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ORIGINAL ARTICLE – THORACIC

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Airtightness of lung parenchyma without a closing suture after atypical resection using the Nd:YAG Laser LIMAX® 120

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Abstract

OBJECTIVES: Lung metastases can be non-anatomically resected with a Nd:YAG Laser. It is recommended that the resected lung surface be sealed by slowly resorbable sutures. However, the lung tissue may be restricted by the sutures once it is re-ventilated. Thus, it was analysed whether the lung parenchyma is airtight after laser resection without suturing the defect.

METHODS: The pulmonary artery of unimpaired paracardial lung lobes of freshly slaughtered pigs (mean weight 46 g) was cannulated and rinsed out via a hypotonic saline–heparin solution (5000 IE) until the perfusate was clear of body fluid. The lobular bronchus was connected to an airtight ventilation tube (Fa. VYGON 520 3.5 oral tube) and ventilated pressure-controlled (PEEP + 5 cm H_2O, P_1 = 20 cm H_2O, frequency = 10/min) via a respirator. All lobes were perfused with Ringer solution at 42°C at normothermia and normotonia. In group 1 (n = 8), an atypical peripheral parenchymal resection (average resected surface: 2 × 2 cm^2) and in group 2 (n = 8), a deep atypical parenchymal resection (average resected surface: 4 × 4 cm^2) were performed with the Nd:YAG Laser LIMAX® 120 (output power at 100 watts). After post-resection ventilation of 15 min, the resection surface was tested for airtightness and burst pressure.

RESULTS: All group 1 lobes tested airtight under pressure-controlled ventilation. The mean burst pressure was 34.4 mbar (SD ± 3.2 mbar). Six lobes of group 2 were also completely airtight. The remaining two lobes, however, revealed a serious parenchymal leak (score 3). This was caused by the cross-opening of a segmental bronchus, although the surrounding lung parenchyma was also airtight. The mean burst pressure of these lobes was 31.7 mbar (SD ± 4.08 mbar). There was no significant difference between the two groups (P = 0.12).

CONCLUSIONS: Peripheral lung defects after Nd:YAG Laser resection might not be sutured, since the laser-induced vaporization of the lung parenchyma seems to be initially airtight. These experimental data warrant confirmation in a controlled clinical study.

Keywords: Airtightness • Atypical lung parenchyma resection • Laser • Parenchyma closure

INTRODUCTION

Thirty percent of all tumour patients develop pulmonary metastases during their disease course [1]. Lung metastases can be resected in patients with adequate cardiopulmonary capacity [2] and no mediastinal lymph-node metastases [3]. Surgeons aim to spare as much parenchyma as possible, while resecting lung metastases, and avoiding by all means a situation where there is tumour at the histological examination of the resection margins (called R1) [4]. These goals can almost always be achieved by using a Nd:YAG laser (wavelength: 1318 nm) [5]. In case of laser metastectomy, the entire non-ventilated lung will be palpitated after thoracotomy, and lung metastases will be resected leaving a safety margin of 5 mm. When the laser ray touches the lung parenchyma, the intensive (>900°C) heat causes tissue vaporization. A large surface of tissue can thus be penetrated in a very short time. At the same time, the surface of the irradiated lung tissue coagulates, and the metastasis can be removed with minimal blood loss [6]. Since the surgeon uses the knob on the laser, the tissue can also be resected around curved surfaces providing the ability even to remove highly irregularly shaped or round tumours sparing a maximum of healthy parenchyma. The location of the metastases is of secondary importance, because both central and peripheral tumours can be safely resected with the laser [7]. Usually, it is recommended that the coagulated lung parenchyma be closed after laser resection with sutures. Superficial lesions might be closed with a single-row suture, and deeper defects with several rows of continuous sutures [8]. This approach primarily serves to alleviate the surgeon's safety concerns. In case of a parenchymal leakage, the patient has to frequently undergo reoperation to close the leak. Another theoretical problem is the laser-induced coagulation necrosis on the lung surface, which might cause secondary parenchymal fistulas several days after the resection, which also might require reoperation. However, there are yet no data evaluating the primary airtightness of the lung parenchyma, nor the prevalence of secondary parenchyma fistulas after laser resection.

The parenchymal closing sutures have one obvious drawback. They can pucker severely around the parenchyma's resected surface and cause significant restriction of expansion of the remaining lung tissue, especially if several metastases were resected. The inability of the lung for full expansion is a risk factor for postoperative pneumonia and even empyema. Thus, the aim of the presented experimental study was to examine whether parenchymal closing sutures after atypical laser resection are necessary to guarantee initial airtightness during ventilation.

MATERIALS AND METHODS

The unimpaired hearts and both lungs from freshly slaughtered pigs (weight 100 kg) were removed. Intact paracardial lung lobes were then separated from these specimens (mean weight: 46 g). The pulmonary artery supplying the lobes was exposed and a cannula attached (Vinyle 12 G). The lobes were rinsed with a saline–heparin solution (5000 IE) until the perfusate of the venous lobe cuff was clear. The lobar bronchus was connected to an airtight ventilation tube (VYGON 520 3.5 oral tube). The lobe was recruited and clamped. Each lobe was then wrapped in a moist compress and was immediately transported in a bag to the laboratory.

In the laboratory, each lobe was connected to the pulmonary artery cannula. We perfused the lung lobes with a NaCl solution at 42°C, in order to keep normothermia (in the pig lung 37, 5°C is physiological) during the whole experiment, cause of heat dissipation during the experiment. We perfused the lobes during the entire experiment.

All lobes were hung up vertically and the ventilation tube was hooked up to the ventilation unit (Cicero EM, PM 8060, Firma Dräger Lübeck, Germany). Pressure-controlled ventilation was carried out during the entire experiment (PEEP + 5 mbar, $P1 = 20$ mbar, frequency: 10 1/min). All lobes were initially ventilated for 5 min. After interrupting the ventilation, an atypical peripheral laser resection (group 1, average resected surface: 2×2 cm^2) or a deeper atypical parenchymal resection (group 2, average resected surface: 4×4 cm^2) with the Nd:YAG Laser LIMAX® 120 at a 100-watt output was performed (Fig. 1). Ventilation was resumed immediately after the resection. The resection surface was then kept in water for 15 min to test the surface for airtightness (Fig. 2). We considered the lung airtight when no air escaped from the lung. The impermeability was assessed using a modified scoring system [9–12]: 0, absolute impermeability; 1, singular bubbles or a stream of tiny bubbles; 2, multiple bubbles (2–5) or a stronger stream of bubbles; 3, more than five bubbles or a continuous, strong stream of bubbles. The degree of parenchymal impermeability was assigned after 5 min of observation. The burst pressure was assessed via a sloping increase of the ventilation pressure at 5 mbar steps every 5 min. The burst pressure was reached whenever the lung parenchyma showed the first signs of leakage (score of 1). The mean burst pressure was calculated for both groups compared by the unpaired *t*-test. A *P*-value of <0.05 was considered significant.

RESULTS

All lobes of group 1 ($n = 8$) were entirely airtight under pressure-controlled ventilation conditions during the observation time. The mean burst pressure measured 34.4 mbar (SD ± 3.2 mbar). None of the lobes became permeable below a ventilation pressure of 25 mbar, which in our clinical setting is the maximum pressure for reinflation of the operated lung side checking after bronchial suture and lung parenchyma airtightness (Table 1).

In group 2 ($n = 8$), six of eight lobes (75%) were airtight during ventilation. However, two lobes were permeable as soon as the ventilation started. The permeability of these two lobes was quite pronounced with a permeability score of 3. The cause of the leakage was in both lobes a small defect of a segmental bronchus (Fig. 3). However, the lung parenchyma surrounding the segmental bronchus was completely airtight during ventilation. The mean burst pressure on the initially airtight lobes ($n = 6$) was 31.7 mbar (SD ± 4.08 mbar) (Table 2). While attaining the burst pressure, all lobes displayed relevant parenchymal leakage. Between the two groups, the burst pressures were not significantly different ($P = 0.12$) (Fig. 4).

DISCUSSION

After laser resection of lung metastases it is generally recommended that the parenchyma defects be closed with continuous slowly resorbable sutures regardless of the depth and location of the defect. The presented study is the first that examined the airtightness and the burst pressure of the lung parenchyma after atypical laser resections without closing parenchyma sutures. It could be demonstrated that all lobes undergoing peripheral resections were completely airtight under a standard, pressure-limited, pulmonary-protective ventilation. Marulli *et al.* [13] compared stapler and laser techniques for interlobar fissure

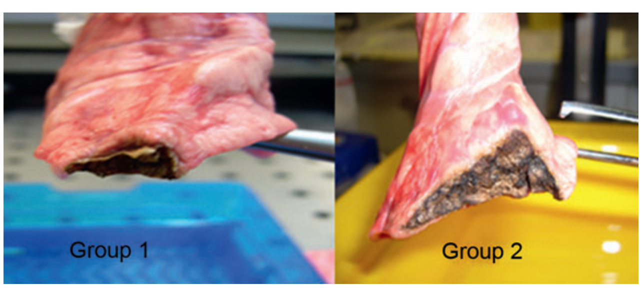

Figure 1: Area of resection after peripheral (Group 1) and deeper (Group 2) atypical lung resection (laser output power: 100 watt).

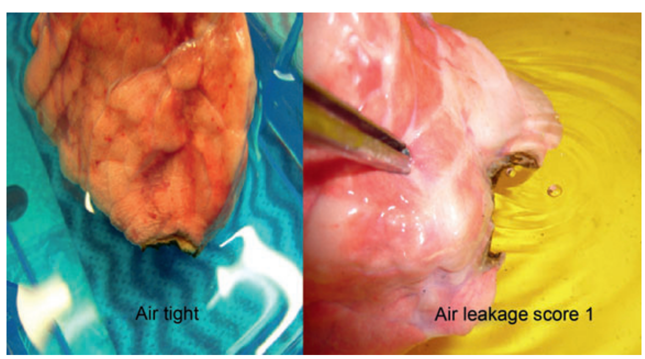

Figure 2: Test for evaluation of the burst pressure: total airtightness of the resection area after superficial lung resection and air leakage score 1.

Table 1: Airtightness and burst pressure in peripheral atypical lung resection (*n* = 8)

Group 1(*n* = 8) Paracardial lung lobe	Airtightness (score)	Burst pressure (mbar)/ airtightness (score)
1	0	35/2
2	0	30/2
3	0	35/2
4	0	30/2
5	0	35/1
6	0	40/1
7	0	35/1
8	0	35/1

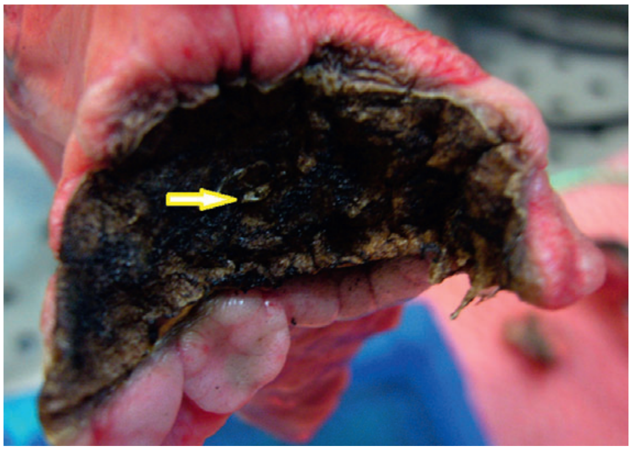

Figure 3: Open segmental bronchus after deep atypical laser resection; the remaining coagulated lung parenchyma is airtight under ventilation.

Table 2: Airtightness and burst pressure in deep atypical lung resection (*n* = 8)

Group 2 (*n* = 8) Paracardial lung lobe	Airtightness (score)	Burst pressure (mbar)/ airtightness (score)
1	0	35/2
2	3	
3	3	
4	0	30/2
5	0	35/1
6	0	25/2
7	0	35/2
8	0	30/1

completion during pulmonary lobectomy. He used a thulium laser (wave length 2010 nm; power output: 40 W). In his study, he showed that the laser dissection of the fissure—cutting here also peripheral lung tissue—without suture is effective and comparable with the stapler technique to prevent air leaks. Lesser [14] resected atypically small subpleural lung nodules by VATS with a bare fibre in a noncontact manner (power output: 40 W) in 28 patients. He did not suture the lung parenchyma, and the patients had no significant prolonged air leak ($P = 0.49$) vs the stapler group and no longer chest tube time ($P = 0.49$).

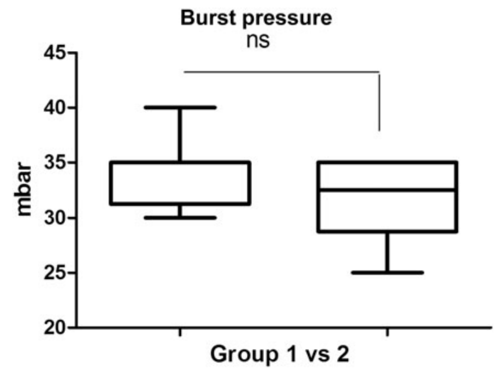

Figure 4: Comparison of the burst pressures peripheral (group 1) vs deep (group 2) atypical lung resection ($P = 0.12$).

Based on these experiments, one might suggest that there is no need for a closing suture to ensure airtightness of the lung parenchyma after peripheral laser resection. Rolle *et al*. [8] recommended a closure of the visceral pleura also for reconstruction of the lung architecture and orientation by re-approximating the visceral pleura with a running absorbable suture (4–0 Vicryl). In our opinion, the sutures prevent a full re-expansion of the lung, especially, in case of many laser resections. In deeper, central atypical resection seems to be a significant risk for iatrogenic injury of the segmental bronchi. In our study, 25% of the examined lobes displayed considerable and immediate permeability under standard ventilation. The reason for air leakage was not the lung parenchyma itself, but an artificial opening of a segmental bronchus during laser resection, which was not identified. Thus, the resection surface after deep laser resections must be carefully inspected for openings in the segmental bronchus that require closure by suturing. The burst pressures in the two groups did not differ significantly (group 1: 34.4 mbar vs group 2: 31.7 mbar); $P = 0.12$. So also Rolle [15] recommended a closure of exposed bronchial branches at the segmental level with absorbable suture (4-0 Vicryl; Ethicon, Sommerville, NJ, USA). In a clinical setting, this would require that the lungs should be slightly inflated after deep resections to enable the surgeon to identify and close any open segmental bronchus. We prefer the closure of a segmental bronchi with monofil resorbable suture (5–0 PDS, Ethicon). After suture, we do another check for airtightnes to be sure that there is no persistent problem. We plan further experimental studies on this topic to examine not only the initial, but also the permanent airtightness of the lung parenchyma after laser resection without suture closure.

CONCLUSION

Laser resection of peripheral lung metastases might not require closure of the parenchyma defect by sutures. This has to be confirmed in further experimental and clinical studies. Deep central laser resections have a significant risk of injuring segmental bronchi which have to be identified and repaired during the procedure to avoid significant leakage and reoperation.

Conflict of interest: none declared.

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