



Limax Nd:YAG laser–assisted thoracoscopic resection of pulmonary metastases; a single centre’s initial experience

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Abstract

Introduction Pulmonary metastasectomy and indeed redo-pulmonary metastasectomy are now commonly performed thoracic surgical procedures. The air-sealant, haemostatic, and necrotic properties of the KLS Martin Limax Nd:YAG laser at 1.318 μm make it an ideal tool for limited lung resection such as metastasectomy. We present our initial experience of thoracoscopic laser metastasectomy.

Methods We reviewed data from the first seven patients in our unit to undergo thoracoscopic laser metastasectomy, in particular, patient age, gender, primary malignancy, primary treatment, complications, length of stay (LOS), and final histopathology. All procedures were performed using a two- or three-port thoracoscopic technique with some lesions requiring CT-guided wire localisation. A single drain was inserted via the camera port site and was removed upon confirmation that there was no air leak.

Results Seven patients underwent thoracoscopic laser wedge metastasectomy of eight lesions in our centre between February 2017 and October 2017. The median age was 61 years. The primary disease was colorectal carcinoma in five cases, eccrine carcinoma in one case, and high-grade uterine leiomyosarcoma in one case. Only one patient had a prolonged air leak in the other six cases; the drain was removed on post-operative day 1. The median post-operative LOS was 1 day. All patients had confirmed metastatic disease with clear resection margins on histopathology.

Conclusion In our early experience, thoracoscopic laser wedge metastasectomy is a safe and efficient method for performance of pulmonary metastasectomy. We experienced a low complication rate and a short post-operative stay.

Keywords Laser · Metastasectomy · Pulmonary · Thoracoscopic

Introduction

The concept of pulmonary metastasectomy has evolved dramatically over the past 60 years. Pulmonary metastasectomy and indeed redo-pulmonary metastasectomy are now commonly performed thoracic surgical procedures with approximately 30% of all cancer patients developing lung metastases at some point [1]. The first pulmonary metastasectomy took place in 1930 with the resection of a single renal cell carcinoma deposit by Barney and Churchill [2]. Shortly thereafter, a team from The Memorial Hospital Sloan-Kettering Cancer Centre, New York, published a paper on their experiences of pulmonary metastasectomy [3]. Their study reported 663

resections in 448 patients with an almost equal split between metastatic sarcoma and carcinoma being resected. At this time, the operation was performed through a thoracotomy with resection of all visible metastases using various techniques from wedge resections to pneumonectomies. Seventy percent of these patients were managed with either a wedge resection of segmentectomy.

To date, the published evidence for pulmonary metastasectomy is comprised of registry data and follow-up studies where selection bias may have influenced results [4]. In an effort to overcome this data deficit, Pastorino et al. published a data from The International Registry of Lung Metastases. This showed lung metastasectomy to be a safe and potentially curative procedure [5]. In 2011, a follow-up single-centre study confirmed that completeness of the resection, tumour histology, and disease-free interval were independent prognostic factors identifying patients that may benefit from pulmonary metastasectomy. Over a 5-year follow-up period, the survival in patients with complete resection was

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36% compared to 13% in those with incomplete resection [5]. In contrast to the 1997 study, Casiraghi et al. demonstrated no statistical significance that the number of metastases resected influenced survival [6].

The indications for pulmonary metastasectomy have evolved since 1958 from those first proposed by Ehrenhaft [7]. The National Comprehensive Cancer Network (NCCN) has published guidelines for the resection of colorectal cancer lung metastases. The indications proposed throughout the literature for pulmonary metastasectomy and are now largely in concordance. The primary malignancy must be controlled or controllable, there must be an absence of extra-thoracic metastasis or resectable extra-thoracic metastasis, the tumour must be fully resectable with adequate remaining pulmonary reserve, and there must be an absence of medical treatment options with lower morbidity [8–10].

The current surgical approach to pulmonary metastasectomy has evolved since its conception. The techniques adopted have mirrored the changing trends and thoracic surgical technologies across this time period. Resection via precision cautery was first described by Perelman in 1983 [11]. This technique describes the careful separation of the lesion from the surrounding lung tissue using electrocautery and ligation of sizeable vessels. On removal of the lesion, a black coagulated lung surface remains with limited air leak occurring. This area can either be sutured closed or be left open. This approach facilitated excision of deep-seated lesions while conserving the maximum lung tissue [11].

With the progression of video-assisted thoracoscopic surgery (VATS) within the speciality, many of these open techniques have been refined for a minimally invasive approach. VATS minimises the systemic insult from surgery and aims to reduce any delay to further systemic therapies [12]. The inherent reduced exposure to the lungs via a VATS approach limits the possibility for bimanual palpation of lesions making identification of the targeted lesion potentially troublesome. Failure to identify the target pulmonary lesion has been cited as a common reason for conversion from VATS to open [13]. Preoperative CT-guided wire localisation can be utilised to prevent this. This is a safe, cost-effective, and reliable method of identifying the target lesion [14]. It facilitates accurate lesion identification intra-operatively making the procedure quicker with reduced likelihood of conversion to open and accuracy of acceptable resection margins.

Laser-assisted pulmonary resection has a number of advantages. These include limited excision of deep-seated lesions allowing as much sparing of healthy lung tissue as possible. There is minimal deformity or damage to adjacent tissue improving the accuracy of follow-up surveillance scanning. For lesions located near a major bronchus or blood vessel, a maximum margin of tissue around the lesion can be obtained without injury to the adjacent structures. The major disadvantage of early laser-assisted pulmonary resection had been in

the development of a laser with adequate coagulation properties as well as cutting properties. The KLS Martin Limax Nd:YAG laser at 1.318 μm is ideally designed for pulmonary resection allowing both extremely accurate dissection and immediate coagulation, which in turn allows precise resection with minimal blood loss and pneumothorax. Nd:YAG lasers operating at this particular wavelength have been gaining in popularity recently in the setting of laser-assisted lung metastasectomy, and they have been shown to provide oncologic safe resection in up to 93% of cases with varying lesion sizes and locations [15, 16]. We report the preliminary experiences of the first seven cases of thoracoscopic laser metastasectomy performed in Ireland.

Methods

This single-centre study took place in a national thoracic surgery specialist unit. The service provides an enhanced recovery protocol for all thoracic surgery patients. This programme aims to provide a patient-tailored and procedure-specific pathway, centred around patient education, pulmonary prehabilitation, active drain management, consistent analgesic pathways, and extensive physiotherapy. All cases within this series were performed using KLS Martin Limax 120 system. This is a diode pumped neodymium-doped yttrium aluminium garnet (Nd:YAG) laser operating at 1.318 μm . The power setting initially used was 40 W but was often increased up to 50 W. The laser functions as light energy which is converted to heat in the tissue with temperatures in excess of 900 °C. This causes local tissue vaporisation. Given the unique hazards posed by the use of laser devices, additional safety measures were implemented. Certification in laser safety was mandatory for theatre staff involved in its operative use. Appropriate blacking out of theatre windows and utilisation of signage was enforced. All staff present within the theatre at the time of its use were required to wear certified laser protection goggles during the case. Three patients had lesions that were deemed to be too small or deep on the preoperative CT scan to be located visually or on palpation at surgery, and therefore, it was felt that these lesions required preoperative wire localisation. In each of these cases, a hooked wire was inserted using CT guidance by the interventional radiology team on the morning of surgery.

All procedures were performed using single-lung ventilation and a double-lumen endotracheal tube with the patient positioned in the lateral position. A two- or three-port standard thoracoscopic technique with an anterior approach was used for all cases. The first port was a 2–2.5-cm anterior incision in the fourth intercostal space. A wound protection film (Alexis Protector; Applied Medical) was used within this incision, and through this, the hand-held laser device was deployed as well as providing a port for smoke extraction

using the Limax laser's integrated smoke evacuator. A second port was sited below and lateral to the first for the introduction of a 10-mm camera port, and a 30° Olympus endoscopic camera was used. In most cases, a third incision was made in the second or third intercostal space anterior to the mid axillary line. This third port allowed for bimanual palpation of the lung parenchyma to be performed and provided a second port for retraction. The lesions were located either using visual identification and manual palpation or by the presence of the CT-guided wire. Once the lesion and appropriate resection margin were confirmed, the hand-held thoracoscopic laser instrument was introduced through the utility port. This instrument carried the 600- μ m bore optical fibre which is used to deliver the output light from the Limax laser to the treatment site. The laser beam was then directed on the lung tissue with the aid of a red pilot light which was also transmitted down the delivery fibre. The tip of the delivery fibre was then positioned 1 to 10 mm from the target tissue, and the output of the laser system was activated via foot pedal control (the closer the tip of the fibre to the tissue the more effective the cutting versus coagulation, and vice versa). The laser device itself is fitted with an inbuilt suction system for smoke extraction. However, during tissue coagulation, additional smoke evacuator tubing was held at the external aspect of the utility port to improve smoke extraction from within the chest cavity, thereby permitting unobstructed visualisation. The laser was then used to dissect the lesion, with a small rim of normal tissue from the surrounding parenchyma. Once resected, the lesion was removed via the utility port. The resected surfaces underwent additional laser coagulation and the PuraStat[®] haemostatic agent was applied to improve pneumostasis in four cases. The resected area was not oversewn in any case. A single 24Fr drain was inserted via the camera port site and placed under thoracoscopic guidance. The drain was attached to a Thopaz digital chest drainage system (Medela). All patients were extubated in theatre and returned to the thoracic surgical unit for further monitoring.

We reviewed the data of the first seven patients in our unit to undergo thoracoscopic laser metastasectomy, examining patient age, gender, primary malignancy, primary treatment, complications, length of post-operative stay (LOS), and final histopathology.

Results

Seven patients underwent thoracoscopic laser wedge metastasectomy of eight lesions in our centre between February 2017 and October 2017 (Table 1). All patients met the criteria for pulmonary metastasectomy in that the primary disease had been controlled; they did not have any distant metastatic disease, and the lesion was amenable to wedge resection on CT with sufficient remaining pulmonary reserve.

The age range was 46–67 with a median age of 61 ± 6.92 years. The primary disease was colorectal carcinoma in five cases, eccrine carcinoma in one case, and high-grade uterine leiomyosarcoma in one case. The left lung was operated on in six cases with the left upper lobe targeted in five of these cases and the left lower lobe in one case. Only one patient had right-sided disease; this patient had a lesion resected from both the upper and lower lobes. There were no technical complications with the laser device during any of the cases. No cases required conversion to a full thoracotomy. The drain was removed on post-operative day 1 in six cases and on day 8 in the remaining case. The median post-operative LOS was 1 day (range 1–10 days, SD 4.36). All patients had confirmed metastatic disease with clear resection margins on final histopathology. There were no perioperative mortalities. One patient had a prolonged air leak requiring the drain to remain in situ until post-operative day 8. In this case, the PuraStat[®] haemostatic agent had not been used to cover the resected surface.

Discussion

Despite the lack of randomised control trials in this area, pulmonary metastasectomy has largely been accepted as a treatment that can provide a significant improvement in long-term patient survival. It is an area of ongoing clinical research; the PulMiCC trial based in the UK is currently in the feasibility phase for a randomised control trial [17]. It aims to assess the survival benefit for metastasectomy for those with pulmonary metastatic colorectal cancer. This has already been seen in the setting of pulmonary metastasectomy for metastatic melanoma and metastatic sarcomatous disease [18, 19]. The use of laser for non-thoracoscopic metastasectomy has been shown to have similar overall survival to conventional resection and also with a trend for a lower risk of local relapses [20].

With VATS surgery becoming mainstay for a large proportion of thoracic procedures, the movement of metastasectomy to VATS is not surprising. There are many benefits of VATS over open thoracic surgery, both for primary lung cancer or metastatic disease. These include smaller incisions, better visualisation of the pleural cavity, less post-operative pain, less surgical morbidity, shorter length of hospitalisation, fewer adhesions in cases of redo metastasectomy, shorter interval between surgery and adjuvant therapy, and better treatment compliance [21]. Within the area of VATS metastasectomy, the current surgical devices commonly available are either a surgical stapling device or the Nd:YAG laser. While surgical stapling devices are commonplace in many institutions for both open and thoracoscopic lung resections, they are not without complications. In the event of recurrence at the area of previous stapled resection, radiologic diagnosis is made more difficult. Stapling devices cause dense adhesions within

Table 1 Breakdown of patients

Case	Age	Sex	Primary disease	Primary treatment	CT findings	Operation	Histology	Complications	LOS (days)
1	60	F	Metastatic colon cancer with single liver and lung metastases	Laparoscopic right hemicolectomy and adjuvant chemotherapy	1.1-cm spiculated nodule in the left upper lobe	VATS left upper lobe laser wedge metastasectomy	Moderately differentiated mucinous adenocarcinoma consistent with metastatic disease	Nil	1
2	61	F	Rectal adenocarcinoma—T3N2	Anterior resection and adjuvant chemotherapy	0.7-cm left upper lobe pulmonary nodule	VATS left upper lobe laser wedge metastasectomy	Deposit of metastatic adenocarcinoma, consistent with a colorectal primary	Nil	1
3	55	F	Rectal adenocarcinoma—T3N1	Neoadjuvant chemoradiotherapy and anterior resection	6.6-mm nodule in the left upper lobe concerning for oligometastatic disease PET negative	Wire-guided VATS left upper lobe laser wedge metastasectomy	Moderately differentiated adenocarcinoma in keeping with colorectal metastasis	Air leak: drain in situ until POD8	10
4	46	F	High-grade uterine leiomyosarcoma	Total abdominal hysterectomy and bilateral salpingo-oophorectomy	10-mm left upper lobe nodule	VATS left upper lobe laser wedge metastasectomy	Leiomyosarcoma	Post-drain removal pneumothorax managed conservatively	2
5	67	M	Sigmoid adenocarcinoma—T2N1	Anterior resection and adjuvant chemotherapy	7.5-mm left lower lobe pulmonary nodule with cavitation	Wire-guided VATS left lower lobe laser wedge metastasectomy	Metastatic colorectal adenocarcinoma	Nil	1
6	64	M	Eccrine tumour of thumb	Thumb amputation and axillary clearance 2015. Open Perlman-type right lower lobe metastasectomy	8-mm nodule left upper lobe	VATS left upper lobe laser wedge metastasectomy	Necrotic basophilic tumour similar to previous eccrine carcinoma	Nil	1
7	62	M	Metastatic rectal adenocarcinoma—T3N1M1 Hepatic metastases and a solitary left upper lobe metastases	Neoadjuvant chemoradiotherapy, anterior resection, and Liver metastasectomy.	7-mm nodule right upper lobe 5-mm subpleural nodule right lower lobe	VATS laser wedge resection of a right upper lobe lesion and a wire-guided right lower lesion	Moderately differentiated metastatic adenocarcinoma	Nil	2

the thoracic cavity making any attempted redo surgery difficult. During redo resections, lesions near the previous stapled tissue become hard to localise intra-operatively. The use of stapling devices also results in loss of normal lung parenchyma due to the straight lines and the permitted geometry of the stapler. The tissue loss that occurs with laser resection is in the order of one seventh of that occurring for staple resections independent of the location of the metastasis [16]. This ability for lung sparing surgery also facilitates radical metastasectomy, in particular in the setting of multiple

pulmonary lesions or impaired lung capacity [22]. In addition there have been reported cases of the development of granulomas following the stapling of lung parenchyma [23–26].

Pulmonary air leak is a common complication in thoracic surgery. It results in both prolonged hospital stays and greater healthcare costs [27]. We did not experience significant problems with prolonged air leak in patients where the PuraStat[®] haemostatic agent was applied to the resection bed. The PuraStat[®] haemostatic agent was not used to cover the resection area for the third patient in the series. This patient had a

prolonged air leak requiring the chest drain to remain in situ until POD 8. In all subsequent cases, the resected areas were covered with PuraStat[®] with no further prolonged air leaks experienced. The use of similar sealant products has been shown to be safe and effective method of treating pulmonary air leaks as well as reducing hospital stay [28]. We plan to continue to use the PuraStat[®] agent as part of our operative strategy for these cases.

The routine use of the Thopaz digital chest drainage allowed continuous objective monitoring for air leak and the timely removal of the drain where no air leak existed. The drain was removed on the first post-operative day for 86% patients. In keeping with our enhanced recovery protocol, four of seven patients were discharged home on post-operative day 1 once their analgesic requirements were controlled and the post-drain removal chest radiograph was satisfactory. Both our time to drain removal and post-operative LOS were considerably shorter than a recent similar study. In 2017, Myer et al. published a paper analysing their initial experience of laser resection of lung metastases under video-assisted thoracoscopic control via a minithoracotomy. They published median days to drain removal of 4 (range 3–5) and median hospital stay of 5 (range 3–6) days [29].

A 2013 study analysed the cost differences comparing the use of the laser compared to staples for division of the interlobar fissure. They showed that the mean cost of the stapled procedure was significantly higher than that of the laser procedure when considering the cost of consumables with a mean cost increase of 77%. They estimated that within the completion of 300 laser procedures, the fixed cost of the laser system would be recovered [30]. We have not yet performed full cost analysis; however, our initial evaluations suggest that by using the laser instead of staples for one case per week, the initial equipment costs would have been met within 2 years. Considering our short post-operative length of stay, we believe this surgical approach will also reduce the mean cost of hospitalisation.

Conclusion

In our early experience, thoracoscopic laser wedge metastasectomy is a safe and efficient method for performance of pulmonary metastasectomy. We experienced a low complication rate and a short post-operative stay. Additionally, we anticipate that resection using the KLS Martin Limax Nd:YAG laser at 1.318 μm will improve the interpretation of our follow-up imaging and reduce the presence of adhesions at any subsequent surgery. We plan to expand on our patient numbers undergoing this procedure while monitoring their surveillance imaging. The concept of thoracoscopic laser resection is currently being expanded into our other areas of

practice including lung biopsies, the resection of benign lesions, and the division of lung fissures.

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Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

Conflict of interest The authors declare that they have no conflict of interest.

Consent Informed consent was obtained from all individual participants included in the study.

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