

Robotic assisted lung resection needs further evidence

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Submitted Aug 04, 2016. Accepted for publication Aug 11, 2016.

doi: 10.21037/jtd.2016.10.89

View this article at: <http://dx.doi.org/10.21037/jtd.2016.10.89>

Since robotic assisted thoracic surgery (RATS) for lung resection using the “Da Vinci robotic system” has been introduced into the clinical practice of thoracic surgery by Dr. Melfi from Pisa in 2001 and published in 2002 (1), several steps ahead have been done, and the procedure has become more commonly used worldwide. Nevertheless in their article Bao and colleagues conclude “that robotics for lung cancer seems to have higher costs and longer operative time without superior advantage in morbidity rates and oncologic efficiency” (2). In few words, the authors add questions to the already known controversy about the application of RATS for lung resection, and confirm that the use of robotics is not yet based on good evidence of any effect on survival when compared with open surgery or standard video assisted thoracic surgery (VATS). In particular, the observations of Bao *et al.* (2) are in contrast with those who reported that robotics surgery has several advantages. The proponents of RATS have in fact reasoned that more intuitive movements, greater flexibility and high-definition three-dimensional vision render surgery easier for the surgeon, with shorter learning curve than VATS. Furthermore the proponents affirm that robot-assisted approaches to lung cancer resection and lymph node dissection appear to offer comparable radicality and safety to VATS and open surgery (3-5). Nevertheless it is wise here to remember that many of the proponents of RATS declare relationships with the robotic industries (6).

Nevertheless, although RATS thoracic centers are increasing, a few questions should be posed: is the use of RATS for lung resection justified on the available evidence? Should hospitals invest in robots? Should residency program in thoracic surgery include robotic surgery?

I try briefly to answer.

Is the use of RATS for lung resection justified on the available evidence?

Veronesi *et al.* in 2010 (7) and Cerfolio *et al.* in 2011 (8) arrived at the same results. The former performed a comparative study between 38 patients with stage I–II lung cancer operated with RATS *vs.* 34 patients operated through an open muscle sparing thoracotomy. The latter performed a similar study comparing 106 RATS *vs.* 318 nerve sparing lobectomy. Both authors concluded that the procedure is practicable, safe, and associated with shorter postoperative hospitalization than open surgery. They also showed that the mean duration of RATS lobectomy was longer than open surgery (2.2 *vs.* 1.5 hours), and the median numbers of lymph nodes removed were indistinguishable between the robotic and open procedures, suggesting that the robotic approach achieves similar oncological radicality to that achieved by thoracotomy.

Louie *et al.* (9) have shown that although RATS operative times were longer (median 186 *vs.* 173 min), all postoperative outcomes were similar, including complications and 30-day mortality (robotic lobectomy, 0.6% *vs.* VATS, 0.8%; $P=0.4$). Median length of stay was 4 days for both, but a higher proportion of patients undergoing robotic lobectomy had hospital stays less than 4 days (48% *vs.* 39%; $P<0.001$). Nodal upstaging overall was similar ($P=0.6$) but with trends favoring VATS in the cT1b group and robotic lobectomy in the cT2a group.

A recent publication of Yang HX *et al.* (10) confirms the results of Park *et al.* (11) regarding the estimation of survival after robotic lobectomy. Both studies confirm that Robotic lung resections result in similar long-term survival as compared with VATS and thoracotomy. Robot-assisted and VATS procedures are associated with short

Table 1 Evidence table: reviewing the reviews. RATS *vs.* VATS and systematic reviews

Author	Publication year	Study type	No. of pts. or papers	Central message
Cao <i>et al.</i> (13)	2012	Systematic analysis	17 papers	RATS is feasible and can be performed safely for selected patients in specialized centers. Perioperative outcomes including postoperative complications were similar to historical VATS
Kent <i>et al.</i> (14)	2014	Review of a national database (State Inpatient Database); propensity-matched analysis	20,238 open; 12,427 VATS; 430 RATS	RATS as an alternative to VATS—associated with improved outcomes <i>vs.</i> open thoracotomy
Paul <i>et al.</i> (15)	2014	Propensity-matched analysis	37,595 VATS; 2,498 RATS	RATS associated with higher rate of intraoperative injury and bleeding at a significantly higher cost
Swanson <i>et al.</i> (16)	2014	Results from a multihospital database (Premier Database) propensity-matched analysis	14,837 VATS; 675 RATS	RATS seem to have higher hospital costs and longer operating times, without any differences in adverse events
Louie <i>et al.</i> (9)	2016	Society of thoracic surgeon database	12,378 VATS; 1,220 RATS	RATS operative times were longer, but quality outcome measures, suggest that RATS and VATS are equivalent
Agzarian <i>et al.</i> (6)	2016	Systematic analysis	20 papers	RATS as a safe procedure that demonstrates no difference in clinical outcomes, as compared to VATS

lengths of stay in hospital, and the robotic procedure in particular results in superior lymph node assessment. These findings suggest that robotic lobectomy for non-small cell lung cancer (NSCLC) affords long-term stage-specific survival consistent with historical results for VATS and thoracotomy.

In short, it is evident that the operation performed via RATS is the same performed by open surgery or VATS, and therefore it would be a surprise to find different long-term survival. Whether more extended lymphadenectomy influences long-term outcome remain uncertain.

Nevertheless, it is interesting to note that few surgeons after initial experience with RATS decided to return to standard VATS resection, as the clinical advantages of the robotic approach were insufficient to justify the greater expense and longer operating times. They showed a Median hospital stay of 11 days (range, 7–53 days), median operating time of 228 min (range, 162–375 min), and one death occurred within 30 days (12).

Reviewing the reviews

There aren't many papers comparing RATS to VATS, and all of them could be found in one of the most recent comprehensive reviews (6). Nonetheless, I made a short review of the reviews with large data or meta-analysis

(*Table 1*), and interestingly the central message is similar to all of them: RATS is feasible and clinical results including quality outcome measures such as hospital stay, 30-day mortality, and nodal upstaging are comparable to standard VATS or thoracotomy. Most authors agree that the robotic approach results in greater lymph node assessment, and this could influence long term survival, which unfortunately has not yet been demonstrated (*Table 1*).

Surgeons are always concerned with the risk of intraoperative bleeding for their patients, and bleeding control could be difficult during RATS. Paul *et al.* (15) demonstrated in their study that specific complications including cardiovascular complications (23.3% *vs.* 20.0%) and iatrogenic bleeding complications were higher during RATS than VATS (5.0% *vs.* 2.0%). The higher risk of iatrogenic bleeding complications during RATS persisted in multivariable analyses (adjusted OR, 2.64; 95% CI, 1.58–4.43) (15). However, Cerfolio *et al.* (17) have recently shown that during robotic anatomic pulmonary resection the incidence of major vascular injury was 2.4% (15 of 632). Of these, 13 patients required thoracotomy performed in a nonurgent manner while the injury was displayed on a monitor, two had the vessel repaired minimally invasively, two required blood transfusion (0.15%), and one patient had 30-day mortality (0.16%).

He concluded that major vascular injuries can be safely managed during minimally invasive robotic surgery (17).

Should hospitals continue to invest in robotic thoracic surgery?

Looking the real world, the high capital and running costs, long operating times and operating room usage do not justify such enormous cost. The high cost of the robot is not reasonable for the majority of hospitals especially in rural areas, but recently it has been shown that regional competition could influence the hospital's decision to acquire a surgical robot to attract more patients (18). Many surgeons and oncologists believe it would be unethical to buy a robot just to attract patients instead of buying it because longer survival is demonstrated. Another big problem is the reported long duration of the operating room usage, which will translate into higher cost. We know that with a good organization in some operating thoracic centers it is possible to perform three major VATS lung resections from 9.00 am to 5.00 pm. This is unlikely to happen with the robot because it is necessary to add the "preparation" time of the operating room. Certainly, in the future when companies will be able to drive down costs, and operating room usage will be similar to standard VATS it could be possible to use more robotic surgery for lung.

Should residency program train juniors thoracic surgeons in robotic surgery?

Residents can participate as the primary surgeons in a variety of thoracic operations during the implementation of a robotics program (19). Operative time, estimated blood loss, and length of stay were similar regardless of level of resident participation (20). As Toker (21) clearly wrote that standardization in surgical education could only be provided through computer-based systems, rather than the classical Halstedian learning systems (see one—do one—teach one), the new generation of surgeon may learn through simulation rather than on patients, and therefore RATS training program will be probably necessary in all surgical school.

The future

Already in the 1970s, NASA suggested to look into the option of remote-controlled robots to operate on

astronauts, and we know that it is now possible that long-distance robotic surgery could be used more widely in the earth, allowing people to access world-leading surgeons without having to travel (22). Another more than realistic option is that robots could in the future use algorithms and databases to make decisions during surgery to perform, and finish the operation without human guiding the scalpel. Modern robots combine advanced mechanical, motion and task dexterity features with human-like cognition and intelligence capabilities, and uniportal RATS could become a reality. We could envisage an "octopus" with the head outside the chest and the moving tentacles inside the chest. Certainly the intelligent and autonomous robots offer new opportunities, doubts, law and ethical issues that have to be evaluated and resolved (22).

Nevertheless, because the lack of persuasive level data displaying patient benefit when compared to conventional VATS surgery, in these days, it may be some time before the robot is widely embraced in thoracic surgical practice. In the era of minimal invasiveness, robotic surgery for lung resection deserves a 360° evaluation (including cost, chest pain and long term survival) in a randomized trial *vs.* the different type of VATS approaches and open lung resection (23-25).

Pragmatically, the fact that RATS did not demonstrated to provide longer survival than VATS or thoracotomy makes it hard to justify buying a robot for lung resection, furthermore the longer duration of the operation and the longer operative room usage and higher cost make the adoption of the robot even more problematic.

Furthermore it is evident that only one operating surgeon is "in charge" in the console, and this might translate in the future to less need for surgeons with elevated surgical skills (26). The next generation of surgeons will decide to operate according to the approach that suits them best (RATS, VATS, single incision, biportal or 3-portal technique) and not according to what technology and patients demand.

When a new surgical innovation is introduced into clinical practice, the balance between advantages and disadvantages should be in favor of the advantages for patients and surgeons, and the therapeutic success must be evident. This is not yet the case of robotic assisted lung resection.

Acknowledgements

None.

Footnote

Provenance: This is an invited Editorial commissioned by Editor-in-chief Nanshan Zhong (Academician, Chinese Academy of Engineering, Guangzhou Institute of Respiratory Disease, Guangzhou, China).

Conflicts of Interest: The author has no conflicts of interest to declare.

Comment on: Bao F, Zhang C, Yang Y, et al. Comparison of robotic and video-assisted thoracic surgery for lung cancer: a propensity-matched analysis. *J Thorac Dis* 2016;8:1798-803.

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Cite this article as: Migliore M. Robotic assisted lung resection needs further evidence. *J Thorac Dis* 2016;8(10):E1274-E1278. doi: 10.21037/jtd.2016.10.89