# Robotic is better than VATS? Ten good reasons to prefer robotic versus manual VATS surgery in lung cancer patients

**Michela Solinas, Pierluigi Novellis, Giulia Veronesi**

Division of Thoracic and General Surgery, Humanitas Clinical and Research Center, Milan, Italy

*Correspondence to:* Michela Solinas. Division of Thoracic and General Surgery, Humanitas Clinical and Research Center, Via Alessandro Manzoni 56, 20089 Rozzano, Milan, Italy. Email: michela.solinas@cancercenter.humanitas.it.

**Abstract:** Different variants of minimally invasive lung resection have been described during the last decades including uniportal, non-intubated video-assisted thoracoscopic surgery (VATS), as well as, more recently, the subxiphoid VATS lobectomy. Robot-assisted thoracic surgery (RATS) is a relatively recent evolution of manual videoendoscopic surgery, born with the idea to make minimally invasive techniques an option even for complex procedures with the help of computer and micromechanics. Thus, after a period to gain confidence with the new system, robotic surgery found a great consensus among surgeons. With its development and diffusion in many surgical disciplines, including thoracic surgery, studies on its efficacy, safety and feasibility compared to conventional techniques have been performed. This has produced a healthy competition between VATS and RATS, even if these studies gave controversial results in terms of perioperative outcome and complications. A definitive conclusion is not available about a real benefit for the patients in the field of lung cancer treatment. Despite that, many aspects of robotic surgical platforms foreshadow that robotic systems will become an essential reality in the surgeon's armamentarium of the future. We expose the main features of robotic surgery to demonstrate that RATS is better than VATS to treat lung cancer patients.

**Keywords:** Robotic surgical procedures; robotics; minimally invasive surgical procedures; thoracoscopy

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The first video-assisted thoracoscopy is credited to a Swedish internist of the early twentieth century, Hans Christian Jacobaeus, who used a cystoscope to assist a closed intrathoracic pneumolysis, to treat tuberculosis, despite new findings suggest that video-assisted thoracoscopic surgery (VATS) was probably born half century earlier (1,2). Italy has a long history regarding the use of VATS and minimally invasive techniques in general (1). One example is the Forlanini's artificial pneumothorax in pre-antibiotics era, and the "Atlas thoracoscopicon" published by Felix Cova in 1928, that illustrates more pioneering findings during thoracoscopic procedures (3). At the beginning the VATS was reserved to simple diagnostic procedures, such as biopsies and only in the 80s we observed the evolution to VATS for major lung resection, thanks to the introduction of single lung ventilation and high-definition endoscope (4). In 1992 Roviaro and co-workers (5) proposed the first VATS lobectomy with anatomical hilar dissection, while Peracchia and colleagues (6) were the first to report its use to treat esophageal cancer. After that moment, a great number of authors from around the world described its safety and advantages when compared with thoracotomy, including a shorter hospitalisation, less postoperative complications and less postoperative pain, and most scientific societies established VATS as the standard procedure for early stage lung cancer (4).

Already since 1940, the concepts of "telemanipulation" and "telesurgery" were introduced (7). These words were created with the aim to perform complex tasks in dangerous and unhealthy places by machines, which were manipulated from the distant site. So that, engineers started to develop the first "performers", the ancestors of actual robots (7).

Many institutions recognize their potentials, so minimally invasive techniques were pooled with robotics to overcome the limitation of conventional procedures (7). The first robotic-assisted surgery was in 1983 during an orthopedic procedure. Later, robotics extended in neurosurgery, urology, gynaecology, cardiac surgery and so on, until 1993, when there was the first application of robotics in abdominal surgery with AESOP system (7). In 2001 ZEUS (Computer Motion Inc., Goleta, CA, USA) was introduced and it represented the real step towards a modern concept of general robotic surgery till the marketing of Da Vinci system, which remains the only available tool for the surgical applications till today (7).

Again, Italy had a role in the initial exploration of robotic applications with the publications of Giulianotti (8), who first used Da Vinci system for general and thoracic surgery, and Melfi (9), who described the first robotic lobectomy performed worldwide. Since that moment, the technological development contributed to spread the use of robotic surgery all over the world and the first comparative studies with traditional surgical techniques were published (10,11). Initially robot-assisted thoracic surgery (RATS) was considered a tool for privileged hospitals and criticized for the costs and for the complexity of the system (12); this is a common destiny of new technologies and revolutionary techniques. It is true that the studies, comparing RATS and VATS, did not demonstrate a definitive superiority of one technique over the other in terms of clear benefits for the patients, however these studies had some limitations, first of all VATS surgical teams had obviously a longer experience, than robotic ones, as the technique is older (12). Despite that, there are some indisputable peculiarities, which support the superiority of RATS over VATS, and convince us that robotics will be the minimally invasive technique of the future in particular for complex cases. More recent literature in addition demonstrated some clinical advantage of RATS compared to manual VATS. Here we present ten technical and general features to show why RATS is better than VATS.

(I) High-definition and three-dimensional vision: robotic system offers a stable camera platform, which facilitates a precise anatomical dissection while the distance between the screen and the table in VATS requires continuous adaptations of surgeons eyes to focalise the target and the field suffer of continuous movements due to human arms. There is no more necessity of a skilled camera operator like in conventional VATS procedure and, although the high definition is available also for VATS, RATS platform establish a stereoscopic vision with optimal depth perception (2). The console surgeons control the more suitable position of the camera and takes advantage of an eye-hand-target alignment (13). The magnification of the imaging permits to operate and to reach narrow spaces, like the mediastinum (2).

(II) Ergonomics: fatigue and musculoskeletal efforts related to prolonged standing are avoided, using the robot (2). The surgeon, sitting at the console in a relaxed position, can, especially during long and complex operations, concentrate himself in more accurate dissections and can spare energy, for unexpected difficulties. Furthermore, robotic is a women friendly tool, for the more comfortable position and tools, which do not require particular muscular strength.

(III) "EndoWrist" system: robotic instruments mimic the human wrist movements and empower human capability. They are characterised by 7-degree of angles with a 360-degree freedom rotation of movements (7). This allows reaching hidden spaces in the chest (2). Manoeuvrability allows more complex movements than VATS instruments, such as suturing parenchyma, or vessels, any type of precise and delicate dissection, saving anatomical delicate structures.

(IV) "Fulcrum-effect": robotic arms can rotate around a fulcrum point at the level of the trocar, avoiding the pressure on the ribs and the torque on the chest wall. It decreases damage to the intercostal nerves and surrounding tissues with less pain, and consequent reduction of analgesic use (14).

(V) Motion scaling and tremor filtering: the console translates the great movements of the surgeon in smaller and finest ones, in the meantime neutralizing the physiological human tremor (2). VATS instruments, on the contrary, being rigid and long, tend to amplify the small involuntary movements of the surgeons hands. The finer dissection, allowed by robotic tools, makes the field cleaner with reduced blood loss (13).

(VI) Ambidexterity, intuitive movement and surgeon independence: with the presence of the "master controllers", each hand can manoeuvre more than a robotic arm and control an instrument. Inside there are algorithms of human articulation of fingers, wrists and shoulders to mimic human arms (7). The possibility to use both hands for the dissection, with a forceps on the left side, and an instrument for dissection on the right side, increases precision in the procedure. The instruments should be a scissors, a bipolar dissector "Maryland bipolar", a monopolar hook or a spatula, according to surgeon's preferences; dissection is less offhanded and more anatomic, avoiding little spots of bleeding and ripping tissues, typical of conventional manual videothoracoscopy, that usually utilize just one hand. Finally, robot guarantees equivalence between hands, even in typical right handed surgeons and allows console-surgeon to control three robotic arms and camera; this permits greater autonomy in all passages of the operation, including positioning of the lung, thanks to the fourth arm, with exposition of small details of the surgical field and use of different dissecting tool thus avoiding the continuous need of the bedside assistant manoeuvre, thanks to the manual joysticks and pedals of the console.

(VII) Lymph-node dissection and upstaging: during VATS lobectomies, the most annoying phase is the mediastinal lymph node dissection due to narrow mediastinal space and uncomfortable and conflicting long rigid manual tools, while robotic hilar and mediastinal lymph nodes dissection is easier, more fluent and more agreeable than that performed on VATS or even open surgery. It is usually performed without any effort and rapidly, even in case of large lymph nodes and adhesions with delicate structures (7).

Despite no definitive conclusions can be made on data available in the literature as only few studies compared VATS and RATS in terms of lymph node dissection. According to Toker *et al.* (15) RATS resulted to be the procedure with higher number of dissected lymph nodes, compared to VATS or open surgery. In particular, there was a significantly higher in number of total N1 lymph nodes. One possible explanation of this result was related to the fact that surgeon has to remove the largest number of lymph nodes to favour the assistant surgeon in positioning vascular stapler (16). Conversely, in conventional VATS surgery the surgeon who makes the dissection is the same who usually cut the vessels, so manoeuvre depends on singular surgeon experience. Another relevant aspect to consider is that the robotic procedure is so precise that lymph node capsule does not break; therefore, a major number of nodes could be resected (15). Surely, number of lymph nodes dissected increases with experience, but robotic can have the same result of dissection of thoracotomy, even in early experienced surgeons (15). So that robotic surgery permits to discover a lot of occult nodes metastasis, allowing a more and more personalized oncologic adjuvant therapy to each patient.

In this sense, the upstaging is considered a consequence of the quality of the radical lymph node dissection, and determines the postoperative treatment of the patients. Park *et al.* (16) reported in their study a 21% rate of upstaging (16). A comparative review by Wilson and co-workers (17) showed that nodal upstaging in robotic-assisted resection was superior to VATS and similar to thoracotomy, if analysed by clinical T stage (17). The outstanding lymph node dissection can be attributed the large number of technical advantages of the robotic technique. However, we cannot exclude selection bias related to disease or preoperative staging reliability, such as patient with locally advanced lung cancer (stage III), tumors that require a very extensive resection (chest wall or vertebral resections), potentially more aggressive tumors (i.e., neuroendocrine carcinomas) and lack of the pre-operative staging (such as by mediastinoscopy or endobronchial ultrasound) for locally advanced disease (18). Velez-Cubian *et al.* (18) describe their experience with the demonstration that robotics facilitates dissection of occult nodal metastasis with results comparable, if not better, to VATS and thoracotomy (18).

(VIII) Learning curve: learning curve is the process of improving and increasing surgeons' capabilities in a specific technique (4). It seems that robotic surgery is easier to learn than conventional thoracoscopy, despite robotic technique requires a standardised and dedicated training too (19). Different investigators consider that approximately 20 robotic lobectomies are necessary to achieve competence (20-22); while 30–60 cases are considered an adequate number for VATS lobectomies (23).

(IX) Extended indications: many studies demonstrate that surgeons do not require necessarily a particular

 

VATS experience to use robotic surgery (13). The dedicated training, the standardization availability of have a standardised procedure and the precise and intuitive technology (i.e., master controllers used as joysticks or the pedals at the console) seem to make surgeons more confident in robotics. RATS can be used to afford more complex operations than VATS and thus expand indications of minimally invasive surgery. This is related to the easier capability of suturing in case of sleeve resection, the delicate isolation of thin and fragile structure in anatomical segmentectomies and the guarantee of radical lymph node dissection in case of locally advanced disease resection, that in VATS are avoided by most surgeons.

(X) Data integration and connectivity: with new digital platform, integrated in the robotic system, the surgeon has the possibility to switch from full-wide screen to a multiple-image mode, through auxiliary accesses (electrocardiography, echocardiography, CT, etc.) (7). He can be always updated on the patient parameters and status, and review images, exams of the patient. These aspects contribute to determine surgeons' independence and decision making.

These are the main aspects in support of robotic technique.

The quality of surgery has an impact on the post-operative patient outcome, despite controversial data have been observed in retrospective comparative studies on complications, and length of stay, some benefits seems to be related to RATS in the study of Farivar *et al.* (24). Data from two institutions were collected and matched with those of the Society of Thoracic Surgery (STS) National Database. A significantly decrease in 30-day mortality and postoperative blood transfusion was observed after robotic lung resection compared to VATS and thoracotomy. Furthermore, the patients were discharged two days earlier than VATS and 4 days earlier than open surgery (24). Similarly, Louie *et al.* (25) found the same results. They thought that robotic technique favoured in patient comfort and mobility, which translated in an earlier discharge (25). About bleeding Louie and colleagues' experience showed that there was no difference in the overall rate of reoperation between the two groups, but proportionally more patients in the VATS group returned to operating room for bleeding (25).

The main argument against RATS over VATS is the increased cost. The high costs of purchase, maintenance and consumables are a concern and continue to limit uptake of robotic system in thoracic surgery, despite few comparative data are available from prospective studies. In particular, such analysis are lacking in the European contest. On this point, we have preliminary data indicating slightly increased costs for RATS versus VATS, but all falling into the profit area in a private Hospital of Northern Italy. Other data also indicate that hospital can make profit from robotic thoracic surgery, as costs seem to be lower than reimbursement from paying bodies. Most studies, however indicate that robotic surgery for lung cancer is more expensive than VATS and open surgery. Today only one producer has marked an effective robotic surgical system, but new robots are being developed by Medtronic and by Verb Surgical. Entry of new surgical robot manufacturers onto the market will bring much-needed competition that may also lead to cost reduction.

From technical point of view some limitations were emphasized at the beginning, such as the spatial footprint of the apparatus, the complexity in installing the robot's arms into the patient's chest and operating at a distance from patient was also considered source of anxiety by many surgeons. As a result, time was needed to gain confidence with the new apparatus. In the mean while advantages related to improved vision over the operative field, increased comfort for the surgeon and the precision of the manipulation became progressively more appreciated.

Robot technology has made enormous strides to date, but in the near future we expect improvements beyond the actual use of robot-assisted surgery. The future developments of this technology will involve simulation, 3D modelling and augmented reality with the possibility to plan preoperatively the surgical intervention and intraoperatively superimposing preoperative data onto a real-world view of the patient. In a far future robotisation of the procedure, replacing the human gesture with robotically automated one will be a possible evolution with new digital surgical platforms combining advanced visualization, with innovative instrumentation, connectivity and robotics.

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