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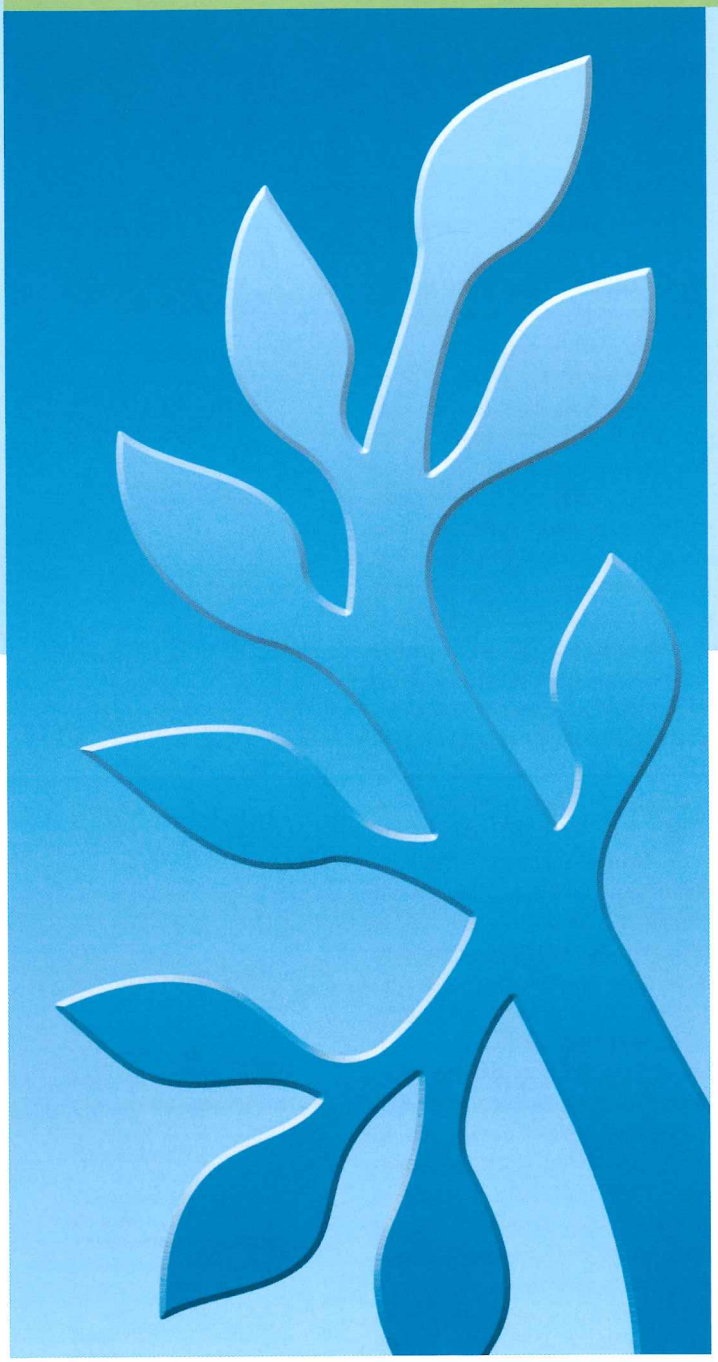

Pulmonary Metastasectomy: Indication and Technique

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Lungenmetastasenchirurgie: Indikationen und Technik

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Key words
- pulmonary metastases
- surgical technique
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Schlüsselwörter
- Lungenmetastasen
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Abstract

Distant metastases of solid tumors are most frequently located in the lung. Most patients with lung metastases suffer from multiple pulmonary lesions or metastases in other organs, which makes these patients unsuitable for surgical treatment. However, several studies suggest a survival benefit if complete resection of all pulmonary metastases is possible. In some patients pulmonary metastasectomy may even be the only curative treatment option. If pulmonary metastases are suspected, contrast-enhanced computed tomography is the diagnostic procedure of first choice. Generally accepted rules for intended curative pulmonary metastasectomy are control of the primary tumor, technically completely resectable metastases, the exclusion of extrapulmonary metastases except for potentially completely resectable hepatic metastases and a functional operability. The most important prognostic factors are complete resection, the exact entity of the tumor, disease-free interval and, to a limited extent, also the number of metastases. In bilateral disease, sternotomy and sequentially staged or one-stage thoracotomy are the standard surgical approaches to be considered, whereby thoracotomy is more advantageous in cases of centrally located lesions and left lower lobe metastases. In unilateral disease, video-assisted resection may be considered under certain circumstances. Primary aim must be R0 resection. Tissue-sparing pulmonary dissection techniques are proposed besides anatomic resections. In particular, in cases of centrally located or multiple lesions, an extensive expertise in thoracic surgery is necessary to preserve as much functional lung parenchyma as possible. Secondary mediastinal lymph node involvement is associated with an adverse prognosis and should therefore be ruled out preoperatively.

Zusammenfassung

Fernmetastasen solider maligner Tumore finden sich am häufigsten in der Lunge. Die meisten Patienten mit Lungenmetastasen weisen eine Vielzahl von Herden auf oder haben Metastasen in anderen Organen, sodass eine operative Therapie nicht in Frage kommt. Viele Untersuchungen belegen jedoch einen Überlebensvorteil für Patienten, bei denen eine vollständige chirurgische Entfernung aller Lungenmetastasen möglich ist. Bei einigen Patienten ist die pulmonale Metastasektomie die sogar einzige kurative Behandlungsoption. Bei V.a. Lungenmetastasen ist die kontrastmittelverstärkte Computertomografie des Thoraxes das diagnostische Verfahren der ersten Wahl. Die bei kurativer Intention geltenden Regeln bei der Indikationsstellung zur Metastasektomie sind die Kontrolle des Primärtumors, die technisch mögliche komplette Resektion aller Metastasen, der Ausschluss extrathorakaler Metastasen mit Ausnahme resektabler Lebermetastasen sowie die funktionelle Operabilität. Die wichtigsten Prognosefaktoren sind die vollständige Resektion, die Tumorentität, das krankheitsfreie Intervall und in beschränktem Maß auch die Anzahl der Metastasen. Bei bilateralen Metastasen kommen die Sternotomie und die sequenzielle oder simultane Thorakotomie als Zugangswege in Betracht, wobei die Thorakotomie bei zentralen Herden oder Herden im linken Unterlappen von Vorteil ist. Bei einseitigem Befall kann unter bestimmten Voraussetzungen auch eine videoassistierte Resektion in Betracht gezogen werden. Primäres Ziel muss immer eine R0-Resektion sein. Neben anatomischen Resektionen finden daher vor allem parenchymsparende lungendissezierende Techniken Anwendung. Insbesondere bei zentralen Metastasen oder multiplen Herden ist große thoraxchirurgische Expertise notwendig, um möglichst viel funktionsfähiges Lungenparenchym zu erhalten. Der sekundäre

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Befall von mediastinalen Lymphknoten ist mit einer ungünstigen Prognose assoziiert, sodass dieser präoperativ ausgeschlossen werden sollte.

Introduction

The lungs are one of the organs most frequently affected by metastatic disease. In the course of the disease, pulmonary metastases arise in around 30% of all tumor patients [1]. Pulmonary metastases occur most commonly in conjunction with tumors of the breasts, colon, kidneys, uterus, prostate and oropharyngeal area. In 1927, at the Royal Brompton Hospital, London, Tudor Edwards performed the pulmonary resection of a metastasis from a sarcoma of the leg that had been treated by amputation six years previously [2]. Alexander and Haight published the first series of studies of pulmonary metastasectomy in 1947 [3]. The resection of pulmonary metastases of the most diverse primary tumors has since come to form a permanent part of the interdisciplinary oncological concept for many solid tumors.

There are no prospective randomized studies on the field of pulmonary metastasectomy, which means that our experience has, to date, been based on case series and tumor registers. The first randomized controlled study comparing pulmonary metastasectomy with any treatment other than resection or ablation in patients with pulmonary metastases in colorectal carcinoma (PulMiCC trial) is currently being conducted under the direction of Tom Treasure [4]. In selected patients, various studies have demonstrated five-year survival rates for various primary tumors of 30–50%, which are far superior to any other methods of treatment [5]. In 1965, Thomford postulated selection criteria for pulmonary metastasectomy, which still essentially hold [6]: 1. the primary tumor is controlled, 2. technically completely resectable lesions, 3. no extrapulmonary nodules apart from potentially resectable hepatic lesions, and 4. justifiable functional risk.

The International Registry of Lung Metastases of the European Society for Thoracic Surgery has retrospectively evaluated 5206 cases from 18 clinics in Europe, the USA and Canada and determined 5-, 10- and 15-year survival rates after complete pulmonary metastasectomy of 36%, 26% and 22%, respectively [7]. For some patients, pulmonary metastasectomy is the only curative therapeutic option [8]. We therefore describe in this overview the current state of knowledge relating to surgical therapy of pulmonary metastases of various primary tumors, focusing on the indications and technical aspects of pulmonary metastasectomy.

Diagnosis

Most patients with pulmonary metastases are initially asymptomatic, which means that metastases are frequently diagnosed as an incidental finding or as part of aftercare. Pulmonary lesions in patients with a history of malignant growth are strong indicators of metastases and should therefore always be further clarified. Particularly where solitary nodules arise, the full range of differential diagnosis of pulmonary nodules should also be considered in patients with a history of cancer. Although, in the case of a 1-cm nodular lesion, the risk of malignancy increases from barely 30% in patients without a history of cancer to over 60% in patients with a positive history, the nodule is benign in some 30% of patients. In addition, in some patients there is no metastasis, but a second tumor is present instead. This applies in particular to patients with risk factors for tumors of the lungs and head/neck. Dyspnea and specific complaints develop only in advanced situations, e.g., invasion of the central respiratory tract with the formation of atelectasis and retention pneumonia or in the case of breakthrough of lymph node metastases or primary metastatic invasion of the bronchial system with hemoptysis. In the case of acute obstruction of the respiratory tract or bleeding, acute symptoms may also arise during chemotherapy. Invasion of the pleura or chest wall may lead to pain.

Where pulmonary metastases are suspected, chest computed tomography (CT) with a contrast agent is the diagnostic procedure of first choice. With the CT scanners currently available, the smallest nodules are detectable down to a few millimeters so that, with careful analysis, scarcely a single nodule is missed. In the case of a slice thickness of 3 mm, Pfannschmidt et al. found a sensitivity of 88.8% compared with resected lesions after manual palpation of the affected lung [9]. Besides assessment of the pulmonary parenchyma, CT scanning of the chest also allows an assessment of potential lymph node invasion. Around 30% of patients with isolated lymph node metastases have pulmonary, mediastinal or hilar lymph node metastases. The invasion of, in particular, mediastinal lymph nodes is generally associated with a more unfavorable prognosis [10], so that secondary lymph node metastases should be ruled out preoperatively by means of endobronchial ultrasound (EBUS) with fine-needle aspiration cytology or mediastinoscopy.

Although, based on theoretical considerations, it seems plausible before a pulmonary metastasectomy to give patients a follow-up CT scan after an interval that, however, has not so far been defined in detail, in order to thereby exclude patients with rapid progression from surgery that would not improve their prognosis. There are, to date, no data to support such an approach [11]. Magnetic resonance imaging does not play an important role in the detection of pulmonary metastases except in special situations (invasion of the chest wall, invasion of major vessels). Nuclear medical investigations may be helpful with radiopharmaceutical-enriching tumors, particularly in the case of extrathoracic findings.

Indication

The indication for surgery of pulmonary metastases is influenced by the most diverse factors. Besides curative approaches, the spectrum extends even to palliative resection for complications that are otherwise uncontrollable (bleeding, retention with abscess formation) or diagnostic interventions associated with multiple nodules that are not resectable (**Fig. 1 a, b**). The following principles continue to apply to pulmonary metastases that are to be operated on for curative purposes:

1. Control of the primary tumor

   For pulmonary metastasectomy to be of value for the patient's survival, the primary tumor must be controlled or controllable [8]. This means that, where the cancer is metachronic, a local recurrence of the primary tumor must be ruled out. In the case of the synchronous diagnosis of pulmonary metastases, the

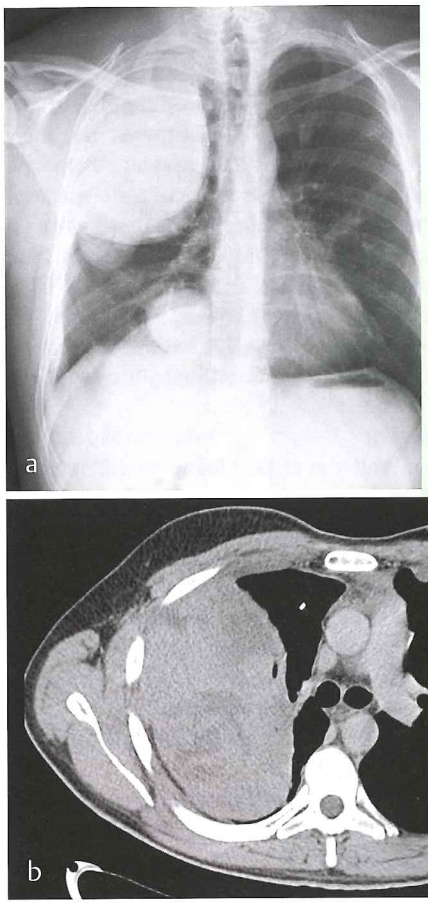

Fig. 1 a and **b** **a** Chest X-ray and **b** CT scan of massive bleeding into an upper lobe metastasis of a synovial sarcoma with subsequent emergency pneumonectomy in connection with further right-sided metastases.

primary tumor must be locally resectable so that sequential resection represents an appropriate therapeutic approach.

2. Complete resection of all pulmonary metastases technically possible
   Technical operability is essentially influenced by the question of whether R0 resection can be achieved. This depends not only upon the number of metastases present but also upon the nature of the primary tumor and the location of the metastases. In some patients, a single central metastasis near the hilus that involves the pulmonary vessels may signify inoperability, whereas more than 20 or 30 metastases can generally be resected in children with osteosarcomas so long as these are far enough away peripherally in the pulmonary parenchyma. In addition, unlike some epithelial tumors (e.g., breast carcinoma), metastases of, for example, osteosarcomas or even parotid tumors scarcely present infiltration of the surrounding pulmonary tissue, which means that these can be resected readily with an economical margin of healthy tissue. Even in the case of multiple metastases, an experienced thoracic surgeon should, therefore, be consulted to be able to clarify the question of resectability. If R0 resection is possible, the number of nodules does not primarily play a major role.
3. Exclusion of extrathoracic metastases
   Secondary metastatic spread into the mediastinal and hilar lymph nodes is associated with significantly poorer survival [10]. Where lymph node involvement is suspected, this should be excluded preoperatively by mediastinoscopy or endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA). FDG positron emission tomography (PET) is not yet used routinely for the clarification or staging of patients with pulmonary metastases. Our own experience and also data from the literature nevertheless indicate that further metastases that are, to date, unknown are detected in 9–15% of patients [12, 13]. As an alternative to PET, when considering the surgical therapy of patients with pulmonary metastases, careful staging of the primary tumor and potentially further metastatic spread sites should take place because further extrapulmonary tumor detection would frequently signify inoperability. The dictum of the compulsory absence of extrathoracic metastases in potential candidates for surgery now no longer consistently holds. Particularly in patients with colorectal carcinomas, sequential therapy of hepatic and pulmonary metastases is generally considered the therapy of choice [14].
4. Functional operability in place
   Besides technical and oncological resectability, functional operability must be assessed prior to an intervention. In addition to analysis of pulmonary function with spirometry and body plethysmography, extended diagnosis may be required via perfusion scintigraphy and ergospirometry to calculate postoperative pulmonary function and, where applicable, to clarify cardiovascular status where relevant risk factors apply.

Prognostic Factors

Through the work of the International Registry of Lung Metastases on the long-term results of pulmonary metastasectomy, various parameters have been identified that are associated with a favorable prognosis and that may therefore be helpful in determining indications [7]. These include complete resection, tumor entity and the disease-free interval and, to a limited extent, also the number of pulmonary metastases.

In patients with epithelial tumors, long-term survival of approx. 40% after 5 years and 20% after 10 years may be expected. In sarcoma patients, long-term survival chances are somewhat less favorable. In the overwhelming majority of patients, multimodal therapy of germ cell tumors, including pulmonary metastasis resection, is associated with lasting freedom from tumors, whereas only a small percentage of patients with melanomas may be expected to have long-term freedom from tumors (**Table 1**).

The significance of the disease-free interval for the prognosis of the patient after pulmonary metastasectomy indicates the influence of tumor biology in the individual case. Patients with a long disease-free interval of, for example, more than one year, have more than a 50% chance of long-term survival, whereas patients with a shorter disease-free interval (< 12 months) remain postoperatively tumor-free for the first five years only with a probability of 38% [7].

Table 1 Long-term survival after pulmonary metastasectomy in various tumor entities (modified according to [7]).

	Long-term survival		
Tumor entity	**5 years**	**10 years**	**Median (months)**
Epithelial tumors	37%	21%	40
Sarcomas	31%	26%	29
Germ cell tumors	68%	63%	–
Melanomas	21%	14%	19

Specific Aspects of the Commonest Tumor Entities

Surgery is indicated in the case of virtually all solid tumors (◉ Fig. 2). Specific features are set out below for the commonest tumor entities:

Colorectal carcinomas

Pulmonary metastases arise in 10–20% of all patients with colorectal carcinomas. In view of the formation of pulmonary metastases, the presence of individual pulmonary metastases and a normal CEA value are favorable prognostic factors [15]. Initial epidemiological studies are now available; these show that, in the case of colorectal carcinoma in synchronous and metachronic resectable pulmonary metastases, three-year survival may be increased from 11% and 13% to 53% and 59%, respectively [16]. Whereas the coexistence of pulmonary and hepatic metastases meant virtual inoperability several years ago, current studies have shown that five-year survival is achievable in more than 40% of patients by the combined procedure [14].

Renal cell carcinomas

At diagnosis, around 25–30% of all patients with renal cell carcinomas have metastases, and a further 30% develop metastases in the course of their illness, with the lungs being the most frequently affected organ [17%]. Besides the pulmonary parenchyma, the mediastinal lymph nodes are also frequently affected by metastatic spread. A survival benefit after complete pulmonary metastasectomy with five-year survival rates of 41–45% compared with 8–22% after incomplete resection has been demonstrated [18, 19], which means that renal cell carcinomas are the second commonest indication for pulmonary metastasectomies. In the case of isolated mediastinal lymph node invasion without involvement of the pulmonary parenchyma, surgery also constitutes a good option, not least in order to avoid local complications such as tumor invasion and atelectasis. In the case of primary multiple pulmonary lesions, in isolated cases we have positive experience of neoadjuvant systemic therapy and subsequent resection.

Malignant melanoma

The surgical treatment of pulmonary metastases in malignant melanoma is controversial because long-term results after complete resection, unlike with the other entities listed, are rather unfavorable, with five-year survival of 21–25% [20,21]. In the study by Neuman et al., median survival after metastasectomy was 40 months versus 13 months in patients without metastasectomy. The same study was unable to find any difference in survival between responders and non-responders to systemic therapy [21]. In a study by Petersen, five-year survival after complete metastasectomy is reported to be 21% versus 13% after incomplete resections. The therapeutic gain after complete resection is thus far superior to any drug therapy. Unfavorable predictors are a short disease-free interval (< 5 years), a greater number of metastases (≥ 2) and the detection of extrathoracic metastases [20]. In case of doubt, surgery should, in our view, be considered, particularly in otherwise medically uncompromised young patients.

Carcinomas of the breast

Planchard et al. [22] and Welter et al. [23] found no difference in survival after complete and incomplete resection of pulmonary metastases in carcinomas of the breast. An influence of resection on survival therefore seems doubtful. In the case of a solitary pulmonary metastasis, five-year survival is around 44%, while 10- and 15-year survival rates are reported to be around 23%. Because receptor status has a bearing on survival [23], the value of diagnostic resection in confirming the entity and determining the receptor status should, however, be mentioned [5].

Sarcomas

Many patients with osteosarcomas develop metastases purely in the lungs. Where tumors recur, the lung is the most frequently affected organ. A survival benefit from complete and, where applicable, also repeated pulmonary metastasectomy with five-year survival rates of over 40% has long been known [24,25]. Soft-tissue sarcomas also metastasize preferentially in the lung. In the case of complete resection, in which 20–30 metastases are completely resectable, five-year survival rates of over 50% may be achieved [26]. The thoracic surgeon is, in this context, traditionally firmly involved in the therapeutic concept.

Germ cell tumors

Non-seminoma germ cell tumors typically metastasize in multiple form, preferentially in the lung, and are to a large extent chemosensitive. Metastasectomy takes place in accordance with cisplatin-based chemotherapy. The aim is to resect the residual tu-

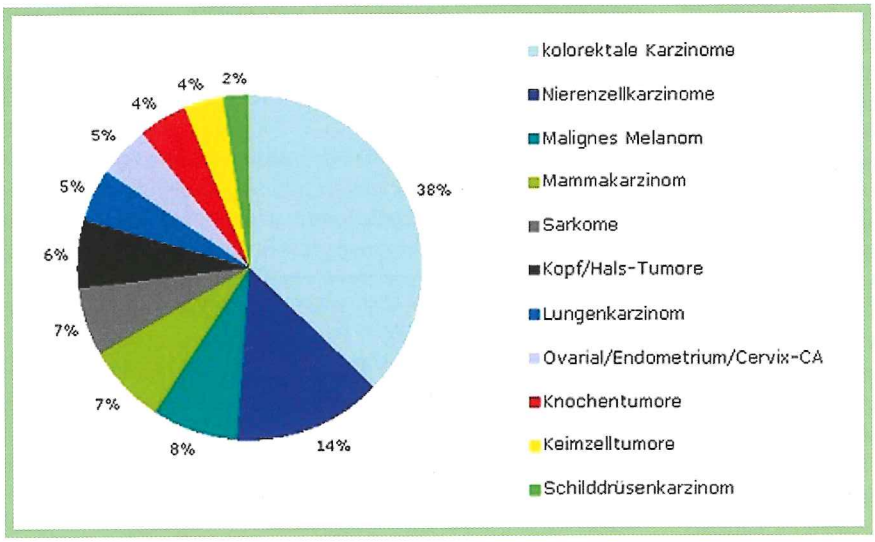

Fig. 2 Percentage of the various primary tumors in 300 patients with curatively intended pulmonary metastasectomy seen in the authors' department between January 2005 and June 2010.

mor and identify vital tumor cells as an indicator for adjuvant therapy. Ten-year survival rates of over 80% have been reported following complete resection of all residual tumors after chemotherapy [27].

Other entities

A survey of the members of the European Society for Thoracic Surgery revealed that the primary tumor entity is not, in most cases, regarded as limiting or a contraindication. Most rarely the indication of pulmonary metastasectomy is confirmed for gynecological tumors. Of those surveyed, 69% also confirmed the indication of metastasectomy in primary pulmonary carcinoma [28].

Surgical Strategies

Complete resection is the main prognostic factor [7]. The aim must therefore always be complete resection in healthy subjects. With regard to the number of metastases, no absolute upper limit can be indicated. More recent investigations show that even with multiple lesions, long-term survival can be achieved so long as an R0 resection seems feasible [29].

Surgical Approaches

Until a few years ago, median sternotomy based on the need for bilateral exploration of the lung in connection with metastatic disease, which was thus to be regarded as systemic, was the approach of choice. The intention behind this approach was to detect metastases that had not been found by imaging [5]. The rationale for this was refuted by Roth et al. and others [30,31]. In the case of unilateral metastases on preoperative imaging, sternotomy was therefore abandoned in favor of lateral thoracotomy. In the presence of bilateral metastases with posterior lesions or lesions in the left lower lobes or in the case of revision surgery, sequential thoracotomy is recommended because median sternotomy seems rather unsuitable in these cases [32]. As a result of modern imaging with high-resolution CT scanners, the need for thoracotomy for bimanual palpation of the lung is now being called into question. In 57 patients with metastases that imaging had proven to be thoracoscopically resectable, an investigation by Cerfolio detected additional pulmonary nodules in 21 patients (37%) during thoracotomy, which corresponded to histological metastases in 10 patients (18%) [33]. Many authors therefore continue to favor bimanual palpation in order not to overlook any metastases [32].

There is now scarcely any doubt that open surgical exploration is capable of detecting lesions that had not been picked up by preoperative imaging. There are, however, no data confirming the prolongation of life via initially manually detected micrometastases [5]. Randomized studies comparing minimally invasive video-assisted thoracoscopic surgery (VATS) with open surgical exploration in connection with pulmonary metastasectomy have not been published to date. We advocate an approach geared to the individual case that is aimed at preoperative CT investigations so that minimally invasive video-assisted thoracoscopic surgery can be employed. Particularly in elderly patients, where the subject has a long disease-free interval and also where there is imaged morphological evidence of only one metastasis that can be soundly resected by thoracoscopy, a minimally invasive approach seems justifiable. In these cases, careful follow-up must nevertheless be carried out in order to be able to detect any further lesions in good time. **Table 2** illustrates approaches for pulmonary metastasectomy as a function of preoperatively demonstrated tumor invasion.

Techniques of Pulmonary Metastasectomy

The primary aim of the operation must be complete resection of all metastases. Recurrent pulmonary metastases are, however, not rare. In the study by Pastorino, the long-term results of patients after a second pulmonary metastasectomy were remarkably good, with 5- and 10-year survival rates of 44% and 29% versus 34% and 25% in patients with only one operation [7]. Jaklitsch et al. investigated the value of sequential pulmonary metastasectomy in various primary tumors and found 5-year survival rates of > 33% in up to five procedures [34]. With the loss of local tumor control in the case of non-resectability, two-year survival fell to 19%. The authors concluded that repeated pulmonary metastasectomies are eminently justifiable provided that local control by intrathoracic means is possible. More recent studies also confirm that the number of metastasectomies does not significantly influence long-term survival [29]. In daily practice, this means that repeated revision surgery is not uncommon. The secondary aim should therefore be to leave as much functionally viable pulmonary parenchyma in place as possible.

Peripheral pulmonary nodules are most frequently resected atypically. In the case of very large or centrally located lesions, however, anatomical resections in the form of segmental resections, lobectomies or even pneumonectomies are also required, with this being necessary and appropriate in only a few patients. Welter et al. have considered the question of the safety margin in patients with pulmonary metastases in association with colorectal carcinomas. In their study, they found, by means of immunohistochemistry in 16 out of 17 resected pulmonary metastases, a total of 205 satellite lesions in the form of tumor cells in decreasing numbers as a function of distance and size of the metastasis, and concluded that a safety margin of 3 mm should be observed for small metastases (< 2 cm) and a safety margin of 8–10 mm for large metastases [35]. However, the evidential value of this study is limited by the fact that, naturally, it is not possible to discriminate reliably between satellite tumor cells of an individual metastasis and the presence of tumor cells that form an independent metastatic spread from the primary tumor. For atypical resections, stapling devices are employed in some cases, with which a lot of pulmonary parenchyma must often be needlessly sacrificed. A number of alternative techniques that spare parenchyma are described in the literature:

Table 2 Approaches for pulmonary metastasectomy as a function of preoperatively proven tumor invasion.

Unilateral invasion:
→ lateral thoracotomy, where appropriate VATS
Bilateral invasion with peripheral, small lesions:
→ sternotomy
Bilateral invasion + central lesions or left lower lobes:
→ sequential thoracotomy (interval: 3–4 weeks)

Electrocauterization

In a resection by electrocauterization, superficial lesions may be excised directly using diathermy. To resect central lesions, following pleural marking of the area to be resected by means of cauterization, the pulmonary parenchyma is coagulated and incised in small steps by fine-armed forceps. Blood vessels and bronchi are isolated and sealed by ligature or suturing, and the parenchymal defect formed is then sealed with a visceralizing suture. This technique, which was initially described by Perelman [36], presents itself as a solution for pleurally located small pulmonary nodules, but is, on the other hand, limited for larger and central lesions owing to the frequent lack of blood coagulation and subsequent parenchymal leakage and the restricted usability for thoracoscopic resections.

Laser resections

Laser resection offers many benefits: it allows for a parenchyma-sparing resection to be undertaken, even with central lesions, without having to damage excessive quantities of uninvolved pulmonary parenchyma and also, in the case of lesions in the immediate vicinity of a bronchus or vessel, allows for the resection without damaging nearby structures (**Fig. 3a, b**). In laser resection, the interstice, capillaries and small lymph and blood vessels are sealed. The parenchymal defect formed is sealed by visceralizing suturing. Rolle et al. have reported five-year survival rates of 41% after resection of a median of eight metastases in 328 patients with the 1318-nmNd : YAG laser [37]. Compared with other techniques, a disadvantage is the possibly slightly increased expense of equipment and additional time required. An advantage is the fact that the operation entails very little bleeding and that it always allows optimal control of the resection margins. Where there are multiple metastases, the palpation capacity of the pulmonary tissue is preserved, which is of very great importance in tracing small lesions.

LigaSure system

The LigaSure Vessel Sealing System is an electrothermal bipolar tissue sealing system. Experience with the LigaSure system in thoracic surgery is limited. Case series with a total of 84 atypical resections in 36 patients via VATS and thoracotomy prove the effectiveness of this technique. Disadvantages seem to be a longer operating time with deep intraparenchymatous lesions and a lack of certainty in the excision of lesions near the hilus [38].

Lymphadenectomy

The question of lymphadenectomy as part of pulmonary metastasectomy is controversial. In a survey of members of the European Society for Thoracic Surgery, 55% stated that they performed mediastinal lymph node sampling [28]. Of all the patients in the International Registry of Lung Metastases, lymph node dissection was performed on only 4.6%. Pfannschmidt et al. performed systematic lymph node dissection on 245 patients as part of pulmonary metastasectomy and found lymph node involvement in 42.4% of cases in connection with renal cell carcinomas, in 31.3% in connection with colorectal carcinomas, and in 20.3% in connection with sarcomas [10]. In a review, the same authors found five-year survival rates of 0–33.5% in patients with colorectal carcinomas with lymph node involvement compared with 38.7–71% in patients without thoracic lymph node metastases [39]. It remains unclear whether lymphadenectomy is associated with a survival benefit. The prognosis of patients with lymph node metastases is nevertheless certainly much less favorable so

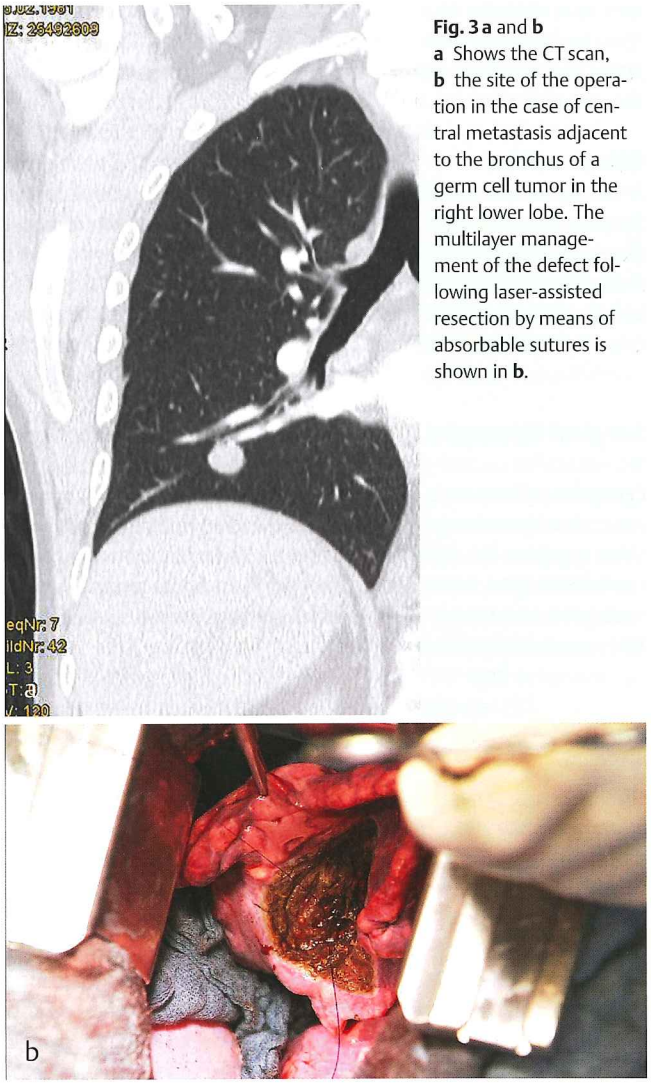

Fig. 3a and **b**
a Shows the CT scan, **b** the site of the operation in the case of central metastasis adjacent to the bronchus of a germ cell tumor in the right lower lobe. The multilayer management of the defect following laser-assisted resection by means of absorbable sutures is shown in **b**.

that, where operability is questionable, mediastinal lymph node invasion should be ruled out preoperatively if this is suspected at the imaging stage. During the pulmonary metastasectomy itself, at least dissection of the locoregional lymph nodes should take place in order to obtain information on lymph node status. This may be important for further decisions, e.g., adjuvant therapy, particularly in patients with colorectal carcinomas.

Alternative Procedures in the Case of Inoperability

Where high-risk patients are medically inoperable, radiofrequency ablation (RFA) provides an alternative therapeutic option. In their investigations, Pennathur et al. have been able to show that percutaneous CT-guided RFA is an uncomplicated procedure in high-risk patients [40]. Proof of the effectiveness of this procedure on the preparation was provided by the study by Schneider et al. In their study, complete ablation was found histopathologically in 7 (39%) of the patients following resection of the lesions located via thoracotomy and manual palpation with intraoperative RFA and subsequent resection [41]. In nine (50%) of the patients, the degree of ablation was still over 9%. No clear spectrum of indications has nevertheless yet arisen for RFA, because often only isolated lesions can be treated in a favorable location.

Stereotactic radiotherapy can contribute to locoregional tumor control in inoperable patients and should be available as an important alternative or additional procedure. In some patients, surgery and stereotactic radiotherapy may supplement one another, depending on the tumor site, which means that appropriate experience should be available on site.

Conclusions

Pulmonary metastasectomy is a potentially curative therapeutic procedure. Provided that the selection criteria in effect are observed, the prognosis of patients with systemic dissemination of their malignant disease can be improved by pulmonary metastasectomy. So long as an R0 resection is technically possible, the number of lesions is often of secondary importance. Even in the case of multiple metastases, an experienced thoracic surgeon should, therefore, be consulted. Open surgical exploration is the most sensitive method of detection. Where there are solitary findings, video-assisted resection may nevertheless also be considered. In these cases, the complete differential diagnosis of pulmonary nodules should be considered preoperatively and, where metastasis is detected, careful aftercare should be undertaken. Because revision surgery is not uncommon, as much functional pulmonary tissue as possible should be preserved. The laser techniques allow parenchyma-sparing resection even in the case of central lesions. It is unclear whether lymphadenectomy is associated with a survival benefit. Because patients with lymph node involvement nevertheless present a much poorer prognosis, dissection of the locoregional lymph nodes should be carried out as part of the metastasectomy, at least on diagnostic grounds.

Conflict of interest: None

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