Editorial

Thoracoscopic surgery in lung cancer: the rise of the robot

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Robot-assisted thoracoscopic surgery (RATS) has advanced the era of minimally invasive thoracic surgery. The robotic system's increased manoeuvrability, vision and training capability offer an attractive alternative from traditional thoracotomy or video-assisted thoracoscopic surgery (VATS) anatomic pulmonary resections. Miyajima and colleagues' retrospective study examines one centres' case load of VATS and RATS lobectomies for lung cancer between 2017 and 2020, reporting safe and efficient implementation of RATS lobectomies, when compared to VATS (1). However, current literature comparing RATS and VATS resections in thoracic surgery offers conflicting evidence across a range of peri-operative outcomes. For the purposes of this editorial, we are going to focus only on the DaVinci systems provided by Intuitive Surgical; despite the emergence of competitors in recent years the DaVinci remains the platform of choice for most centres.

The first use of the robotic platform for pulmonary resections was reported by Melfi and colleagues in 2002, with an initial report of three cases (2). Shortly afterward Bodner and colleagues demonstrated the potential of the platform across a wider range of thoracic procedures; reporting a small series of thymectomies, fundoplications, oesophageal dissections, benign mediastinal mass resections and a single lobectomy. While these early adopters recognised the significant potential of the platform in terms of precise dissection in difficult areas (for example when dissecting out the superior horns of the thymus), a lack of specialised thoracic instrumentation was felt to limit its use in pulmonary resection (3).

Things have changed significantly since those early days. Fast forward twenty years and the robotic platform is in widespread use for thoracic procedures across Europe and the United States, and experience is growing in Asia (4,5). Uptake has perhaps been even swifter than the move from open surgery to VATS in the 1990s. This is likely in part to do with the fact that from the operator's perspective the robotic platform has two significant advantages compared to VATS; vision is 3-dimensional (3D), and instruments are wristed, and therefore more suited to precise hilar dissection (6). As such robotic lung resection is typically associated with a shorter learning curve than VATS; around 20 cases for RATS compared to 50 for VATS (7).

Significant work has been done comparing the outcomes of the RATS versus VATS approach for pulmonary resection. The superiority of RATS over VATS in terms of reduced blood loss, lower conversion rate, more extensive lymph node dissection, shorter length of postoperative stay, lower recurrence rate and lower overall complication rate was demonstrated by Ma and colleagues in their 2021 meta-analysis (8). O'Sullivan and colleagues found RATS to be superior to VATS with regard to 30-day mortality [odds ratio (OR) 0.61, 95% confidence interval (CI): 0.45–0.83], but inferior with regard to operative duration (9). There have been multiple smaller retrospective studies suggesting superiority of RATS over VATS with regard to

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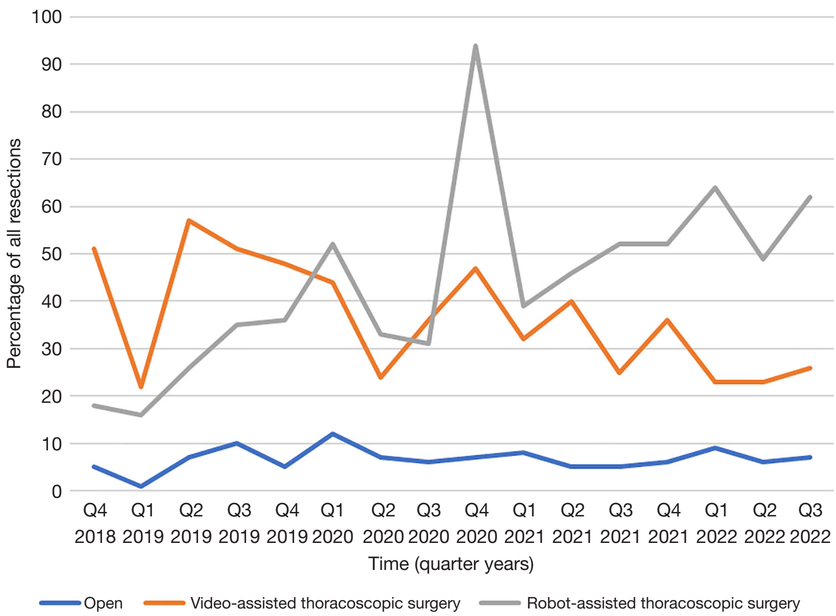

Figure 1 Surgical approach to lung cancer Q4 2018–Q3 2022 (absolute numbers).

conversions, complications and length of stay (10-12).

Despite these encouraging early results, we must remember that this evidence needs to be interpreted carefully. In their meta-analysis Zhang and colleagues comment that the majority of studies currently available are retrospective, with only two randomised controlled trials (RCTs) included in their review 2022 review. Further-more they caution that long-term oncologic outcomes have not been reported (due to the novelty of the platform). There is also a likely publication bias with RATS evidence (13). Many of these studies contain several uncontrolled variables; including but not limited to small caseloads, surgeon to surgeon variability (particularly in terms of experience with the robotic platform), variation in patient selection etc. These issues are not unique to RATS, and to some extent they do exist with the introduction of any new technique or technology; however, all of these issues point to the need for further large multicentre RCTs to better compare outcomes across the two techniques.

It is widely accepted that RATS is significantly more expensive than VATS, and this is seen as one of the principal barriers to its widespread adoption. Costs vary widely across different health systems, however for illustrative purposes one retrospective database study from the United States suggested an average per case cost of $25,040 for RATS compared to $20,476 for VATS (14). In their 2019 review, Singer and colleagues point out the same issues exist with the current cost literature as with the rest of the outcome data comparing the two approaches; namely that most of the available data is retrospective, from single centres or small studies, and crucially that it mostly addresses early experiences. It is suggested that the cost of RATS pulmonary resection will fall with reduced operative times, improved outcomes and higher operative volumes; indeed data from current high-volume centres reflects this (15). In contrast however our own group analysed the drivers of the increased cost associated with robotic lobectomy, and found the high cost of consumable robotic equipment to be the most significant issue, accounting for 63% of the cost difference between the two approaches. Capital costs accounted for only 34% of the difference (16). This would suggest that improvements in operating room efficiency, and increased capital equipment utilisation will not significantly reduce the cost. It is potentially more important that we see more competition enter the market, in order to drive down the cost of expensive consumable equipment.

Our unit has seen a significant expansion of our RATS programme in the last 5 years, with just 18 RATS resections performed in Q4 2018, up to 63 resections by Q3 2022 (*Figure 1*). Furthermore, RATS has facilitated a shift toward segmentectomy as the resection of choice for early-stage lung cancer. The change in our approach to anatomic resection is illustrated by *Figure 2*, which demonstrates that segmentectomy comprised 23% of all resections in

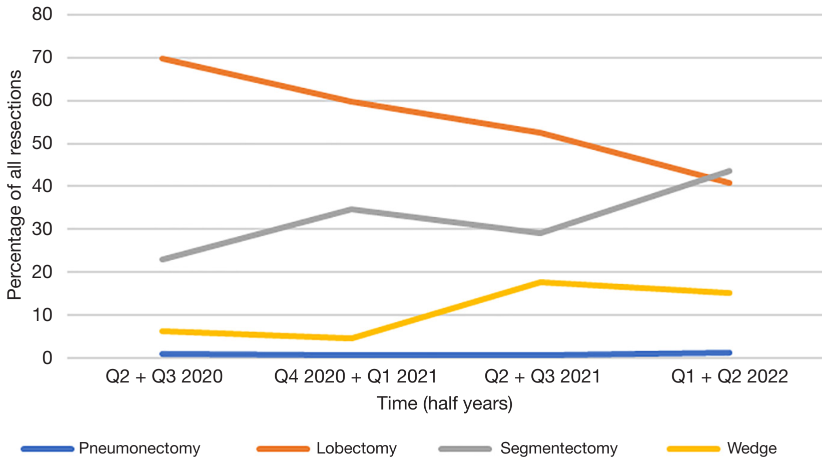

Figure 2 Anatomic resections for lung cancer (% of all resections), Q2 2020–Q2 2022.

early 2020, rising to 43% by 2022. In contrast lobectomy, which accounted for 70% all resections in early 2020, accounts for just 41% by 2022. The operator advantages offered by the robotic platform including high-definition 3D vision, wristed instrumentation and use of intravenous indocyanine green with an infra-red camera to delineate resection margins, confer a significant advantage over VATS when performing segmentectomy. The shift in our practice is supported by recent evidence published in the JCOG 0802 trial, which demonstrated improved 5-year overall survival with segmentectomy compared to lobectomy for stage IA non-small cell lung cancer (NSCLC) (17,18). We believe that this shift toward lung preservation in anatomic resection will continue in the coming years.

Several aspects of the robotic platform make it ideal for delivering training to more junior surgeons. At our unit we have a dual surgeon console setup, allowing for efficient switching of control between the trainee and the trainer. Further-more the trainee has the opportunity to engage in a wide range of virtual reality simulation modules provided by the manufacturer; such high-fidelity simulation is not easy to achieve in VATS or open surgery training.

Although the study by Miyajima and colleagues is a small single centre retrospective review the use of propensity score matching sets it apart from similar works. The matching of patients for fissure completeness in particular, which as the authors correctly point out greatly influences operative difficulty, complications and operative time, attempts to address the issue of selection bias that exists in other studies, and to the best of our knowledge is a novel approach. Propensity score matching (PSM) was also used to control for other covariates including age, sex, tumour location, smoking status, body mass index, FEV_1 and FVC, and maximum tumour diameter—but as the authors correctly point out this has been done previously (1).

Interestingly the authors report using an epidural catheter for analgesia in all patients—this would not be normal practice in our centre, where we favour the use of intercostal blocks, a paravertebral catheter and a multimodal oral analgesia regimen. We base our practice on recent evidence demonstrating similar analgesic efficacy with paravertebral catheters but a superior side effect profile, reduced haemodynamic instability and increased preservation of pulmonary function when compared to epidural anaesthesia (19,20).

The authors also report a technique of pulmonary artery (PA) ligation using a silk tie and the vessel sealer instrument. At out institution we favour the use of a stapler to seal and divide the PA. While the rationale for this technique is not discussed by the authors, they do point out that it requires an experienced operator, particularly in light of the lack of tactile feedback on the robotic platform. We agree with the authors on this point, and suggest that perhaps the approach of stapling the PA is favourable for those embarking on a robotic practice (1).

In the unmatched cohort outcomes reported by the authors broadly reflect those seen across the literature, with RATS conferring a statistically significant advantage over VATS in terms of conversion to open, persistent air leak, intraoperative blood loss, chest tube duration and hospital length of stay. RATS was inferior to VATS with regard to operative time. After PSM the advantage only remained statistically significant for intraoperative blood loss, and hospital length of stay. Interestingly after PSM the difference in resected lymph nodes (total: 20 *vs.* 17.6, P=0.05) achieved statistical significance. There was no difference between the two approaches in terms of resection completeness and upstaging (1).

The authors conclude that their initial experiences of RATS pulmonary resection had no significant disadvantages when compared to VATS using PSM. It would seem clear that RATS offers several distinct advantages to the operator, and these may translate into improved outcomes for patients, however the current evidence to support this is insufficient. There is a need for large scale multi centre RCTs comparing RATS and VATS for pulmonary resection, in order not only to fully assess patient outcomes, but also to analyse the cost-benefit of robot assisted pulmonary resection.

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy and integrity of any part of the work are appropriately investigated and resolved.

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