Concomitant Electromagnetic Navigation Transbronchial Microwave Ablation of Multiple Lung Nodules is Safe, Time-saving and Cost-effective

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</table>
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All authors have completed the ICMJE uniform disclosure form. Calvin S.H. Ng is a consultant for Johnson and Johnson; Medtronic, USA; and Siemens Healthineer. Rainbow W.H. Lau is a consultant for Medtronic, USA; and Siemens Healthineer. Tony S.K. Mok has no potential conflicts of interest that exist with companies/organizations whose products or services are discussed in this article. All remaining authors declare no potential conflicts of interest that exist with any companies/organizations whose products or services are discussed in this article.

Author contributions:

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(IV) Collection and assembly of data: J. Chan, R. Lau, A. Chang, I. Siu
(V) Data analysis and interpretation: J. Chan, R. Lau
(VI) Manuscript writing: all authors
(VII) Final approval of manuscript: all authors

Glossary of Abbreviations

ENB: electromagnetic navigation bronchoscopy
CBCT: cone beam computer tomorography
MWA: microwave ablation
RFA: radiofrequency ablation
SBRT: stereotactic radiation therapy
EGFR: epidermal growth factor receptor

Word count: 2214 words
Number of Figures and Tables: 1 central picture, 3 figures and 3 tables
Central Message (197 characters)
Concomitant transbronchial microwave ablation in same operative session is feasible, safe, time-saving and cost-effective as one-stop treatment for multifocal lung cancers and lung oligometastases.

Perspective Statement (359 characters)
Increasing prevalence of multifocal lung cancers and lung oligometastases call for lung-preserving local treatment like transbronchial microwave ablation. Proof of safety, feasibility and cost-effectiveness of concomitant multi-nodular ablation is essential for the adoption of this one-stop option to streamline patient care and improve patient satisfaction.

Structured Abstract (250 words)
Objectives
Transbronchial microwave ablation of lung nodules using electromagnetic navigation bronchoscopy is an emerging local therapy for lung oligometastases and multifocal lung cancers as part of lung preserving strategy. Concomitant ablation of multiple lung nodules in a single operating session may provide a one-stop solution.

Methods
Between April 2019 and April 2022, 25 patients had two or more lung nodules ablated concomitantly in our hybrid theatre. Nodules were proven or highly suspicious of malignancies or metastases. Feasibility and safety were retrospectively reviewed.

Results
A total of 56 nodules in 25 patients underwent concomitant multi-nodular ablation, with a mean age of 60. Reasons for lung preserving strategy were multifocal lung cancer (80%) and lung oligometastases (20%). Among those with multifocal disease, 65% had previous major lung resection for lung cancer. Two to four nodules were ablated in each session. Mean nodule size is 9.9mm (range 5-20mm), and mean minimal margin was 5.9mm. When comparing concomitant nodule ablation to the single nodule ablations in our institute, a mean of 86 minutes of operative time and 131 minutes of anesthetic time is saved. There were no increased complications despite overlapping ablation zones, and mean hospital stay was 1.23 days. Rate of pneumothorax was 8%, while that of pleural effusion, pain and fever were 4%.

Conclusions
Concomitant transbronchial microwave ablation of multiple lung nodules is feasible, safe and is associated with reduction in overall anesthetic and operative time. It is an important armamentarium in the contemporary lung preserving strategy for battling multifocal lung cancer or lung oligometastases.

**Keywords:** concomitant ablation, transbronchial ablation, microwave ablation, lung cancer, lung metastases, lung preservation strategy, lung ablation
Introduction

Since population-based lung cancer screening has been proven to be cost effective\(^{(1,2)}\), increasing numbers of computer tomography (CT) are being performed each year leading to an exponential rise in the discovery of incidental lung nodules. Many patients are found to harbour multifocal lung cancers and a stage-shift towards earlier detection\(^{(3)}\) allows effective treatment and longer survival. In addition, advancement in treatment of other later stage cancers gives rise to a larger proportion of patients with lung oligometastases. Both of these situations call for local treatment, ranging from sublobar surgical resection, stereotactic body radiation therapy (SBRT)\(^{(4)}\), and percutaneous ablation techniques including radiofrequency (RFA)\(^{(5)}\), microwave (MWA)\(^{(6)}\) and cryotherapy\(^{(7)}\), which are associated with satisfactory 2-year local control rates between 64% and 70%. The novel technique of combining transbronchial access, offering potential benefit of fewer pleural based complications, with microwave ablation, which has been shown to produce larger, faster and more predictable ablation zones than RFA\(^{(8)}\), has been developed and utilized in our institute 4 years ago with satisfactory safety and efficacy profile\(^{(9,10)}\). Owing to the nature of these disease entities, patients are likely to have multiple lung nodules that require local treatment, coupled with the low complication rate of single session transbronchial microwave ablation, our institute started performing concomitant MWA for multiple lung nodules in the same operative session for indicated patients. In this article we retrospectively discuss the safety, feasibility and short term outcomes of concomitant transbronchial MWA in comparison to a cohort of single ablation cases.

Methods

Trial Design

This study is a single-centre retrospective analysis of patients who underwent electromagnetic navigation bronchoscopy (ENB) transbronchial microwave ablation of multifocal lung cancers or lung oligometastases. The study was conducted in compliance with the Declaration of Helsinki and approved by local institutional review board (the Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee), CREC reference number of 2020.524 (5/24/2020). All study participants gave informed consent for publication of study data.

Enrolment criteria

Patients with confirmed or radiologically suspicious T1N0M0 (TNM classification 8\(^{th}\) edition) multifocal lung cancers or \(\leqslant 5\) lung metastases with controlled primary...
maligancy are eligible for consideration of ENB transbronchial MWA if they are unfit for surgical resection or have borderline lung function. Favorable nodule factors include presence of bronchus sign (segmental airway seen leading to lesion), tumours less than 2.5cm in size, and at least 5mm away from large blood vessels or sensitive mediastinal structures.

Concomitant ENB transbronchial microwave ablation procedure

All ablations were performed in our hybrid theatre with the help of cone-beam CT (CBCT) (Artis Zeego PURE® platform, Siemens Healthineers, Germany) and fluoroscopy, both as confirmation of lesion access and for assessment of ablation results. The ENB platform utilized was SuperDimension™ Navigation System (Covidien™, Plymouth, MN, USA), while ablation was performed with Emprint™ Ablation Catheter with Thermosphere™ technology (Covidien™, Plymouth, MN, USA). The procedural steps for single nodule MWA has been described in our previous publication(9) (Figure 1). During concomitant nodule ablation, patients were anesthetized similarly, the first nodule was navigated to and ablated, and while analyzing the 10-minute post-ablation CBCT scan, the bronchoscope was withdrawn temporarily from the endotracheal tube to allow better ventilation, minimize atelectasis and avoid CO2 retention due to prolonged procedure. Subsequent ablation to other lung nodules is only carried out if there are no immediate complications after the first ablation. Technical success was defined by post-ablation CBCT showing ablation zone covering original lesion. Post-operative course was similar to single nodule ablation, including chest x-rays on day 0 and day 1 and discharged earliest at 1 day post-ablation if no complications arise. Fine-cut plain CT scans were arranged as per institute protocol at 1st, 3rd 6th and 12th month post-ablation, then half yearly afterwards.

Results

Between April 2019 and April 2023, 56 nodules in 25 patients (9 males and 16 females) underwent concomitant transbronchial ENB MWA in our institute. All cases have been discussed in multidisciplinary meeting. Major findings have been summarized in Figure 2. Mean age is 60 years old ranging from 34 to 79. The lesion maximal diameter has a mean of 9.3mm, ranging from 4 to 20mm in size. Reasons for lung preserving strategy in this cohort includes lung oligometastases (20%) and radiological or confirmed multifocal lung cancers (80%). Among the latter, 13 out of 20 patients have had previous major lung resection, while the rest had lung resection or other local treatment planned for other lesions. Majority of the 25 patients had two nodules ablated in the same operative session, while 2 had three nodules ablated and 2
had four nodules ablated concomitantly. Seventeen patients had nodules ablated that resided in the same lobe, 7 in different lobes on same side, and 3 had contralateral nodules (Table 1). ENB biopsy was obtained in 2 of the nodules just before ablation, and in 2 other cases ENB ablation was followed by surgical resection of other lung nodules during the same operative session.

Results and safety of concomitant ablation was compared to the 103 single nodule MWA performed in our institute during the same period (Table 2). The operative time of single nodule versus double nodule ablation was 144±11 minutes and 204±39 minutes respectively, amounting to a mean of 86 minutes difference, or time saved, if the two nodules were to be ablated in separate operative sessions. Similarly, the anesthetic time was 183±11 minutes and 235±41 minutes respectively, estimating 131 minutes saved in time under general anesthesia when the two nodules were ablated in the same session. The estimated time saved is the approximate time difference between two times that of single nodule ablation minus that of double nodule ablation. The mean ablation energy delivered during single and multiple nodule ablation was 77569J and 220950J respectively, mean radiation dose was 31492µGym² and 61673µGym² respectively, and mean number of CBCT required was 8.3 and 15.4 respectively (Table 2).

Of 17 patients who had ablation to the same lobe, 6 of them had overlapping or merged ablation zones on their 1-month post-ablative CT scan. No complications due to merged ablation zones arose.

Technical success for planned multiple nodule ablation was 100% (Figure 3). The mean minimal margin was 6.1±0.7mm, which is a conservative measurement given that we do not take into consideration of tissue contraction that can be as much as 40% (9). Thirty five nodules (62.5%) required double or triple ablation to ensure good ablation zone coverage of the nodule, and these include same position reablation, pull-back reablation, and renavigation reablation (bracket ablation). Mean hospital stay for multiple nodule ablation was 1.23 days (range 1-3 days), in comparison to 1.69 days for single nodule ablation. Mean post-ablation day 1 C-reactive protein (CRP) was 15.6mg/L for multiple nodule and 22.7mg/L for single nodule ablation, while day 1 white cell count (WBC) was 7.8 x10^9/L and 9.0 x10^9/L respectively. Complications of concomitant ablation include 1 case of pain, 1 case of post-ablation fever, 1 case of self-limiting pleural effusion not requiring drainage, and 2 cases of peri-operative pneumothorax (Table 3).
In terms of oncological outcomes of the 56 nodules, there was 1 case of local recurrence and death at a mean follow up of 406 days.

Discussion

For multifocal lung cancers and lung oligometastases indicated for local treatment, although surgical resection is the gold standard and provides the most reliable confirmation of treatment success (11,12), many of these patients had unfavorable factors, including inadequate lung function due to previous major lung resection for primary lung cancer, central lung lesion requiring resection of a large amount of lung for a relatively small nodule, higher risk and complexity of re-do operation, poor premorbid and patient reluctance due to prior operative experience. In Asian populations, the proportion of EGFR-expressing lung tumours is higher than Caucasians and commonly present with multiple pre-malignant or early malignant lesions with different molecular mutation (13,14), sometimes as many as 5-10 suspicious ground glass opacities or mixed lesions in the presenting CT scan. These patients have a much higher life-time risk of lung cancer, likely will need long term surveillance with CT and multiple treatment sessions for growing lesions. An early lung-preserving consideration is recommended (15,16), acknowledging that these patients will live a reasonably long life if treated appropriately, with diminishing lung reserve after each treatment, and general approach is to treat the most suspicious lesions first. The dominant lesion may be amenable to lobectomy or sublobar anatomical resection, while the remaining growing lesions can be treated with local ablation (17). SBRT is a reasonable alternative as local therapy (18), although it is limited by inability to obtain histology during treatment, and safety concerns for patients with interstitial lung disease or lesion proximity to critical mediastinal structures like the heart (19). In addition, while treating multiple nodules scattered in different lobes by SBRT, a large portion of lung would have to be irradiated for treatment of small lesions.

Transbronchial microwave ablation is a relatively novel technique, with several authors reporting safety and feasibility. Bau et al reported 7 lung lesions treated by ENB microwave ablation, of which one had mild hemoptysis and pneumonia with good recovery (20). Zeng et al reported 96 nodules in 65 patients treated with ENB microwave ablation, of whom 57 simultaneously underwent minimally invasive thoracic surgery. Complication rate was low and there were no local recurrence after a short term follow up (21).
Single nodule transbronchial ENB MWA has been shown to be safe and efficacious based on our results published 2 years ago (9). The mean minimal ablation margin was 5.5mm, mean hospital stay was 1.73 days, and complication rate was low, including pain (13.3%), pneumothorax (6.7%), post-ablation reaction (6.7%), pleural effusion (3.3%) and hemoptysis (3.3%). After overcoming the initial learning curve of this novel technique, our institute started performing the first concomitant nodule ablation after approximately 35 cases, and has been more liberally performing it after the 70th case. In two patients, 4 nodules in same or different lobes have been ablated concomitantly successfully without complication.

There have been concerns regarding multiple nodule ablation initially. For multiple nodule percutaneous ablation, the risk of pneumothorax is likely doubled due to multiple pleural punctures (22). Even with transbronchial approach, pneumothorax is a possibility (23, 24) and ablation to nodules on different sides may theoretically lead to bilateral pneumothorax, leading to ventilatory difficulty if not promptly recognized. Ablation to nodules in the same lobe, on the other hand, may lead to high concentration of energy delivered in a relatively small volume, large and merged ablation zones, the effect of which is uncertain and seldom reported. Possibility of significant post-ablation reaction with fever, large ablation zone involving pleura causing pneumothorax and bronchopleural fistula (25, 26), infection of such large area of necrosis, or significant hemorrhage, are among the concerns during our initial experience. Prolonged occupancy of the endotracheal tube by large bore bronchoscope may also increase risk of CO2 retention and atelectasis during procedure.

Our results show that ENB MWA of multiple nodules in same operative session is largely safe without added complications. Ablation zones achieved in these 25 patients ranges from small and separate zones, to large and merged ablation zones occupying up to half a lobe (Figure 4), while the complication rate remains low. There was no statistical difference between post-ablation day 1 CRP and WBC levels between single or concomitant nodule ablation, which remains low. The mean radiation dose and number of CBCT required was approximately doubled when comparing single to multiple nodule ablation, which is to be expected. Despite at least nearly tripling the ablation energy delivered (mean of 77569J for single nodule and 220950J for multiple nodules), there is no increased report of pain or fever (both approximately 4%). There were no major hemorrhage. The two cases of pneumothorax did not occur due to merged ablation zone. The first case occurred intraoperatively, due to dilator tool puncturing pleura during exchange and treated.
with tisseal glue injection via ablation tract, eventually not requiring chest drain insertion. The second pneumothorax occurred several days after ablation with CT showing breached pleura at the ablation zone, requiring endobronchial valve placement (27, 28), which was removed 2 months later with healed ablation region. The culprit ablation zone is separate from the other nodule, and has only been ablated once with 100W for 10 minutes. The 6 patients with overlapping or merged ablation zones did not suffer from complications. Despite not directly related to the effects of multiple ablation, the pneumothorax rate was 8%, similar to that of single nodule ablation (6.7%). Since pneumothorax is often the direct complication of ablation to a single nodule, the actual pneumothorax rate based on nodule number is only 3.6% (2 occurrences out of 56 nodule ablations), an improvement from our previous early results (29), representing heightened cautiousness and refined technique. Unfortunately, there is significant difference between the distance to pleura in the single and multiple nodule cohort (7.46 vs 13.3mm, p<0.05), making direct comparison of pneumothorax rate difficult.

Concomitant nodule ablation benefits from fewer general anesthesia sessions, providing one-stop treatment for patients which multiple lung malignancies. The estimated time required for pre-procedural patient positioning, intubation, bronchoscopic toileting and assessment, and ENB registration and verification was approximately 40 minutes for each case. In the comparison between single and double nodule ablation, a mean of 86 minutes of operative time and 131 minutes of anesthetic time was saved due to concomitant ablation instead of separate session ablation. With no added complications, patients are likely to report better overall satisfaction due to reduced sum of hospital stay and doctor visits. Furthermore, the same ablation catheter can be used for concomitant ablation, thus reducing overall cost. Of note, the duration of procedure time depends on the ease of navigation and presence of bronchus sign, which range from 15 minutes to 1 hour, while the meticulous evaluation of post-ablation CBCT and subsequent re-ablations take up the rest half of the usual procedure time.

There were two cases where resection and ablation were performed in the same operative session. In the first case the patient had two relatively deep and faint left upper lobe nodules which were ablated, subsequently proceeding to left lower apical segmentectomy for a larger and more solid nodule. In the other case, the patient had two deep right lower lobe nodules ablation followed by VATS right upper and middle lobe wedges for relatively peripheral lung metastases. The combination of approaches enables maximal lung preservation in patients with multifocal lung cancers.
With increasing experience, our institute has developed certain tips and tricks while performing concomitant ablation. After the first nodule ablation, immediate post-ablation CBCT was performed to grossly assess the adequacy of ablation, and the bronchoscope together with ablation catheter was removed from the endotracheal tube if the ablation zone size is preliminarily satisfactory. While awaiting the 10-minute post-ablation CBCT and while performing detailed assessment of ablation zone and determining exact margin, the patient is ventilated without bronchoscope blocking half the lumen, thus effectively removing CO2 in preparation for a prolonged procedure. In addition, navigation to the second lesion can start soon after the first post-ablation CBCT, as subsequent CBCT for the second lesion was tailored to include the first lesion, from which the final margin of the first lesion can be determined.

Selection of ablation order is also important, as ablating the smaller and fainter nodules in lung base first will evade the nuisance of atelectasis obscuring lesion due to prolonged procedure. Similarly, ablating the nodule with higher risk last, for instance those adjacent to large blood vessels or extremely close to pleura, will avoid the unfortunate event of significant hemorrhage or pneumothorax occurring after first ablation leading to premature termination of procedure, leaving the second lesion unablated. In this series, there were no cases where complications from the first nodule ablation led to procedure abortion such that the second nodule cannot be ablated. In the unusual circumstance when the first ablation obscured the visualization or targeting of the second lesion in the same lobe, overlay software from CBCT system was used to reproduce location of second nodule for navigation and ablation.

**Conclusions**

Concomitant transbronchial electromagnetic navigation bronchoscopy microwave ablation of multiple lung nodules in the same operative session is technically feasible and safe without added complications. Patients benefit from fewer general anesthetic sessions, fewer hospital visits, shorter overall operative and anesthetic time and lower cost. In the era of multifocal lung cancers and lung oligometastases amenable to local therapy, this one-stop treatment is an important component of lung preserving strategy.

**Acknowledgement**

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**Figure legends**

Central Picture (83 characters)

Ablation zones of two right lower lobe nodules after concomitant microwave ablation

**Figure 1**

Key procedural steps of transbronchial microwave ablation using electromagnetic navigation bronchoscopy (ENB) is illustrated. The first step consists of navigation towards the lesion (green ball) using ENB guidance. The second step includes confirmation of locatable guide in close proximity to lesion, exchanging it to ablation catheter with or without transbronchial access tools, and final unsheathing of the ablation catheter followed by a pre-ablation cone beam CT (CBCT). In this case, the lesion is marked by orange outline, punctured by ablation catheter, while the green and red ovals represent the predicted ablation zones. The third step comprises of microwave ablation, the level of energy used depending on intended ablation size. The last step includes a post-ablation CBCT showing the actual ablation zone represented by ground glass opacities covering the original lesion.

**Figure 2**

Methods, results and implications of the present study has been outlined.

**Figure 3**

An example of concomitant triple nodule ablation for multifocal lung cancer. The patient had right upper lobectomy and right lower lobe wedge for early lung cancer previously. The upper panel shows the pre-ablation CT scans of 3 ground glass lesions in left upper lobe which progressed upon follow up. The lower panel shows the 1-month post-ablation CT scans, demonstrating 2 closely related and merged ablation zones and another more inferiorly.

**Figure 4**

Among patients with multiple concomitant nodule ablation, ablation zones range from small and separate (Figure 3A) to large and merged ablation zones (Figure 3B) on 1-month post-ablation CT. The overlapping ablation zones may develop some cavitation.

**Tables**

<p>| Table 1. Baseline characteristics of concomitant nodule ablation |</p>
<table>
<thead>
<tr>
<th>Number of nodules ablated in same operative session</th>
<th>Number of patients</th>
<th>Mean</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td>One</td>
<td>103</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Four</td>
<td>2</td>
<td></td>
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<table>
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<th>Concomitant Ablation Lesion Location</th>
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<tbody>
<tr>
<td>Same lobe</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Different lobes on same side</td>
<td>7</td>
<td></td>
<td></td>
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<tr>
<td>Different laterality</td>
<td>3</td>
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<table>
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<th>Patient characteristics (25 patients)</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>60</td>
<td>34-79</td>
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<tr>
<td>Gender</td>
<td>Male</td>
<td>9</td>
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<tr>
<td></td>
<td>Female</td>
<td>16</td>
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<td>Charlson comorbidity index</td>
<td>5.4</td>
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<table>
<thead>
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<th>Lesion characteristics (56 lung nodules)</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Lesion size (mm)</td>
<td>9.3</td>
<td>4-20</td>
<td></td>
</tr>
<tr>
<td>Lobe</td>
<td>RUL</td>
<td>16</td>
<td></td>
</tr>
</tbody>
</table>
RML  2
RLL  10
LUL  17
LLL  11
Histology  Lung cancer  7
Proven metastasis  1
Not available  48
Lesion nature  Pure GGO  23
Mixed GGO  17
Solid  16
Distance to pleura (mm)  13.3  0-34

LUL, left upper lobe; RUL, right upper lobe; RML, right middle lobe; LLL, left lower lobe; RLL, right lower lobe.

Table 2. Comparison between multiple nodule concomitant ablation and single nodule ablation

<table>
<thead>
<tr>
<th></th>
<th>Single nodule</th>
<th>Double nodule</th>
<th>Time saved</th>
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<tbody>
<tr>
<td>Operative time (minutes)</td>
<td>144 ± 11</td>
<td>204 ± 39</td>
<td>≈ 86</td>
</tr>
<tr>
<td>Anesthetic time (minutes)</td>
<td>183 ± 11</td>
<td>235 ± 41</td>
<td>≈ 131</td>
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<tr>
<td>Ablation energy (J)</td>
<td>77569 ± 7764</td>
<td>220950 ± 40479</td>
<td></td>
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<tr>
<td>Radiation dose (µGym²)</td>
<td>31492 ± 2813</td>
<td>61673 ± 15953</td>
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<tr>
<td>Number of CBCT</td>
<td>8.3 ± 0.5</td>
<td>15.4 ± 2.5</td>
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Table 3. Complications of concomitant nodule ablation

<table>
<thead>
<tr>
<th>Complications of concomitant ablation</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Fever</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Pleural effusion (not require drainage)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>2 (8%)</td>
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</tbody>
</table>
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Ng. Transbronchial Microwave Ablation of Early Lung cancers and Lung
Oligometastases – Mid-term Results. Ann Oncol Nov 2022; vol.33( Suppl
9):Page S1549.
Table 1. Baseline characteristics of concomitant nodule ablation

<table>
<thead>
<tr>
<th>Number of nodules ablated in same operative session</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>103</td>
</tr>
<tr>
<td>Two</td>
<td>21</td>
</tr>
<tr>
<td>Three</td>
<td>2</td>
</tr>
<tr>
<td>Four</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concomitant Ablation Lesion Location</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Same lobe</td>
<td>17</td>
</tr>
<tr>
<td>Different lobes on same side</td>
<td>7</td>
</tr>
<tr>
<td>Different laterality</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2. Comparison between multiple nodule concomitant ablation and single nodule ablation

<table>
<thead>
<tr>
<th></th>
<th>Single nodule</th>
<th>Double nodule</th>
<th>Time saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operative time (minutes)</td>
<td>144 ± 11</td>
<td>204 ± 39</td>
<td>≈ 86</td>
</tr>
<tr>
<td>Anesthetic time (minutes)</td>
<td>183 ± 11</td>
<td>235 ± 41</td>
<td>≈ 131</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Single Nodule</th>
<th>&gt;=2 Nodules</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ablation energy (J)</td>
<td>77569 ± 7764</td>
<td>220950 ± 40479</td>
</tr>
<tr>
<td>Radiation dose (µGym²)</td>
<td>31492 ± 2813</td>
<td>61673 ± 15953</td>
</tr>
<tr>
<td>Number of CBCT</td>
<td>8.3 ± 0.5</td>
<td>15.4 ± 2.5</td>
</tr>
</tbody>
</table>

Table 3. Complications of concomitant nodule ablation

<table>
<thead>
<tr>
<th>Complications of concomitant ablation</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Fever</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Pleural effusion (not require drainage)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Pulmonary hemorrhage</td>
<td>0</td>
</tr>
</tbody>
</table>
Concomitant Transbronchial Microwave Ablation of Multiple Lung Nodules is Safe, Time-saving and Cost-effective

<table>
<thead>
<tr>
<th>Methods</th>
<th>Results</th>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single institute retrospective study</td>
<td>Feasible</td>
<td>Concomitant transbronchial microwave ablation is a useful lung preserving strategy for patients with multifocal lung cancers or lung oligometastases</td>
</tr>
<tr>
<td>56 nodules in 25 patients</td>
<td>Safe - No added complications (comparable to single nodule ablation)</td>
<td></td>
</tr>
<tr>
<td>Concomitant multiple nodule transbronchial microwave ablation in hybrid theatre</td>
<td>Saves operative and anesthetic time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cost-effective</td>
<td></td>
</tr>
</tbody>
</table>

[Image of CT scan showing lung nodules]
Concomitant Electromagnetic Navigation (ENB) Transbronchial Microwave Ablation (MWA) of Multiple Lung Nodules is Safe

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