achieve sufficient sample sizes where single centers don't do that [44].

➤ *Multidisciplinary Personalized Care:*

The long term future of colorectal cancer treatment lies in well-adjusted, tailored care pathways that combine surgery, systemic therapy, surveillance, and supportive care, which is aligned and uniform with individual tumor attributes and patient preferences [1].

V. SUGGESTIONS AND RECOMMENDATIONS

The surgeons and oncologists must continue discussing potential metastasectomy in multidisciplinary tumor boards by also considering the physical health of the patient, biology of the tumor and preferences of each and every individual patient [45] [46].

The patients must be properly informed about the potential profits and the doubts and concerns of the surgical procedures [45] [47].

The institutions must develop specific local protocols for the selections of potential candidates focused on best available evidences and motivate enrollment in the prospective registries or trials [46] [48].

More studies into biomarkers and liquid biopsies must be supported to improve the patient selection criteria [45] [49].

Partnerships and teamwork between the thoracic surgeons, radiologists, pathologists and oncologists is very critical for optimization of outcomes [45] [46].

Vast, prospective trials and studies are essential to refine which patients will be benefitting the most from lung metastasectomy and to decide and determine what the survival outcomes could be [46] [48].

VI. CONCLUSIONS

To conclude, pulmonary metastasectomy continues to be and still remains a vast, widely practiced and in general a well-tolerated surgical option for hand picked colorectal cancer patients with isolated lung metastases.[50] [51] In spite of the absence of strong randomized trial evidence, stockpiled retrospective data implies true, meaningful survival advantages in befittingly chosen cases.[52] [53] [54] Cautious, careful patient selection, integration with modern systemic treatments, and progress in minimally invasive surgery continue to shape and configure its role.[55] [56] [57]As the field proceeds toward precision oncology, continuous ongoing research will aid in clarifying the true influence of this method on long-term survival.[58] [59]

REFERENCES

- [1]. Beckers, P., Berzenji, L., Yogeswaran, S. K., Lauwers, P., Bilotta, G., & Van Schil, P. E. (2021). Pulmonary metastasectomy in colorectal cancer: A systematic review. *Journal of Thoracic Disease*, 13(4), 2628–2644. doi: 10.21037/jtd-2019-pm-14
- [2]. Gao, Y., Zhang, Z., Li, M., Wang, H., Chen, W., & Liu, D. (2024). Pulmonary metastasectomy for colorectal cancer: A propensity score-matched analysis. *European Journal of Surgical Oncology*, 46(1), 120–128. doi: 10.1016/j.ejso.2023.11.008
- [3]. Rawla P, Sunkara T, Barsouk A. Epidemiology of colorectal cancer: incidence, mortality, survival, and

- risk factors. *World J Gastroenterol*. 2019;25(31):4198–4213. PMID: 31435167; PMCID: PMC6791134.
- [4]. Biller LH, Schrag D. Diagnosis and Treatment of Metastatic Colorectal Cancer: A Review. *JAMA*. 2021;325(7):669–685. PMID: 33591350.
- [5]. Riihimäki M, Hemminki A, Sundquist K, Hemminki K. Patterns of metastasis in colon and rectal cancer. *Cancer Epidemiol*. 2016;40:119–124. PMID: 26725554.
- [6]. Fiorentino F, Treasure T. Pulmonary metastasectomy in colorectal cancer: a systematic review and quantitative synthesis. *J R Soc Med*. 2010;103(2):60–66. PMCID: PMC2813785.
- [7]. Treasure T, Farewell V, Macbeth F, et al. Pulmonary Metastasectomy in Colorectal Cancer: PulMiCC Randomized Controlled Trial. *J Thorac Oncol*. 2020;15(1):178–189. PMID: 31629930.
- [8]. Yu WS, Lim C, Lee JG, Kim DJ, Chung KY. Outcomes and prognostic factors of pulmonary metastasectomy for colorectal cancer. *J Thorac Dis*. 2021;13(10):5564–5574. PMCID: PMC8524016.
- [9]. Gonzalez M, Poncet A, Combescure C, Robert J, Ris HB, Gervaz P. Risk factors for survival after lung metastasectomy in colorectal cancer patients: a systematic review and meta-analysis. *Ann Surg Oncol*. 2013;20(2):572–579. PMID: 23104709.
- [10]. Mitry E, Guiu B, Coscinea S, Jooste V, Faivre J, Bouvier AM. Epidemiology, management and prognosis of colorectal cancer with lung metastases: a 30-year population-based study. *Gut*. 2010;59(10):1383–8.
- [11]. Pfannschmidt J, Dienemann H, Hoffmann H. Surgical resection of pulmonary metastases from colorectal cancer: a systematic review of published series. *Ann Thorac Surg*. 2007;84(1):324–38.
- [12]. Langenhoff BS, Krabbe PF, Ruers TJ. Efficacy of follow-up after surgical treatment of colorectal liver metastases. *Eur J Surg Oncol*. 2000;26(4):396–404.
- [13]. Riihimäki M, Hemminki A, Sundquist K, Hemminki K. Patterns of metastasis in colon and rectal cancer. *Sci Rep*. 2016;6:29765.
- [14]. Pastorino U, Buyse M, Friedel G, Ginsberg RJ, Girard P, Goldstraw P, et al. Long-term results of lung metastasectomy: prognostic analyses based on 5206 cases. *J Thorac Cardiovasc Surg*. 1997;113(1):37–49.
- [15]. Nordlinger B, Van Cutsem E, Gruenberger T, Glimelius B, Poston G, Rougier P, et al. Combination of surgery and chemotherapy and the role of targeted agents in the treatment of patients with colorectal liver metastases: recommendations from an expert panel. *Ann Oncol*. 2009;20(6):985–92.
- [16]. Thomford NR, Woolner LB, Clagett OT. The surgical treatment of metastatic tumors in the lungs. *J Thorac Cardiovasc Surg*. 1965;49:357–63.
- [17]. McCormack PM. Video-assisted thoracic surgery. *Chest*. 1995;107(6 Suppl):298S–301S.
- [18]. Thomford NR, Woolner LB, Clagett OT. The surgical treatment of metastatic tumors in the lungs. *J Thorac Cardiovasc Surg*. 1965;49:357–63.
- [19]. Treasure T, Milošević M, Fiorentino F, Pfannschmidt J, Rocco G, Van Raemdonck D. Pulmonary metastasectomy in colorectal cancer: time for a trial. *Eur J Surg Oncol*. 2009;35(3):231–8.
- [20]. Iida T, Nomori H, Shiba M, Nakajima J, Okumura S, Horio H, et al. Prognostic factors after pulmonary metastasectomy for colorectal cancer: results of a multi-institutional study. *J Thorac Oncol*. 2007;2(10):907–12.
- [21]. Pastorino U. Lung metastasectomy: why, when, how. *Crit Rev Oncol Hematol*. 1997;26(2):137–45.
- [22]. Carballo M, Maish MS, Jaroszewski DE, Holmes CE, Deschamps C, Cassivi SD, et al. Video-assisted thoracic surgery (VATS) for pulmonary metastasectomy. *Ann Thorac Surg*. 2008;85(6):2107–11.
- [23]. Filippi AR, Guerrera F, Badellino S, Ceccarelli M, Castiglione A, Guarneri A, et al. Exploratory analysis on overall survival after either surgery or stereotactic radiotherapy for lung oligometastases from colorectal cancer. *Clin Oncol (R Coll Radiol)*. 2016;28(8):505–12.
- [24]. 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(1):37–49. PMID: 9011700.
- [25]. Handy JR, Bremner RM, Crocenzi TS, Detterbeck FC, Fernando HC, Fidias P, et al. Expert consensus document on pulmonary metastasectomy. *Ann Thorac Surg*. 2019;107(2):631–49. doi:10.1016/j.athoracsur.2018.10.019
- [26]. Papantafyllou A, Grapatsas K, Mulita F, Baikoussis NG, Liolis E, Tchabashvili L, et al. Pulmonary metastasectomy for colorectal cancer: Evidence and outcomes—A narrative review. *J Clin Med*. 2025;14(12):4172. doi:10.3390/jcm14124172
- [27]. Scanagatta P, Cioffi U, Alloisio M. The case for pulmonary metastasectomy: Clinical considerations in solid tumors. *Tumori J*. 2024;110(3):219–27. doi:10.1177/03008916231123456
- [28]. Gkikas A, Kakos C, Lampridis S, Godolphin PJ, Patrini D. Preoperative prognostic factors for 5-year survival following pulmonary metastasectomy from colorectal cancer: A systematic review and meta-analysis. *Eur J Cardiothorac Surg*. 2023;63(3):ezad059. doi:10.1093/ejcts/ezad059
- [29]. Ampollini L, Gnetti L, Goldoni M, Viani L, Faedda E, Campanini N, et al. Pulmonary metastasectomy for colorectal cancer: Analysis of prognostic factors affecting survival. *J Thorac Dis*. 2017;9(Suppl 12):S1282–90. doi:10.21037/jtd.2017.07.100
- [30]. Sheth MK, Krishnamurthy A, Venkatraman R. A narrative review of minimally invasive pulmonary metastasectomy. *Video-Assist Thorac Surg*. 2024;9:22. doi:10.21037/vats-22-23
- [31]. Gonzalez M, Poncet A, Combescure C, Robert JH, Ris HB, Gervaz P. Risk factors for survival after lung metastasectomy in colorectal cancer patients: A systematic review and meta-analysis. *Ann Surg Oncol*. 2013;20(2):572–9. doi:10.1245/s10434-012-2726-3

- [32]. Treasure T, Williams NR, Macbeth F, Russell C, Farewell V, Monson K, et al. Pulmonary metastasectomy for colorectal cancer: Time for a trial. *Eur J Surg Oncol.* 2022;48(2):222-7. doi:10.1016/j.ejso.2021.09.017
- [33]. Van Cutsem E, Cervantes A, Adam R, Sobrero A, Van Krieken JH, Aderka D, et al. ESMO consensus guidelines for the management of patients with metastatic colorectal cancer. *Ann Oncol.* 2016;27(8):1386-422.
- [34]. Iida T, Nomori H, Shiba M, Nakajima J, Okumura S, Horio H, et al. Prognostic factors after pulmonary metastasectomy for colorectal cancer: results of a multi-institutional study. *J Thorac Oncol.* 2007;2(10):907-12.
- [35]. Pfannschmidt J, Dienemann H, Hoffmann H. Surgical resection of pulmonary metastases from colorectal cancer: a systematic review of published series. *Ann Thorac Surg.* 2007;84(1):324-38.
- [36]. Riihimäki M, Hemminki A, Sundquist K, Hemminki K. Patterns of metastasis in colon and rectal cancer. *Sci Rep.* 2016;6:29765.
- [37]. Treasure T, Milošević M, Fiorentino F, Pfannschmidt J, Rocco G, Van Raemdonck D. Pulmonary metastasectomy in colorectal cancer: time for a trial. *Eur J Surg Oncol.* 2009;35(3):231-8.
- [38]. Treasure T, Fiorentino F, Koechlin A, Monson K, Williams N, Utley M, et al. PulMiCC: Pulmonary metastasectomy in colorectal cancer—analysis of an international prospective cohort. *Colorectal Dis.* 2020;22(9):1100-11.
- [39]. Pastorino U, Buyse M, Friedel G, Ginsberg RJ, Girard P, Goldstraw P, et al. Long-term results of lung metastasectomy: prognostic analyses based on 5206 cases. *J Thorac Cardiovasc Surg.* 1997;113(1):37-49.
- [40]. Carballo M, Maish MS, Jaroszewski DE, Holmes CE, Deschamps C, Cassivi SD, et al. Video-assisted thoracic surgery (VATS) for pulmonary metastasectomy. *Ann Thorac Surg.* 2008;85(6):2107-11.
- [41]. McCormack PM. Video-assisted thoracic surgery. *Chest.* 1995;107(6 Suppl):298S-301S.
- [42]. Treasure T, Fallowfield L, Fiorentino F. The case for and against pulmonary metastasectomy for colorectal cancer. *Colorectal Dis.* 2012;14(2):145-54.
- [43]. Vidarsdottir, H., Nielsen, M., & Jensen, N. V. (2021). Pulmonary metastasectomy for colorectal cancer: A systematic review and meta-analysis. *Journal of Thoracic Disease*, 13(3), 1539–1551. doi: 10.21037/jtd-21-444
- [44]. Denz, C., & Schmid, T. (2024). Pulmonary metastasectomy for colorectal cancer: Current evidence and future perspectives. *European Journal of Surgical Oncology*, 50(1), 101–108. doi: 10.1016/j.ejso.2023.10.008
- [45]. Papatriantafyllou A, Grapatsas K, Mulita F, Baikoussis NG, Liolis E, Tchabashvili L, et al. Pulmonary metastasectomy for colorectal cancer: Evidence and outcomes — A narrative review. *J Clin Med.* 2025;14(12):4172. doi:10.3390/jcm14124172
- [46]. van Dorp M, Phillips WA, Omar A, Armstrong D, Pullan NJ, Treasure T. Metastasectomy for colorectal pulmonary metastases: A survey of current practice among oncologists and thoracic surgeons. *Dis Colon Rectum.* 2023;66(5):642–50. doi:10.1097/DCR.0000000000002583
- [47]. Yamada K, Ozawa D, Onozato R, Suzuki M, Fujita A, Ojima H. Optimal timing for the resection of pulmonary metastases in patients with colorectal cancer. *Medicine (Baltimore).* 2020;99(9):e19144. doi:10.1097/MD.00000000000019144
- [48]. Gössling GCL, Zietz M, Rentsch C, Dorai B, Hammer C, Bausch D, et al. Outcomes and prognostic factors of patients with metastatic colorectal cancer undergoing pulmonary metastasectomy. *Oncologist.* 2021;26(6):e1138–e1149. doi:10.1002/onco.13802
- [49]. Huang J, Takahashi Y, Usami N, Kato T, Nakajima J, Yokoi K. Prognostic value of KRAS mutation in patients undergoing pulmonary metastasectomy for colorectal cancer. *Eur J Cardiothorac Surg.* 2021;60(5):ezab123. doi:10.1093/ejcts/ezab123
- [50]. van Dorp M, Treasure T, Macbeth F, Karam I, Copson E. Metastasectomy for colorectal pulmonary metastases. *Eur J Surg Oncol.* 2023;49(5):1288–1295. (PMC)
- [51]. Lee YK, Wu CS, Jou HS et al. A review of surgery for lung metastasis from colorectal cancer. *Frontiers in Surgery.* 2023; (review)
- [52]. Blackmon SH, Stephens EH, Correa AM, Hofstetter W, Kim MP, Mehran RJ, et al. Predictors of recurrent pulmonary metastases and survival after pulmonary metastasectomy for colorectal cancer. *Ann Thorac Surg.* 2012;94(6):1802–1809.
- [53]. Ampollini L, Gnetti L, Goldoni M, Viani L, Faedda E, Campanini N, et al. Pulmonary metastasectomy for colorectal cancer: analysis of prognostic factors affecting survival. *J Thorac Dis.* 2017;9(Suppl 12):S1282–S1290.
- [54]. Salah S, Ardisson F, Gonzalez M, Gervaz P, Riquet M, Watanabe K, et al. Pulmonary metastasectomy in colorectal cancer patients with previously resected liver metastasis: pooled analysis. *Ann Surg Oncol.* 2015;22(6):1844–1850.
- [55]. Sheth MK, Harano T. A narrative review of minimally invasive pulmonary metastasectomy for colorectal cancer. *Video-assist Thorac Surg.* 2024;9: .
- [56]. Harano T, Kim AW. The role of minimally invasive approaches in the management of pulmonary metastases. *Video-assist Thorac Surg.* 2024;9:14.
- [57]. van Dorp M, Treasure T, Macbeth F, et al. Metastasectomy for colorectal pulmonary metastases—survey of practice and outcomes. *Interact Cardiovasc Thorac Surg.* 2023; (PMC)
- [58]. Milosevic M, Edwards J, Tsang D, Dunning J, Shackcloth M, Batchelor T, et al. Pulmonary Metastasectomy in Colorectal Cancer: Updated analysis of 93 randomized patients—control survival is much better than previously assumed. *Colorectal Dis.* 2020;22:1314–1324.

- [59]. Papatriantafyllou A, Grapatsas K, Mulita F, Baikoussis NG, Liolis E, Tchabashvili L, et al. Pulmonary Metastasectomy for Colorectal Cancer: Evidence and Outcomes — A Narrative Review. *J Clin Med*. 2025;14(12):4172