Editorial

Extended lobectomy—how minimally invasive can we go?

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In a recent issue of *Translational Lung Cancer Research*, Chen and colleagues published a propensity-matched study on open versus minimally invasive extended lobectomy for non-small cell lung cancer (NSCLC) based on data from the National Cancer Database (NCDB) of the American College of Surgeons (1). This study reported on short-term outcomes and 5-year overall survival after open versus minimally invasive extended lobectomy. The authors hypothesized that minimally invasive surgery (MIS) for an extended lobectomy was safe, feasible, and provided for improved patient outcomes when compared to open. In relation to this subject several factors should be considered: the evolvement of neoadjuvant therapy, differing types of MIS, and the associated learning curve.

The role of neoadjuvant therapy

Primary lung cancer with invasion of the chest wall was deemed inoperable until Coleman reported the first case series of a pneumonectomy with chest wall resection for primary lung tumors invading the chest wall in 1947 (2). Since then, numerous advancements have been made and more invasive tumors have been resected through extended procedures with chest wall, pericardium, or diaphragm resection. Over time, with the introduction of neoadjuvant therapy, a broader patient population, including patients with advanced NSCLC, has become eligible for surgery due to downstaging of initially irresectable lung tumors (3). In recent years, addition of targeted therapy to neoadjuvant therapies like chemoradiation has contributed to an increased potential of complete resection of invasive T3/T4 tumors. A recent meta-analysis showed that neoadjuvant chemo-immunotherapy increased the down-staging rate, resection rate, and R0-resection rate when compared to neoadjuvant chemotherapy alone (3). Consequently, the administration of (neo)adjuvant therapy has been recommended in a recent expert consensus on chest wall resections for invading lung cancer tumors (4). However, neoadjuvant therapies can come at a cost. Besides effects on patient condition and possible toxicities, neoadjuvant therapy may make surgery more difficult due to risk of pleural adhesions and inflammation in the operating field and fragility of the tissues, with possibly more conversions and complications (5). However, the evidence concerning operative safety after neoadjuvant therapy is not unequivocal. A recent cohort study showed no difference in terms of postoperative complications between patients that did or did not receive neoadjuvant treatment before minimally invasive sleeve lobectomy. Of note, in this study thoracotomy and operative time longer than 150 minutes were predictors for postoperative complications (6). Targeted immunotherapy specifically has not shown inferior outcomes when compared to neoadjuvant chemotherapy in terms of rate of MIS, conversion rate, resection margin

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and short-term postoperative morbidity and mortality (3). Unfortunately, the inclusion period of the study conducted by Chen and colleagues coincided with a time when neoadjuvant immunotherapy was not yet available.

From open to MIS

Since the late nineties minimally invasive video-assisted thoracoscopic surgery (VATS) technique has gained increasing acceptance for anatomical resection of lung cancer with proven benefits over open surgery regarding short-term postoperative outcomes like pain, length of hospital stay, and blood loss (7). Moreover, in some studies VATS has also improved long-term outcomes like overall survival, which is likely due to a higher rate of, and better compliance to adjuvant therapy administration (8). Also for major pulmonary resections minimally invasive thoracic surgery enhances the quality of life of patients as shown in the VIOLET-trial (9). As such, it is considered as the primary approach in the latest enhanced recovery after surgery (ERAS) guidelines for thoracic surgery by the European Society of Thoracic Surgery. This has resulted in a major transition within the last two decades from open to minimally invasive thoracic surgery, as demonstrated by the study of Chen *et al.* showing almost a double amount of minimally invasive cases from 18% in 2010 to 33% in 2014 (1). Concomitantly, surgical techniques and equipment have improved. The introduction of endoscopic rib cutters, improved needle drivers, and synthetic and biological meshes have all contributed to the increase of minimally invasive extended thoracic surgery procedures with chest wall resections (10,11). To improve results, pre-operative planning by means of imaging is essential (4). Recent developments in 3D reconstruction models of computed tomography (CT)-scans and virtual reality imaging, nowadays predominantly used for pre-operative planning of minimally invasive segmentectomies, could improve surgical planning for extended lobectomies (12,13).

Parallel to VATS, robot-assisted thoracic surgery (RATS) has evolved as a mature alternative for minimally invasive thoracic surgery (14). RATS is characterized by advanced articulating instruments, enhanced 3D vision, and improved ergonomics for the surgeon (14). Proponents report that extended procedures are less difficult to perform when compared to VATS, with the more intuitive camera movements and consequently more fluent conduct of the surgery (15). Although the outcomes between VATS and RATS do not seem to differ largely, a recent review on minimally invasive thoracic surgery reported lower conversion rates for RATS versus VATS (16). Chen and colleagues showed that RATS was non-inferior to VATS with respect to resection margin, lymph node harvest, length of hospital stay, 30-day mortality, and 90-day mortality. However, it should be considered that the study by Chen and colleagues is limited by the inclusion that occurred over a decade ago. Hence, their results might not fully apply to the current population of lung cancer patients since many advancements have been made, and more experience has been gained with these minimally invasive techniques over the last decennium.

From multiportal to uniportal

To minimize surgical harm and improve patient outcomes even further, Gonzalez *et al.* described the single-incision, also known as uniportal VATS (uVATS), anatomical lung resection in 2011 (17). A recent meta-analysis has shown favorable outcomes of uVATS over the conventional multiportal VATS (mVATS) technique in perioperative, and short-term patient outcomes (18). Long-term oncological safety in terms of 1- and 3-year survival rates are not compromised for uVATS procedures compared to mVATS. Over time, more complex and extended operations such as segmentectomies, and bronchial and arterial sleeve lobectomies are being performed using uVATS, showing low complication rates (19). Despite its relatively recent introduction, extended lobectomies with uVATS for tumors invading the chest wall that, preferably, are limited to four or fewer ribs have been reported to be safe and feasible (11). Endoscopic rib cutters may be used, and rib retractors are not necessary. Chest wall reconstruction is usually performed with a mesh, depending on its dimension and location. It must be noted that these cases are reported by expert high-volume centers for thoracic surgery.

Learning curve and annual caseload

Even though the patient outcomes after minimally invasive approaches seem promising, a new technique comes with a learning curve, as also mentioned by Chen *et al.* as a potential explanation for the higher conversion rate in their study (1). Different studies show a decrease in conversion rate as experience and case volume go up (20,21). Conversion rates for VATS and RATS can be as low as 3% in the hands of experienced surgeons and centers but can also be as high as 24% in less experienced teams and centers.

Important to note, is that the learning curve does not only apply to the surgeon alone, but to the entire surgical team. RATS possibly adds even more challenges for the entire team than VATS, as there can be barriers in communication due to the remote position of the surgeon, difficulty with port placement and instrument changes (22). However, it is suggested that the learning curve for RATS may be shorter when compared to VATS, which is probably due to the enhanced 3D vision and articulating instruments, but also to simulation programs that can be easily run on the robotic system (23). The learning curve for RATS lobectomy has been defined to be as short as 20 to 34 in centers doing over 100 RATS cases per year, and 23 to 63 cases in another center that performs 25 cases per year (24,25). As for (uniportal) VATS, a learning curve of 52–156 cases has been described depending on the outcome measure that was used (complications, operating time, or blood loss). These learning curves only apply to standard minimally invasive lobectomy. As such, learning curves for extended lobectomy might be even longer, but literature on this subject is not yet available.

Conclusions

In conclusion, Chen and colleagues have shown the short-, and long-term advantages of MIS for extended lobectomy using the NCDB whilst possibly showing the effects of going through a learning curve. Increased experience with minimally invasive extended lobectomy surgery, advancements in technology, and the added value of neoadjuvant therapy all contribute to a higher rate of patients who are eligible to undergo surgery for more extensive and complex lung cancer tumors. To keep broadening the scope of operable patients, advancements in minimally invasive techniques like uVATS and RATS should be embraced and trained in high-volume centers to ensure the best outcomes.

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