Robotic versus thoracoscopic lung resection
A systematic review and meta-analysis
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Abstract

Background: Robotic video-assisted surgery (RVATS) has been reported to be equally effective to video-assisted surgery (VATS) in lung resection (pneumonectomy, lobectomy, and segmentectomy). Operation time, mortality, drainage duration, and length of hospitalization of patients undergoing either RVATS or VATS are compared in this meta-analysis.

Methods: A systematic research for articles meeting our inclusion criteria was performed using the PubMed database. Articles published from January 2011 to January 2016 were included. We used results of reported mortality, operation time, drainage duration, and hospitalization length for performing this meta-analysis. Mean difference and logarithmic odds ratio were used as summary statistics.

Results: Ten studies eligible were included into this analysis (5 studies for operation time, 3 studies for chest in tube days, 4 studies for length of hospitalization, and 6 studies for mortality). We were able to include 3375 subjects for RVATS and 58,683 subjects for VATS. Patients were mainly treated for lung cancer, metastatic foci, and benign lesions. We could not detect any difference between operation time; however, we found 2 trends showing that drainage duration and length of hospitalization are shorter for following RVATS than for following VATS. Mortality also is lower in patients undergoing RVATS.

Conclusions: Therefore, we conclude that RVATS is a suitable minimal-invasive procedure for lung resection and suitable alternative to VATS. RVATS is as time-efficient as VATS and shows a trend to reduced hospital stay and drainage duration. More and better studies are required to provide reliable, unbiased evidence regarding the relative benefits of both methods.

Abbreviations: RVATS = robot-assisted minimally invasive surgery, VATS = video-assisted minimally invasive surgery.

Keywords: lung cancer, robot-assisted minimally invasive surgery, video-assisted minimally invasive surgery

1. Introduction

Surgery is a pre-requisite for successful cancer management, both for diagnostics and treatment.[1,2] During the last years, minimal-invasive surgery procedures such as video-assisted thoracic surgery (VATS) or robot video-assisted thoracic surgery (RVATS) have become increasingly refined and are meanwhile commonly used for lung resection instead of an open thoracotomy approach.[3]

Patients undergoing VATS suffer from fewer complications, have less pain and blood loss, and recover faster than patients subjected to open thoracotomy.[4,5] Furthermore, VATS lobectomy is associated with shorter chest tube duration, hospitalization, lower morbidity, and improved survival.[6]

The da Vinci robotic surgical (RVATS-system) has been established in several different disciplines and has found application in urologic, gynecologic, and rectal surgery. It appears to be especially advantageous of surgery of deep and narrow spaces such as the pelvis or the mediastinum.[7] The da Vinci system was introduced to thoracic surgery as RVATS.[8] It offers several technical advantages such as 3-dimensional high-definition field of view, tremor filtration, augmented dexterity, or the capability of tele-surgery.[9] The application of RVATS underwent various improvements and upgrades since the first case-series report in 2002, whereas different techniques have been described and developed for performing robotic lobectomy.[10–12] Patients treated with a robotic approach show a lower morbidity and mortality than patients undergoing open thoracotomy.[13]

Both VATS and RVATS are superior to open thoracotomy in terms of survival, morbidity, and mortality.[2,4,6,13] Both approaches were recently compared by Ye et al.[14], whose meta-analysis mainly focuses on morbidity and mortality. We additionally included parameters such as operating time, hospitalization, and drainage duration. Since Ye et al published their meta-analysis, 2 more comparative studies have been published, showing the issue to be topical.[15,16] We included several new studies[17–19] in addition to those by Ye et al.

2. Methods

2.1. Literature review and data extraction

A systematic literature review was performed by searching PubMed on 26 January 2016, using the search terms ("surgery" OR...
“resection” OR “lobectomy”) AND (“thoracic” OR “thoracosco- 
ptic” OR “lung” OR “pulmonary”) AND (“robotic” OR “robot 
assisted” OR “da Vinci” OR “DaVinci”). No language restric- 
tion and no filters were applied. A total of 990 records were 
identified by the search. Only data of already published studies 
found through online research were used for meta-analysis, 
and we did not require the approval of the local ethics com- mittee. Ten studies were selected for meta-analysis (listed in 
Table 1), all reporting lung resection (pneumonectomy, lobectomy, and segmentectomy) for either 
VATS or RVATS as the new operation method. Patients were treated for 
lung cancer, metastatic foci, and benign lesions (Table 3). The 
mortality endpoint definitions of studies included varied (refer 
also to Table 2). Although operation time, length of hospitali- 
zation, and chest were analyzed by these studies, we found no studies 
reporting and evaluating pain or quality of life. Indication for 
operating patients was lung cancer, metastatic foci, or benign 
lesions. Only 2 studies reported the number of lymph nodes 
removed and the number of lymph node stations dissected for 
both VATS and RVATS. Overall, the number of lymph nodes 
removed and lymph node stations dissected was similar (please refer to Table 3).

Two studies utilized the same cohort of VATS patients (from a 
national database), which common underlying data induces a 
positive correlation between the resulting estimates. This was 
accordingly accounted for which can be derived based on the 
group-specific standard errors.

3.2. Operation time
Six studies reported data on durations of surgery. The estimated 
mean differences in operating time are shown in Fig. 2. For 
RVATS, there are inconsistently reported longer operation times 
as well as shorter operation times. The combined effect estimate is 
at +8.97 minutes (95% confidence interval [−28.12, +46.07]), 
indicating a slightly longer duration for RVATS. But, it is not 
significantly different from zero (P=.56). The corresponding 
estimate of the between-study heterogeneity is at τ=34.7.

3.3. Duration of hospitalization
Although we could not observe a significant difference in 
duration of hospital stay between the RVATS and the VATS 
group, at least a trend of shorter hospitalization became apparent 
in patients undergoing RVATS in the 6 studies analyzed. Figure 3 
shows the data along with the combined estimate. The estimated 
difference in hospitalization time is at −1.08 days (95% CI [−2.33, +0.17], P=.078) for RVATS. The between-study heterogeneity 
is estimated as τ=1.06.
3.4. Drainage duration

A trend to shortened drainage duration was reported in patients experiencing RVATS compared to VATS in all 3 studies (see Fig. 4). The combined estimate is at an average of $-0.71$ days (95% CI $[-1.50, +0.10]$, $P = .064$) for RVATS. The between-study heterogeneity $\tau$ is estimated as zero.

3.5. Mortality

Table 2 lists the data on mortality along with the corresponding mortality endpoint definitions. Six studies reported on mortality; 5 of these show fewer deaths in the RVATS group than for VATS, whereas 1 did not observe any deaths in either group. The effect estimates and the combined estimate are illustrated in Fig. 5. The combined effect on the odds ratio scale is 0.52 (95% CI [0.29, 0.92]), that is, an estimated almost 2-fold decrease in mortality. Despite the concerns regarding the comparability of estimates from different studies due to differing endpoint definitions, the between-study heterogeneity $\tau$ here is estimated at zero. Note that although the direction of effect is consistent between studies, the joint estimate is to some extent driven by the large study of Paul et al.[19]

4. Discussion

Increasing evidence suggests that perioperative outcomes of minimally invasive thoracic surgery are better than those of conventional open thoracotomy. The overall incidence of complications such as arrhythmia, pneumonia, pain, and inflammatory markers was reduced in several previous studies.[32–35]

### Table 2

<table>
<thead>
<tr>
<th>Study</th>
<th>VATS</th>
<th>RVATS</th>
<th>Mortality endpoint definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent et al[21]</td>
<td>142/12,427 (1.1)</td>
<td>1/430 (0.2)</td>
<td>Intraoperative</td>
</tr>
<tr>
<td>Farivar et al[17]</td>
<td>36/4612 (0.8)</td>
<td>0/181 (0.0)</td>
<td>30 d mortality</td>
</tr>
<tr>
<td>Lee et al[7]</td>
<td>1/34 (2.9)</td>
<td>0/35 (0.0)</td>
<td>No time-point defined</td>
</tr>
<tr>
<td>Paul et al[19]</td>
<td>487/37,596 (1.3)</td>
<td>18/2408 (0.7)</td>
<td>In hospital mortality</td>
</tr>
<tr>
<td>Demir et al[25]</td>
<td>1/65 (1.5)</td>
<td>0/34 (0.0)</td>
<td>No time-point defined</td>
</tr>
<tr>
<td>Mahieu et al[14]</td>
<td>0/28 (0.0%)</td>
<td>0/28 (0.0%)</td>
<td>30 d mortality</td>
</tr>
</tbody>
</table>

RVATS = robot-assisted minimally invasive surgery, VATS = video-assisted minimally invasive surgery.
VATS lobectomy has been associated with highly satisfactory results and has become the most exciting technical development in thoracic surgery over the past 5 years. Compared with open lobectomy, VATS lobectomy appears to have improved long-term outcomes and is supported by evidence-based treatment guidelines.[32,36,37]

RVATS lobectomy or segmentectomy is not, at this time, widely performed because of its technical difficulty. Furthermore, the availability of the DaVinci system is still limited due to the substantial acquisition and running costs.[38] Nonetheless, robotic pulmonary resections prove to be safe and effective even at the initial learning experience. The duration of operations is

<table>
<thead>
<tr>
<th>Study</th>
<th>Entities</th>
<th>Tumor stage</th>
<th>Surgery after radiation or chemotherapy</th>
<th>Number of lymph nodes removed</th>
<th>Lymph node stations dissected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jang et al.[20]</td>
<td>NSCLC IA-IIIA</td>
<td>IA-IIIA</td>
<td>No data</td>
<td>0/40</td>
<td>No data</td>
</tr>
<tr>
<td>Kent et al.[21]</td>
<td>Lung cancer, not specified</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Lee et al.[22]</td>
<td>Lung cancer, carcinoid</td>
<td>IA-IVB</td>
<td>IA-IVB</td>
<td>4/35</td>
<td>0/34</td>
</tr>
<tr>
<td>Deen et al.[23]</td>
<td>Lung cancer, carcinoid, metastatic foci</td>
<td>I-III</td>
<td>I-II</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Swanson et al.[24]</td>
<td>Primary lung cancer, metastasis, other lesions</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Adams et al.[18]</td>
<td>Entity not specified</td>
<td>T1a-T2b</td>
<td>T1a-T2b</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Paul et al.[19]</td>
<td>Not specified</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td>Farivar et al.[17]</td>
<td>Lung cancer, metastasis, benign foci</td>
<td>T1a-T2b</td>
<td>N0-N1</td>
<td>T1a-T2b</td>
<td>N0-N1</td>
</tr>
</tbody>
</table>
| Demir et al.[25] | Lung cancer, metastasis, benign foci | No data | No data | No data | Resection of hilar and peribronchial nodes, if positive for lung cancer conversion to open lobectomy

*NSCLC = non small cell lung cancer, RVATS = robot-assisted minimally invasive surgery, VATS = video-assisted minimally invasive surgery.*
found that outcome of patients undergoing RVATS is not worse than those undergoing VATS, but our finding of shorter hospitalization time in favor of RVATS should be economically counterbalanced in further considerations.

Summing our results up, we conclude that RVATS lobectomy is a suitable surgical procedure in pulmonary surgery with a potential to prove beneficial to patients even when compared to VATS lobectomy.

From our result we are able to conclude that RVATS is suitable for thoracic surgery. However, future clinical research is needed to investigate suitable indications and contraindications of RVATS lung resection to institutionalize training programs to standardize the systems, and to reduce procedure related costs and limitations to widen its area of application. By improving and implementing robotic techniques during routine clinical practice, we believe that in the near future RVATS will become a standard procedure when applying minimally invasive surgical techniques. However, more well-designed studies are required to provide reliable and less biased evidence regarding the relative benefits of both RVATS and VATS.

### References


[31] Conducting Meta-Analyses in R with the Metafor Package | Viechtbauer | Journal of Statistical Software [Internet]. [cited April 28, 2016]. Available at: https://www.jstatsoft.org/article/view/v036i03.


