Pulmonary segmentectomy is defined as the removal of an anatomic subdivision or segment of the pulmonary parenchyma in a lobe of the lung. Pulmonary segmentectomy has been most commonly used by general thoracic surgeons for the resection of tumors in patients with poor pulmonary function who could not tolerate lobectomy. However, recently the concept of segmentectomy over lobectomy has been increasingly applied and used for patients with normal lung function for lesions less than 2 cm, especially those who do not have visceral pleural invasion. Although the benefits of this practice compared with the risk of not removing the entire lobe are not known, several current ongoing prospective multi-institutional studies will help answer this question. One such example is the National Cancer Institute Cancer and Leukemia Group B 140503 study, where patients, who have biopsy-proven non-small-cell lung cancer but do not have a recent history of another solid organ cancer and whose lung lesions are 2 cm or less, are randomized to either a lobectomy or a segmentectomy. The randomization process occurs in the operating room after several specific N2 and N1 lymph nodes are biopsied and proven to be benign. In addition to this North American study, there is also an ongoing study in Asia sponsored by the Japan Clinical Oncology Group and the West Japan Oncology Group.

Importantly, not all lesions are positioned perfectly in the lobe for a segmentectomy and thus do not set up well for a formal anatomic segmentectomy. A formal segmentectomy, as opposed to a “large wedge resection,” refers to one in which the artery to that segment, the vein (sometimes), and the bronchus are all dissected free from the surrounding tissue, individually identified, and then ligated. In addition, all of the appropriate draining N1 lymph nodes are removed. Some types of segments avail themselves to this type of resection better than others. These include, on the right side, in the right upper lobe, an apical, an anterior, and a posterior segment. In the right middle lobe, both the superior and the inferior segments can be performed but are rarely done because the right middle lobe is so small. The segmentectomies of the right lower lobe that can be performed are mainly the right lower superior segment and sometimes the basilar segments.

On the left side, the lingula presents itself as an ideal segment as well as the left upper apical, anterior, and posterior segment. In addition, a trisegmentectomy of the left upper lobe can be performed, which spares the lingula but removes the rest of the left upper lobe. In the left lower lobe, the inferior segment is an anatomically well-defined area where all 3 structures, the artery, vein, and bronchus, are easily identified and individually ligated or stapled. Although basilar segmentectomy can be performed for lesions in either the right or the left lower lobes, they often do not afford ideal anatomy. Segmentectomy can be performed via many surgical approaches including thoracotomy, video-assisted thoracoscopy, and robotic surgery. The example illustrated in this article is a robotic posterior segment of the left upper lobe.
Operative Technique

Figure 1 When minimally invasive techniques are used, such as video-assisted thoracoscopy or robotics, careful and precise port placement is required. A new technique utilizing a completely portal robotic approach (no access incision is made and CO₂ insufflation is used) has been developed at our institution. A completely portal robotic segmentectomy (CPRS) using 4 arms (CPRS-4) is shown for a left-sided robotic segmentectomy or lobectomy.

A zero-degree camera is used. The chest is explored and the N2 mediastinal lymph nodes are completely removed. Frozen sections are sent as indicated. After removal of the subcarinal lymph nodes and the 10 L lymph node that lies between the superior aspect of the left main stem bronchus and the pulmonary artery, the fissure can be dissected from this landmark going posterior to anterior. (Color version of figure is available online at http://www.optechtcs.com.)
Figure 2 The postsegmental artery of the left upper lobe can be visualized as shown. The retraction of the lung is provided by the most posterior arm, robotic arm 3, that is, a 5-mm port, acts as a second right hand, and has a 5-mm lung grasper in it. The dissection is mainly performed by the surgeon’s dominant hand, for most, the right hand (which is robotic arm 1 for a left-sided operation), and it uses bipolar dissectors that are 8 mm in size. Robotic arm 2, the most anterior port serves as the left hand. It has Caudierre forceps in it most commonly. As shown in the figure, the vessel loop is around the artery and is held by robotic arm 1 (the right hand) while the lung is being retracted by the left hand, robotic arm 2. Robotic arm 3 (not in the figure) is holding the left lower lobe downward and out of the picture. This figure depicts a vessel loop encircling the posterior segmental artery to the left upper lobe.
Figure 3  The artery is ligated with a vascular stapler as shown. The stapler is introduced from the access port. We have a bedside nurse perform all of the stapling of the vessels, fissures, and bronchus. The surgeons and resident remain at their consoles to help direct the angle of the stapler and to assist in guiding it into proper position. The access port usually provides the ideal angle for this artery. Some patients have more than 1 artery going to the posterior segment. In these patients, a second posterior segmental artery to the left upper lobe is identified. The lingular artery should be identified and preserved and the surrounding lymph nodes in this area should all be completely removed.
A second artery is depicted going to the posterior segment of the left upper lobe. Note that the lingular artery (running under the robotic instrument) is preserved. This other artery going to the segment of the lung that has the cancerous nodule is dissected free and is subsequently ligated with a vascular stapler. Again, the stapler is introduced via the access (nonrobotic port) and the vessel is surrounded and held up by a vessel loop by the surgeon’s right hand, robotic arm 1.

Once the arteries to the involved segment are divided, the N1 lymph nodes that lie over the segmental bronchus should be removed. It is important that these are removed and sent for frozen section to ensure they are pathologically negative. This ensures the oncologic adequacy of a segmentectomy. Once these N1 lymph nodes are removed, the underlying segmental posterior bronchus to the left upper lobe is easily seen.
Figure 5  The segmental bronchus to the posterior segment of the left upper lobe is dissected free and is eventually encircled with a vessel loop. Care must be taken when this bronchus is encircled to avoid the anterior pulmonary artery. It should be preserved and not ligated during a posterior segmentectomy.
Figure 6  The posterior segmental bronchus to the left upper lobe is stapled closed with a 4.8-mm stapler.
The operation is completed by stapling the posterior segment aspect of the lung from the rest of the remaining left upper lobe as shown. (See also Fig. 8.) The distance of the stapled margin from the nodules should be at least the diameter of the lesion. Sometimes, during this part of the operation, the stapler is best introduced via the relatively posterior location of robotic arm 1. Because there is not a robotic stapler at this time, it is necessary to undock robotic arm 1 and either place the stapler through the port or remove the port and place it directly through the incision. We prefer the latter method because it affords more room for the nurse to open and close the stapler as well as articulate it. The stapler is coming from robotic arm 1. (See also Fig. 8.) We do not recommend placing a stapler in the location of robotic arm 3 because it is too posterior, the ribs are very close in this area, and the intercostal nerve or vessels could be injured.
Figure 8  Stapling the posterior segment aspect of the lung from the rest of the remaining left upper lobe. The stapler is coming from robotic arm 1.
Conclusions

Once both the parenchyma and the bronchial margins are confirmed as negative, the chest should be irrigated. The lack of a bronchopleural fistula and air leaks from the lung parenchyma should be ensured. One small chest tube should be placed. We currently favor a 20-French soft chest tube placed through one of the more anterior ports when performing a minimally invasive segmentectomy.

Prospective randomized studies will tell us the oncologic effectiveness of segment versus lobectomy. In the future, it is likely that the true comparison group will be stereotactic radiosurgery compared with minimally invasive segmentectomy.

References


Figure 9 Finally, the specimen is placed in a bag to prevent spillage (as shown) and the segment is removed via the nonrobotic access port. Once removed from the chest and in the bag, it is brought to a back table and the bronchial margin is cut and sent for frozen section analysis.