Carlos Galvez
Sergio Bolufer
Santiago Figueroa
Andrés Obeso
Editors

Video-Atlas of VATS Pulmonary Sublobar Resections

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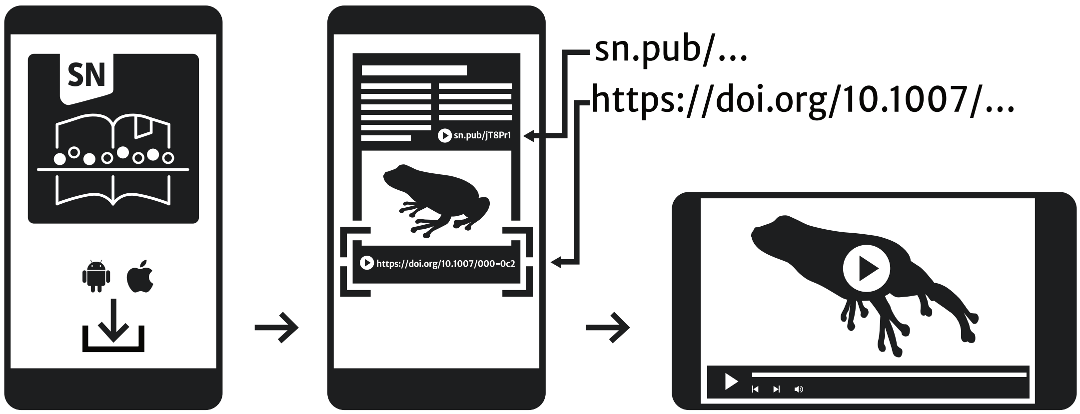

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Editors
Carlos Galvez
Hospital General Universitario Dr. Balmis
de Alicante
Alicante, Spain

Sergio Bolufer
Hospital General Universitario Dr. Balmis
de Alicante
Alicante, Spain

Santiago Figueroa
Thoracic Surgery Dept.
Hosp. Clínico Universitario de Valencia
Valencia, Spain

Andrés Obeso
Hospital Clínico Universitario de Santiago
Santiago de Compostela, Spain

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Prologue

It is a privilege to prologue this new *Video-Atlas of VATS Pulmonary Sublobar Resections*, with Drs. Galvez, Bolufer, Figueroa, and Obeso as Editors.

Fortunately, in the last years, the patients with a diagnosed or suspected lung carcinoma are arriving to the thoracic surgeon earlier than years ago. It means that the mean size of the tumors is smaller and the necessity of a lobar resection is no longer a must. The results of the Japanese phase III randomized trial, between lobectomy and segmentectomy in tumors N0, less than 2 cm, have demonstrated that the latter is not inferior regarding survival and postoperative complications, except a more air leakage was observed [1]. The surgical technique is of paramount importance for the outcome of the procedure, and this video-atlas explores the different technical aspects for all the sublobar resections, including special combinations of segmentectomy. The contents are very well organized for a quick search of the procedure to consult.

Regarding the Editors, I know very well the career of these four seniors, but young thoracic surgeons, who have become a reference in the Spanish thoracic surgical scenario. They have great experience in the field of sublobar resections that has been exposed in multiple national and international meetings. They have put together a high-definition multimedia tool, written by real experts, selected for his/her expertise in the specific assigned procedure. It is a tool for learning and improving the technique, not only for beginners but for advanced surgeons as well.

You will find anatomical 3D reconstructions of each segment with radiological correlation, bronchoscopy segmental anatomy, operative steps, and tips and tricks for each segmentectomy and its variations.

This video-atlas of pulmonary sublobar resections is designed to be a reference multimedia book for thoracic surgeons. I am sure that you will enjoy it!

Reference

1. Suzuki K, Saji H, Aokage K, Watanabe SI, Okada M, Mizusawa J, Nakajima R, Tsuboi M, Nakamura S, Nakamura K, Mitsudomi T, Asamura H; West Japan Oncology Group, Japan Clinical Oncology Group. Comparison of pulmonary segmentectomy and lobectomy: safety results of a randomized trial. J Thorac Cardiovasc Surg. 2019;158:895–907.

Laureano Molins
Thoracic Surgery
Barcelona, Spain

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Contents

Part I

General Considerations and Technical Aspects

1 Indications for Sublobar Resection in the Treatment of Non-Small Cell Lung Cancer (NSCLC)

Ulas Kumbasar and Frank C. Detterbeck

1.1 Introduction

Traditionally, lobectomy has been considered the gold standard procedure for the treatment of stage I non-small cell lung cancer (NSCLC), largely stemming from the Lung Cancer Study Group (LCSG) randomized controlled trial (RCT) conducted in the 1980s [1]. However, many changes have occurred since then. Computed tomography (CT) lung cancer screening has contributed to the identification of early-stage tumors which may show indolent behavior. An increasing population of older patients with comorbidities are diagnosed with early-stage NSCLC. The long-standing recommendation for lobectomy for early-stage NSCLC is increasingly coming into question.

The focus of this discussion is on wedge or segmentectomy as an alternative to lobectomy for the treatment of stage I NSCLC. Other treatment options such as stereotactic radiotherapy or thermal ablation are beyond the scope. One can broadly categorize sublobar resection as elective (i.e., the patient could undergo any resection but tumor characteristics suggest sublobar resection is adequate) or a compromise (i.e., in a patient in whom lobectomy is judged to be high risk). This provides a useful framework, although the dividing line is inherently not always sharp.

For elective sublobar resection the main consideration is whether the long-term outcomes are equivalent; what is gained in short-term outcomes (perioperative morbidity and mortality, quality of life [QOL], pulmonary function tests [PFTs]) is less impactful. For compromise sublobar resections in less healthy patients, the opposite is largely true—a detriment in long-term outcomes is generally accepted if the gain in short-term outcomes is substantial. Nevertheless, selection of the extent of resection involves balancing potential benefits and downsides in an individual patient.

U. Kumbasar · F. C. Detterbeck (✉)
Thoracic Surgery, Yale University School of Medicine, New Haven, CT, USA
e-mail: frank.detterbeck@yale.edu

1.2 Elective Sublobar Resection

1.2.1 Short- and Intermediate-Term Outcomes

Several large randomized controlled trials (RCTs) reveal no difference in mortality and morbidity between lobectomy and sublobar resection in healthy patients [1–4]. Many non-randomized comparisons (NRCs) have reported slightly lower mortality after sublobar resection, but the differences are small and not clinically meaningful [5–10]. Morbidity is also similar in the large RCTs between lobectomy and sublobar resection in the healthy population [2–4]. NRCs show slightly higher grade $\geq$ 3 complications after lobectomy compared to sublobar resection, but the magnitude of the difference is only marginally clinically meaningful [5, 6, 11].

Quality of life (QOL) studies suggest that open thoracotomy is associated with a clinically highly relevant short-term impairment of QOL, which improves but persists long-term in a substantial minority of patients [5]. Video-assisted thoracic surgery (VATS), however, is associated with less short-term QOL impairment, which resolves after a few months [5]. Whether sublobar resection has any QOL benefit is unclear due to confounding by VATS vs open approaches [4, 12, 13]. Pain is also significantly diminished by VATS, and resolves more quickly and thoroughly vs thoracotomy, with little apparent difference between sublobar resection and lobectomy [5].

The difference in pulmonary function tests (PFTs) at $\geq$6 months after segmentectomy vs lobectomy is marginally clinically meaningful in healthy patients. In studies involving predominantly resection of a single segment vs lobectomy the difference in FEV1 is ~7%, whereas in studies including many

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multi-segment resections (e.g., left upper lobe upper division or lingular division vs lobectomy) the difference is ~4%. Limited data suggests there is little loss of FEV1 after wedge resection (i.e., there may be a relevant benefit to wedge over lobectomy in terms of preservation of pulmonary function) [5].

1.2.2 Long-Term Outcomes for Ground Glass Tumors

Lung cancers with a prominent ground glass (GG) appearance are being detected more frequently and are well recognized to have a more indolent behavior. This raises the question whether a lesser intervention is adequate.

To assess GG nodules (GGN) a thin section CT (~1 mm slice thickness) is essential. A GG opacity is a hazy area of increased density that does not obscure lung markings. An area of consolidation obscures normal lung markings on lung window settings, and the consolidation to tumor ratio (CTR) is used to describe the extent of consolidation. This is distinct from a solid area that is visible on mediastinal windows on a thin slice CT.

When intervention is justified for a GGN is an important question that is covered elsewhere [14]. Briefly, clinical and genetic data suggest that there are distinct types of GGNs. About 2/3 never progress significantly over 5–10 years; this is also true for patients with a proven NSCLC and additional GGNs [14, 15]. Those that do progress exhibit more indolent behavior than “traditional” (solid, spiculated) lung cancers, consistent with an observation that the genetic pathways leading to invasive cancer are different for GGNs vs “traditional” lung cancers [16]. Prospective trials have shown that waiting for development of or growth of a solid component (≥2 mm, mediastinal windows) or area of consolidation (≥6 mm, lung windows) is safe, does not risk stage progression or impair curability, and intervention is required in <10% of patients with a GGN [14, 17, 18].

If resection of a GGN is appropriate, segmentectomy is a reasonable alternative to lobectomy. Results were recently published from the JCOG0802 RCT, involving 1106 cIA1,2 cancers with a CTR >0.25 (median consolidation diameter 12.5 mm, 51% with a CTR = 1) [19]. Five-year recurrence-free survival (RFS) was 88% for segmentectomy and 87.9% for lobectomy (HR, 0.998; 95% CI, 0.753–1.323). The OS was 94% vs 91% ($p = 0.008$), oddly despite more local recurrences (10.5% vs 5.4%, $p = 0.0018$) for segmentectomy than lobectomy, respectively (median follow-up 7.3 years) [19]. Several non-randomized comparisons (NRCs) that adjusted for confounders have reported similar results for segmentectomy vs lobectomy [20–27]. Additional important evidence about long-term results should be available soon from a single-arm prospective study (JCOG1211) of segmentectomy for GG tumors ≤3 cm with a CTR of 0.25–0.5, and larger (2–3 cm) predominantly GG tumors.

Wedge resection is less well supported. JCOG0804 was a phase II study involving primarily wedge resection (or segmentectomy) for small, mostly GG tumors (≤2 cm, CTR ≤0.25) and found a 5-year RFS of 99.7% [28]. However, an earlier prospective study of primarily wedge resection for the same tumors, which also demonstrated excellent 5-year results, reported staple-line recurrence by 10 years in 19% [29].

1.2.3 Long-Term Outcomes for Small (≤2 cm) Solid Tumors

A prominent RCT of sublobar resection (58% wedge) vs lobectomy in pIA1,2 NSCLCs (CALGB, 2007-17, n=697) has recently been presented [30]. Extensive intraoperative confirmation of pN0 status was required and a margin of ≥2cm was recommended. OS was equivalent (5-year 80% vs 79%) as well as the cumulative rate of lung cancer death or recurrence (5-year 25 vs 26%) for sublobar resection vs lobectomy, respectively. Details of this study (e.g. margin distance, extent of node assessment) are unpublished at this time. Presumably these tumors were mostly solid.

How to interpret and apply the results of the CALGB trial is still evolving, and the full publication is not available at this time. Clearly it provides data supporting an increased use of sublobar resection. While the JCOG trial results are largely consistent with other studies involving GG tumors, the CALGB study raises some potential inconsistencies that need to be understood. The CALGB study is inconsistent with the earlier LCSG RCT [1] – even more surprising because the CALGB study involved more wedge resections than the LCSG study. A possible explanation is that the CALGB study involved smaller tumors, and that increased use of CT leads to detection of a greater proportion of less aggressive tumors. At first glance, the JCOG and CALGB studies can be viewed as consistent in supporting sublobar resection, but the higher rates of recurrence and lung cancer deaths in the CALGB study creates uneasiness that the results can be combined. Does this signify that sublobar resection can be applied broadly, or that we need to be careful to understand for which tumors the results apply? In actual application it will be difficult to achieve the degree of N1,2 node dissection and intraoperative confirmation of N0 status that characterizes the CALGB study – will the results generalize to a real-world setting? All RCTs (LCSG, JCOG, CALGB) have suggested at least a trend towards more locoregional recurrence with limited resection – why isn't this reflected in OS/RFS (salvage resection was possible in only a minority)?

1.2.4 Decision-Making for Elective Sublobar Resection

In summary, there is substantial evidence supporting segmentectomy for predominantly GG lung cancers (provided intervention is deemed necessary in the first place). This includes data from a RCT. There are some lingering questions about the adequacy of wedge resection for GG lung cancers.

There is little advantage, however, in terms of perioperative morbidity and mortality with sublobar resection. There may be a marginally clinically relevant benefit in terms of preservation of PFTs with a single segmentectomy. It seems unlikely (although not well-studied) that QOL is affected by the resection extent; in contrast, there are substantial QOL benefits for a VATS approach over thoracotomy.

Thus, in patients with GG tumors, segmentectomy appears to be a rational alternative. It is important that a complete resection can be accomplished and that a segmentectomy does not require changing from a VATS approach to a thoracotomy. A suspicion that long-term outcomes might be impaired (e.g., inadequate margin) or increase short- or intermediate-term downsides (e.g., prolonged air leak, a need to convert to thoracotomy) would generally suggest abandoning segmentectomy in favor of lobectomy. A wedge resection of GG tumors is less solidly supported; however, it may be reasonable in certain circumstances—e.g. preservation of lung tissue in a setting of multifocal GG adenocarcinoma.

For more solid tumors ≤2cm, emerging data suggests it may be reasonable to consider sublobar resection in specific circumstances. The tumors should be peripheral and allow an adequate margin; extensive intraoperative node dissection and confirmation of N0 status is required. Concerns that these criteria may be compromised sways the decision towards lobectomy. This is particularly true considering that there is minimal short-term benefit to a sublobar resection, and a 25% 5-year recurrence and lung cancer death rate in such tumors.

1.3 Compromise Sublobar Resection

A sublobar resection undertaken as a compromise inherently involves a trade-off—accepting a degree of lower long-term survival for a short-term benefit. It is hard to define criteria for what is a judgement call involving several relative factors and a continuum. Nevertheless, a framework is needed to guide decisions.

1.3.1 Older Patients

1.3.1.1 Short- and Intermediate-Term Outcomes

Perioperative morbidity and mortality increase with age. However, sublobar resection provides limited, if any, benefit over lobectomy in older patients. As noted in the previous section, the RCTs involving patients in general have found no difference in morbidity and mortality between sublobar resection and lobectomy. Subset results of the CALGB RCT for patients ≥70 show no benefit of SL resection [2]. In an adjusted NRC, Strokes et al. found small increases in 90-day mortality with increasing age but little difference between sublobar resection and lobectomy (a difference of 0.2%, 1%, 0.7%, and 2.2% for age cohorts 66–70, 71–75, 76–80, and ≥ 81—marginally clinically meaningful except for age > 80) [7].

Regarding morbidity, most complications in older patients are minor (e.g., atrial fibrillation, hypotension, urinary tract infection, and wound infection). The severe morbidity rate is ~10–15%—with little difference between sublobar resection and lobectomy except in a few specific complications [2].

Therefore, available evidence suggests that there is little perioperative benefit to sublobar resection over lobectomy in older patients. However, there is much data that suggest there is a benefit to a VATS approach vs thoracotomy, which is increased in older patients [20, 31, 32]. The ability to perform a resection by VATS should weigh more strongly in decision-making than the resection extent.

Pain and QOL appear to be similar for sublobar resection vs lobectomy in patients in general [5]; there is no data specifically in older patients. Again, there is evidence of a clinically meaningful benefit for a VATS approach over a thoracotomy in older patients [20]—making the approach more important to weigh than the resection extent.

1.3.1.2 Long-Term Outcomes

No RCT data is available regarding the impact of resection extent in older patients. Adjusted NRCs consistently note clinically relevant better OS and LCSS (5–10%) after lobectomy [10, 20, 33]. These NRCs do not suggest that the benefit of lobectomy over sublobar resection is associated with the type of limited resection, specific age cohorts, or lower stage tumors. In one NRC worse survival after sublobar resection (primarily wedge) in the overall matched group disappeared in a subgroup of patients who had ≥9 nodes sampled (5% of their original sample) [34]. However, other studies that adjusted for the extent of node sampling report worse survival after sublobar resection vs lobectomy. In summary, the preponderance of data shows a clinically relevant long-term survival detriment for segmentectomy vs lobectomy in older patients, which is not clearly mitigated by age cohorts, tumor stage, type of sublobar resection, or extent of node evaluation.

1.3.2 Patients with Limited Pulmonary Reserve

1.3.2.1 Short- and Intermediate-Term Outcomes

With decreasing pulmonary reserve short-term post-operative morbidity and mortality increases, but reported results (in patients selected for resection) are acceptable. Furthermore, the impact of diminishing pulmonary reserve is markedly ameliorated by VATS [35–39]. In patients with severe pulmonary compromise (below criteria cited as contraindications to surgical resection), 30-day mortality is 2–3% for VATS lobectomy and 3–8% for open lobectomy [20]. Pulmonary complication rates after lobectomy in compromised patients are ~10–20% after VATS vs ~20–40% after thoracotomy [20]. Limited data suggests little difference in short-term outcomes between segmentectomy vs lobectomy [20].

The impact of resection (including lobectomy) on FEV1 is diminished in patients with severely limited pulmonary reserve, and FEV1 is unchanged or even improved in a substantial proportion of patients [20]. Given this variability and the limited data, it is unclear if sublobar resection confers a functional benefit over lobectomy. Limited data suggests little average impact of resection on long-term QOL in patients with limited pulmonary reserve—some patients are better, some worse, and many unchanged [20]. A QOL benefit for lesser resection vs lobectomy has not been demonstrated, but data is limited [20].

1.3.2.2 Long-Term Outcomes

Long-term survival and recurrence by resection extent in patients with limited reserve has not been addressed in a manner that accounts for confounders [20]. Unadjusted data shows no clear difference between segmentectomy/wedge vs lobectomy [20].

Careful selection is crucial in compromised patients, but not well-defined. Good short- and long-term outcomes can be achieved despite limited PFTs, but these patients are likely otherwise robust [20].

1.3.3 Decision-Making for Compromise Sublobar Resection

An obvious concern in patients who appear less robust is avoidance of acute perioperative morbidity and mortality. However, reported results in both older patients and those with limited pulmonary reserve demonstrate acceptable morbidity and mortality rates, and that there is little to be gained from sublobar resection. There is a strong benefit with a VATS approach over a thoracotomy. Because these patients are clearly selected, the interpretation should be that one can be confident in proceeding with resection if clinical judgment suggests they are reasonable surgical candidates despite increasing age or severely limited pulmonary function. The argument for a sublobar resection is quite weak—a concern about perioperative complications points to consideration of non-surgical therapy more than sublobar resection. Similarly, the data is weak that sublobar resection results in better intermediate-term QOL and pulmonary function.

Long-term outcomes favor lobectomy over sublobar resection in older age patients. This is less clear in patients with limited pulmonary reserve—data is limited, confounded but does not appear suggestive of a difference. This may reflect that greater competing causes of death logically diminish the impact of any potential difference between lobectomy and sublobar resection. Older patients generally have reasonable life expectancy from that point on, whereas severe comorbidities may be more likely to be potentially life-limiting.

1.4 Technical Issues

1.4.1 Anatomic Location

Wedge resection is generally feasible for tumors in the outer third of the lung. Achieving an adequate margin is difficult even for segmentectomy when tumors are central or near an intersegmental boundary. However, no study has assessed the long-term outcomes of NSCLC related to its anatomic location. The chance of ending up with an inadequate margin or needing to convert to a lobectomy must be considered when planning the resection extent for an individual patient.

A CT-based simulation model estimated that ~25–33% of 1–2 cm tumors would be amenable to segmentectomy (defined as resulting in a ≥ 2 cm margin from an intersegmental plane; this increased to ~50% if bi-segmentectomy is included) [40].

1.4.2 Resection Margin

Evidence suggests that the resection margin distance is important in sublobar resection despite some variability in the data (likely due to additional confounding factors). Studies suggest an inflection point around 1 cm, with about 25% local recurrence with <1 cm margins vs ~ 10% with greater margin distance [5, 41–46]. Other studies similarly suggest ~20% locoregional recurrence rate for a margin/tumor (M/T) ratio of <1 vs ~10 for MT ≥ 1 [5, 47–53]. Margin distance appears to have little impact in primarily GG tumors [43, 46].

1.4.3 Spread Through Air Spaces (STAS)

The term "spread through air spaces" (STAS) refers to a microscopic observation of tumor cells adjacent to a lung cancer (median distance 1–1.5 mm) [54–57]. STAS is associated with multiple negative prognostic factors; whether STAS is an independent negative prognostic factor has not been clarified [57, 58]. In many studies STAS portends worse RFS and higher recurrence rates [46, 54–56, 59–65]. This is true after both sublobar resection and lobectomy, but is less well-studied for lobectomy and in some studies statistical significance is not maintained in lobectomy patients after adjustment for some confounders [5].

A study [53] with extensive adjustment for confounders found that in STAS-negative patients there was no significant difference in the cumulative incidence of recurrence (CIR) between lobectomy and sublobar resection, whereas in STAS-positive patients, sublobar resection is significantly associated with a higher risk of recurrence than lobectomy (5-year CIR, 39% versus 16%; $p < 0.001$). However, it is unclear whether conversion to lobectomy when STAS is noted can mitigate the negative impact of STAS—available indirect data shows conflicting results [53, 65–67].

1.5 Conclusion

A substantial amount of evidence demonstrates equivalent long-term survival after segmentectomy vs lobectomy in patients with cIA GG lung cancers. While there is no difference in short-term morbidity and mortality, there is a marginally clinically relevant benefit in pulmonary function tests when a single segment is resected.

The role of sublobar resection for cI tumors ≤2cm is emerging. Careful intraoperative confirmation of N0 status through N1 and N2 node dissection is required. Exactly which tumors this applies to is still somewhat unclear, but recent RCT data suggests that sublobar resection is a reasobable alternative to lobectomy. However, conversely, there also appears to be little short- or intermediate-term benefit to a lesser resection.

A compromise sublobar resection inherently involves a trade-off, a judgement call, and careful selection. Reported data suggests that the short-term benefit of segmentectomy is minimal and generally over-rated. Evidence does not support segmentectomy for older patients—there is minimal short-term benefit but a long-term decreased survival when compared to lobectomy. This may be less clear at extremes of age (>80–90 years old).

In patients with severe comorbidities that are potentially life-limiting there is less to be gained by lobectomy. Evidence does not clearly indicate lower perioperative complications for segmentectomy vs lobectomy; however, there is also little evidence suggesting a downside in long-term outcomes. Concern about perioperative risks points to consideration of non-surgical therapy more strongly than sublobar resection.

Other factors need to be considered. For solid tumors evidence suggests that a margin of <1 cm or a M/T ratio of <1 is associated with a substantially higher risk of recurrence. Whether the presence of STAS should affect the choice of segmentectomy vs lobectomy is unclear. Especially in patients who are older or have limited pulmonary reserve, a VATS approach has significant benefits over thoracotomy. Finally, there may be little difference between a lobectomy and a multisegmentectomy (e.g., LUL upper division); indirect data suggests there is neither benefit or downside vs lobectomy for short-, intermediate-, or long-term results.

As the nature of lung cancers currently diagnosed increasingly involves smaller GG tumors, there is no question that the role of segmentectomy is increasing. We need to embrace this fact, and technical proficiency in this intervention is important. However, we need to apply this appropriately as the evidence indicates. Clinical judgment is crucial, but must take into account available evidence as well as the impression of the individual patient and tumor at hand.

Take-Home Messages

1. Available evidence demonstrates similar good long-term outcomes for predominantly GG lung cancers after complete resection by segmentectomy as after lobectomy.
2. Perioperative morbidity and mortality is the same after segmentectomy and lobectomy in healthy patients.
3. Sublobar resection is a reasonable alternative for solid tumors ≤2cm in healthy patients provided extensive node dissection confirms N0 status.
4. In older patients evidence mostly demonstrates a minimal difference in short-term morbidity/mortality but a decrease in long-term outcomes after segmentectomy vs lobectomy.
5. There is no clear difference in short- and long-term outcomes between sublobar resection vs lobectomy in carefully selected patients with severe comorbidities. Generally applicable selection criteria are lacking; careful attention to anticipated perioperative course is important, but a straightforward procedure (wedge or lobectomy) may be of more benefit than a more complicated segmentectomy. A VATS (vs open) approach is particularly impactful.
6. Evidence suggests that a margin of <1 cm or a M/T ratio of <1 is associated with a substantially higher risk of recurrence in solid tumors.
7. The available data is inconclusive whether a negative prognostic impact of STAS can be ameliorated by a more extensive resection (i.e., lobectomy).

References

1. Ginsberg RJ, Rubinstein LV. Randomized trial of lobectomy versus limited resection for T1 N0 non-small cell lung cancer. Lung cancer study group. Ann Thorac Surg. 1995;60(3):615–22. discussion 22–3
2. Altorki NK, Wang X, Wigle D, Gu L, Darling G, Ashrafi AS, et al. Perioperative mortality and morbidity after sublobar versus lobar resection for early-stage non-small-cell lung cancer: post-hoc analysis of an international, randomised, phase 3 trial (CALGB/Alliance 140503). Lancet Respir Med. 2018;6(12):915–24.
3. Suzuki K, Saji H, Aokage K, Watanabe SI, Okada M, Mizusawa J, et al. Comparison of pulmonary segmentectomy and lobectomy: safety results of a randomized trial. J Thorac Cardiovasc Surg. 2019;158(3):895–907.
4. Stamatis G, Leschber G, Schwarz B, Brintrup DL, Ose C, Weinreich G, et al. Perioperative course and quality of life in a prospective randomized multicenter phase III trial, comparing standard lobectomy versus anatomical segmentectomy in patients with non-small cell lung cancer up to 2 cm, stage IA (7th edition of TNM staging system). Lung Cancer. 2019;138:19–26.
5. Detterbeck FC, Mase VJ, Jr., Li AX, Kumbasar U, Bade BC, Park HS, et al. A guide for managing patients with stage I NSCLC: deciding between lobectomy, segmentectomy, wedge, SBRT and ablation. Part 2: evidence regarding resection extent in generally healthy patients. J Thorac Dis. 2022;14(6):2357–86.
6. Linden PA, D'Amico TA, Perry Y, Saha-Chaudhuri P, Sheng S, Kim S, et al. Quantifying the safety benefits of wedge resection: a society of thoracic surgery database propensity-matched analysis. Ann Thorac Surg. 2014;98(5):1705–11. discussion 11–2
7. Stokes WA, Bronsert MR, Meguid RA, Blum MG, Jones BL, Koshy M, et al. Post-treatment mortality after surgery and stereotactic body radiotherapy for early-stage non-small-cell lung cancer. J Clin Oncol. 2018;36(7):642–51.
8. Zhang Z, Feng H, Zhao H, Hu J, Liu L, Liu Y, et al. Sublobar resection is associated with better perioperative outcomes in elderly patients with clinical stage I non-small cell lung cancer: a multicenter retrospective cohort study. J Thorac Dis. 2019;11(5):1838–48.
9. Khullar OV, Liu Y, Gillespie T, Higgins KA, Ramalingam S, Lipscomb J, et al. Survival after sublobar resection versus lobectomy for clinical stage IA lung cancer: an analysis from the National Cancer Data Base. J Thorac Oncol. 2015;10(11):1625–33.
10. Shirvani SM, Jiang J, Chang JY, Welsh J, Likhacheva A, Buchholz TA, et al. Lobectomy, sublobar resection, and stereotactic ablative radiotherapy for early-stage non-small cell lung cancers in the elderly. JAMA Surg. 2014;149(12):1244–53.
11. Bédat B, Abdelnour-Berchtold E, Perneger T, Licker MJ, Stefani A, Krull M, et al. Comparison of postoperative complications between segmentectomy and lobectomy by video-assisted thoracic surgery: a multicenter study. J Cardiothorac Surg. 2019;14(1):189.
12. Schwartz RM, Yip R, Flores RM, Olkin I, Taioli E, Henschke C. The impact of resection method and patient factors on quality of life among stage IA non-small cell lung cancer surgical patients. J Surg Oncol. 2017;115(2):173–80.
13. Schwartz RM, Yip R, Olkin I, Sikavi D, Taioli E, Henschke C. Impact of surgery for stage IA non-small-cell lung cancer on patient quality of life. J Community Support Oncol. 2016;14(1):37–44.
14. Mase VJ Jr, Detterbeck FC. Approach to the subsolid nodule. Clin Chest Med. 2020;41(1):99–113.
15. Kobayashi Y, Fukui T, Ito S, Usami N, Hatooka S, Yatabe Y, et al. How long should small lung lesions of ground-glass opacity be followed? J Thorac Oncol. 2013;8(3):309–14.
16. Yatabe Y, Borczuk AC, Powell CA. Do all lung adenocarcinomas follow a stepwise progression? Lung Cancer. 2011;74(1):7–11.
17. Sawada S, Yamashita N, Sugimoto R, Ueno T, Yamashita M. Long-term outcomes of patients with ground-glass opacities detected using computed tomography. Chest. 2017;151(2):308–15.
18. Kakinuma R, Noguchi M, Ashizawa K, Kuriyama K, Maeshima AM, Koizumi N, et al. Natural history of pulmonary subsolid nodules: a prospective multicenter study. J Thorac Oncol. 2016;11(7):1012–28.
19. Saji H, Okada M, Tsuboi M, Nakajima R, Suzuki K, Aokage K, et al. Segmentectomy versus lobectomy in small-sized peripheral non-small-cell lung cancer (JCOG0802/WJOG4607L): a multicentre, open-label, phase 3, randomised, controlled, non-inferiority trial. Lancet 2022;399:1607–17.
20. Bade BC, Blasberg JD, Mase VJ Jr, Kumbasar U, Li AX, Park HS, et al. A guide for managing patients with stage I NSCLC: deciding between lobectomy, segmentectomy, wedge, SBRT and ablation. Part 3: evidence regarding surgery in compromised patients or specific tumors. J Thorac Dis. 2022;14(6):2387–411.
21. Altorki NK, Yip R, Hanaoka T, Bauer T, Aye R, Kohman L, et al. Sublobar resection is equivalent to lobectomy for clinical stage 1A lung cancer in solid nodules. J Thorac Cardiovasc Surg. 2014;147(2):754–62. Discussion 62–4.
22. Tsutani Y, Miyata Y, Nakayama H, Okumura S, Adachi S, Yoshimura M, et al. Oncologic outcomes of segmentectomy compared with lobectomy for clinical stage IA lung adenocarcinoma: propensity score-matched analysis in a multicenter study. J Thorac Cardiovasc Surg. 2013;146(2):358–64.
23. Zhang C, He Z, Cheng J, Cao J, Hu J. Surgical outcomes of lobectomy versus limited resection for clinical stage I ground-glass opacity lung adenocarcinoma 2 centimeters or smaller. Clin Lung Cancer. 2020;22(2):e160–8. https://doi.org/10.1016/j.cllc.2020.09.022.
24. Kodama K, Higashiyama M, Okami J, Tokunaga T, Imamura F, Nakayama T, et al. Oncologic outcomes of segmentectomy versus lobectomy for clinical T1a N0 M0 non-small cell lung cancer. Ann Thorac Surg. 2016;101(2):504–11.
25. Chiang XH, Hsu HH, Hsieh MS, Chang CH, Tsai TM, Liao HC, et al. Propensity-matched analysis comparing survival after sublobar resection and lobectomy for cT1N0 lung adenocarcinoma. Ann Surg Oncol. 2020;27(3):703–15.
26. Okada M, Mimae T, Tsutani Y, Nakayama H, Okumura S, Yoshimura M, et al. Segmentectomy versus lobectomy for clinical stage IA lung adenocarcinoma. Ann Cardiothorac Surg. 2014;3(2):153–9.
27. Hwang Y, Kang CH, Kim HS, Jeon JH, Park IK, Kim YT. Comparison of thoracoscopic segmentectomy and thoracoscopic lobectomy on the patients with non-small cell lung cancer: a propensity score matching study. Eur J Cardiothorac Surg. 2015;48(2):273–8.
28. Suzuki K, Watanabe S, Wakabayashi M, Yasumitsu M, Yoshino I, Tsuboi M, et al., editors. A nonrandomized confirmatory phase III study of sublobar surgical resection for peripheral ground glass opacity dominant lung cancer defined with thoracic thin-section computed tomography. Chicago, IL: ASCO; 2017.
29. Nakao M, Yoshida J, Goto K, Ishii G, Kawase A, Aokage K, et al. Long-term outcomes of 50 cases of limited-resection trial for pulmonary ground-glass opacity nodules. J Thorac Oncol. 2012;7(10):1563–6.
30. Altorki NK, Wang X, Kozono D, Watt C, Landreneau R, Wigle D, et al. Lobar or sub-lobar resection for peripheral clinical stage IA = 2 cm non-small cell lung cancer (NSCLC): Results from an international randomized phase iii trial (CALGB 140503 [Alliance]). Plenary Session, World Conference on Lung Cancer, Vienna Austria. 2022
31. Ezer N, Kale M, Sigel K, Lakha S, Mhango G, Goodman E, et al. Outcomes after video-assisted thoracoscopic lobectomy versus open lobectomy for early-stage lung cancer in older adults. Ann Am Thorac Soc. 2018;15(1):76–82.

32. Smith CB, Kale M, Mhango G, Neugut AI, Hershman DL, Mandeli JP, et al. Comparative outcomes of elderly stage I lung cancer patients treated with segmentectomy via video-assisted thoracoscopic surgery versus open resection. J Thorac Oncol. 2014;9(3):383–9.
33. Zhang Y, Yuan C, Zhang Y, Sun Y, Chen H. Survival following segmentectomy or lobectomy in elderly patients with early-stage lung cancer. Oncotarget. 2016;7(14):19081–6.
34. Stiles BM, Mao J, Harrison S, Lee B, Port JL, Sedrakyan A, et al. Extent of lymphadenectomy is associated with oncological efficacy of sublobar resection for lung cancer ≤2 cm. J Thorac Cardiovasc Surg. 2019;157(6):2454–65 e1.
35. Burt BM, Kosinski AS, Shrager JB, Onaitis MW, Weigel T. Thoracoscopic lobectomy is associated with acceptable morbidity and mortality in patients with predicted postoperative forced expiratory volume in 1 second or diffusing capacity for carbon monoxide less than 40% of normal. J Thorac Cardiovasc Surg. 2014;148(1):19–28. discussion −9e1
36. Zhang R, Ferguson M. Video-assisted versus open lobectomy in patients with compromised lung function: a literature review and meta-analysis. PLoS One. 2015;10(7):e0124512.
37. Sandri A, Papagiannopoulos K, Milton R, Chaudhuri N, Kefaloyannis E, Pompili C, et al. High-risk patients and postoperative complications following video-assisted thoracic surgery lobectomy: a case-matched comparison with lower-risk counterparts dagger. Interact Cardiovasc Thorac Surg. 2015;21(6):761–5.
38. Ceppa D, Kosinski A, Berry M, Tong B, Harpole D, Mitchell J. Thoracoscopic lobectomy has increasing benefit in patients with poor pulmonary function: a Society of Thoracic Surgeons database analysis. Ann Surg. 2012;256:487–93.
39. Berry MF, Villamizar-Ortiz NR, Tong BC, Burfeind WR Jr, Harpole DH, D'Amico TA, et al. Pulmonary function tests do not predict pulmonary complications after thoracoscopic lobectomy. Ann Thorac Surg. 2010;89(4):1044–51. discussion 51–2
40. Ueda K, Tanaka T, Hayashi M, Tanaka N, Li TS, Hamano K. What proportion of lung cancers can be operated by segmentectomy? A computed-tomography-based simulation. Eur J Cardiothorac Surg. 2012;41(2):341–5.
41. Mohiuddin K, Haneuse S, Sofer T, Gill R, Jaklitsch MT, Colson YL, et al. Relationship between margin distance and local recurrence among patients undergoing wedge resection for small (≤2 cm) non-small cell lung cancer. J Thorac Cardiovasc Surg. 2014;147(4):1169–75. discussion 75–7.
42. Maurizi G, D'Andrilli A, Ciccone AM, Ibrahim M, Andreetti C, Tierno S, et al. Margin distance does not influence recurrence and survival after wedge resection for lung cancer. Ann Thorac Surg. 2015;100(3):918–24. discussion 24–5
43. Moon Y, Lee KY, Moon SW, Park JK. Sublobar resection margin width does not affect recurrence of clinical N0 non-small cell lung cancer presenting as GGO-predominant nodule of 3 cm or less. World J Surg. 2017;41(2):472–9.
44. El-Sherif A, Fernando H, Santos R, Pettiford B, Luketich J, Close J, et al. Margin and local recurrence after sublobar resection of non-small cell lung cancer. Ann Surg Oncol. 2007;14(8):2400–5.
45. Wolf AS, Swanson SJ, Yip R, Liu B, Tarras ES, Yankelevitz DF, et al. The impact of margins on outcomes after wedge resection for stage I non-small cell lung cancer. Ann Thorac Surg. 2017;104(4):1171–8.
46. Masai K, Sakurai H, Sukeda A, Suzuki S, Asakura K, Nakagawa K, et al. Prognostic impact of margin distance and tumor spread through air spaces in limited resection for primary lung cancer. J Thorac Oncol. 2017;12(12):1788–97.
47. Sawabata N, Maeda H, Matsumura A, Ohta M, Okumura M. Clinical implications of the margin cytology findings and margin/tumor size ratio in patients who underwent pulmonary excision for peripheral non-small cell lung cancer. Surg Today. 2012;42(3):238–44.
48. Takahashi N, Sawabata N, Kawamura M, Ohtsuka T, Horio H, Sakaguchi H, et al. Optimal sublobar resection for c-stage I non-small cell lung cancer: significance of margin distance to tumor size ratio and margin cytology (supplementary analysis of KLSG-0801): complete republication. Gen Thorac Cardiovasc Surg. 2019;67(8):690–6.
49. Fernando H, Landreneau R, Mandrekar S, Nichols F III, Hillman S, Heron D, et al. Impact of brachytherapy on local recurrence rates after sublobar resection: results from ACOSOG Z4032 (Alliance), a phase III randomized trial for high-risk operable non-small cell lung cancer (NSCLC). J Clin Oncol. 2014;32(23):2456–62.
50. Moon Y, Lee KY, Park JK. Margin width of resected lepidic lung cancer does not affect recurrence after sublobar resection. World J Surg. 2018;42(5):1449–57.
51. Moon Y, Park JK, Lee KY. The effect of resection margin distance and invasive component size on recurrence after sublobar resection in patients with small (≤2 cm) lung adenocarcinoma. World J Surg. 2020;44(3):990–7.
52. Schuchert MJ, Pettiford BL, Keeley S, D'Amato TA, Kilic A, Close J, et al. Anatomic segmentectomy in the treatment of stage I non-small cell lung cancer. Ann Thorac Surg. 2007;84(3):926–33.
53. Eguchi T, Kameda K, Lu S, Bott MJ, Tan KS, Montecalvo J, et al. Lobectomy is associated with better outcomes than sublobar resection in Spread Through Air Spaces (STAS)-positive T1 lung adenocarcinoma: a propensity score-matched analysis. J Thorac Oncol. 2019;14(1):87–98.
54. Ren Y, Xie H, Dai C, She Y, Su H, Xie D, et al. Prognostic impact of tumor spread through air spaces in sublobar resection for 1A lung adenocarcinoma patients. Ann Surg Oncol. 2019;26(6):1901–8.
55. Kadota K, Nitadori J-i, Sima CS, Ujiie H, Rizk NP, Jones DR, et al. Tumor spread through air spaces is an important pattern of invasion and impacts the frequency and location of recurrences after limited resection for small stage I lung adenocarcinomas. J Thor Oncol. 2015;10(5):806–14.
56. Yanagawa N, Shiono S, Endo M, Ogata SY. Tumor spread through air spaces is a useful predictor of recurrence and prognosis in stage I lung squamous cell carcinoma, but not in stage II and III. Lung Cancer. 2018;120:14–21.
57. Jia M, Yu S, Gao H, Sun PL. Spread Through Air Spaces (STAS) in lung cancer: a multiple-perspective and update review. Cancer Manag Res. 2020;12:2743–52.
58. Chen D, Mao Y, Wen J, She Y, Zhu E, Zhu F, et al. Tumor spread through air spaces in non-small cell lung cancer: a systematic review and meta-analysis. Ann Thorac Surg. 2019;108(3):945–54.
59. Kadota K, Kushida Y, Katsuki N, Ishikawa R, Ibuki E, Motoyama M, et al. Tumor spread through air spaces is an independent predictor of recurrence-free survival in patients with resected lung squamous cell carcinoma. Am J Surg Pathol. 2017;41(8):1077–86.
60. Shiono S, Endo M, Suzuki K, Yarimizu K, Hayasaka K, Yanagawa N. Spread through air spaces is a prognostic factor in sublobar resection of non-small cell lung cancer. Ann Thorac Surg. 2018;106(2):354–60.
61. Uruga H, Fujii T, Fujimori S, Kohno T, Kishi K. Semiquantitative assessment of tumor Spread Through Air Spaces (STAS) in early-stage lung adenocarcinomas. J Thorac Oncol. 2017;12(7):1046–51.
62. Toyokawa G, Yamada Y, Tagawa T, Kozuma Y, Matsubara T, Haratake N, et al. Significance of spread through air spaces in resected pathological stage I lung adenocarcinoma. Ann Thorac Surg. 2018;105(6):1655–63.
63. Toyokawa G, Yamada Y, Tagawa T, Oda Y. Significance of spread through air spaces in early-stage lung adenocarcinomas undergoing limited resection. Thorac Cancer. 2018;9(10):1255–61.
64. Shiono S, Endo M, Suzuki K, Yanagawa N. Spread through air spaces affects survival and recurrence of patients with clinical stage IA non-small cell lung cancer after wedge resection. J Thorac Dis. 2020;12(5):2247–60.

65. Kadota K, Kushida Y, Kagawa S, Ishikawa R, Ibuki E, Inoue K, et al. Limited resection is associated with a higher risk of locoregional recurrence than lobectomy in stage I lung adenocarcinoma with tumor spread through air spaces. Am J Surg Pathol. 2019;43(8):1033–41.
66. Han YB, Kim H, Mino-Kenudson M, Cho S, Kwon HJ, Lee KR, et al. Tumor Spread Through Air Spaces (STAS): prognostic significance of grading in non-small cell lung cancer. Mod Pathol. 2021;34(3):549–61.
67. Kagimoto A, Tsutani Y, Kushitani K, Kai Y, Kambara T, Miyata Y, et al. Segmentectomy vs. lobectomy for clinical stage IA lung adenocarcinoma with spread through air spaces. Ann Thorac Surg. 2021;112:935–43.

2 Anatomical and Radiological Correlation

Juan Arenas-Jiménez

2.1 Introduction

A requisite to perform an adequate and safe sublobar resection is the knowledge of lung anatomy. In contrast with anatomic lobar resection, sublobar resections represent a challenge to the surgeons that is twofold: firstly, lesions resected are frequently small, so that they cannot be properly touched during surgery and both the lesion's approach and resection margins must be preoperatively designed on the basis of optimal anatomic knowledge; and secondly, anatomic variations at the sublobar level are frequent and what is most important, anatomic boundaries between segments frequently are not defined, and the surgeon has to identify, define, and create them during the procedure [1, 2].

In other chapters of this video-atlas, you can find several approaches and discussions about how to define and create the intersegmental planes at surgery. In this chapter, we will review the bronchovascular anatomy of the lungs and the most frequent variations at the segmental level. As an example of the great variation we can find, a report analyzing anatomical variations of the left pulmonary artery described up to 85 types in 320 patients, only for the interlobar portion of the artery [3]. So, although some anatomic patterns and variations repeat, we must have in consideration that patient's anatomic configuration can be unique, and preoperative evaluation must include an anatomic analysis of the lung involved for a better surgical planning and to avoid complications in the operative field.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/978-3-031-14455-4_2. The videos can be accessed by scanning the related images with the SN More Media App.

J. Arenas-Jiménez (✉)
Department of Radiology, Hospital General Universitario de Alicante, Alicante, Spain
e-mail: j.arenasjimenez@gmail.com

2.2 Preoperative Radiological Techniques

The technique used to precisely define lung anatomy is computed tomography (CT). State-of-the-art technology permits to perform a CT scan of the whole chest in just a few seconds, thus permitting to avoid respiratory artifacts that occasionally may limit evaluation. Since the main component of the lungs is air that behaves as dark at most CT window ranges, it acts as a "natural" contrast that allows visualization of denser structures such as blood vessels, walls of the bronchi, and pathological conditions, even without the need of intravenous contrast [4]. Although anatomical identification of vessels is feasible without intravenous contrast, the use of iodinated contrast, that is injected via a peripheral vein, provides a much better distinction of the vessels, mainly at the hilar regions where they contact each other and precise delimitation is more limited.

To get an optimal technique at CT, there are some points of interest:

1. As commented before, an adequate collaboration of the patient by maintaining an adequate full inspiration during scan, without respiratory artifacts, is desirable.
2. We must use a reduced scan thickness, although there is no defined limit, in our experience 1–2 mm should be regarded as adequate, and for final images, some overlap between reconstructed slices should allow to get an adequate multiplanar imaging.
3. Iodine contrast injection and delay time of scanning influence how the vessels are seen. The higher the injection rate, the higher the density in the vessels, thus allowing the 3D reconstruction techniques a better automatic detection and delineation of the vascular structures. One limitation of this approach is the right upper lobe vessels, which at their medial course can be obscured by the streak artifacts from the denser contrast medium entering the superior vena cava. An alternative is the use of delayed scanning, that avoids these artifacts while still maintain-

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Fig. 2.1 Automatic 3D reconstruction showing color-coded bronchi, arteries, and veins

ing an adequate visual opacification of the vascular anatomy of the lungs [5]. The suitability of these delayed images for an adequate 3D reconstruction using a given software depends on the software capabilities, and it is still not defined.

The development of informatics, and consequently of medical imaging analysis, has led to the design of varied tools that permit to get color-coded 3D reconstructions of the different components of the segments (lung, bronchi, arteries, and veins) and to give the surgeon a detailed information about the anatomy before surgery (Figs. 2.1 and 2.2). There is a wide range of software tools that include those designed by the main manufacturers of the CT scanners that usually run in a portal workspace, home-designed software [6], and 3D reconstruction software such as the free open-source OsiriX software [7, 8] that is certified as medical device by American and European directives, FDA approved and CE labeled, respectively. Discussion of pros and cons of each tool is beyond the scope of this book. All of them work with DICOM files (for "Digital Imaging and Communications in Medicine") that are the standard for the

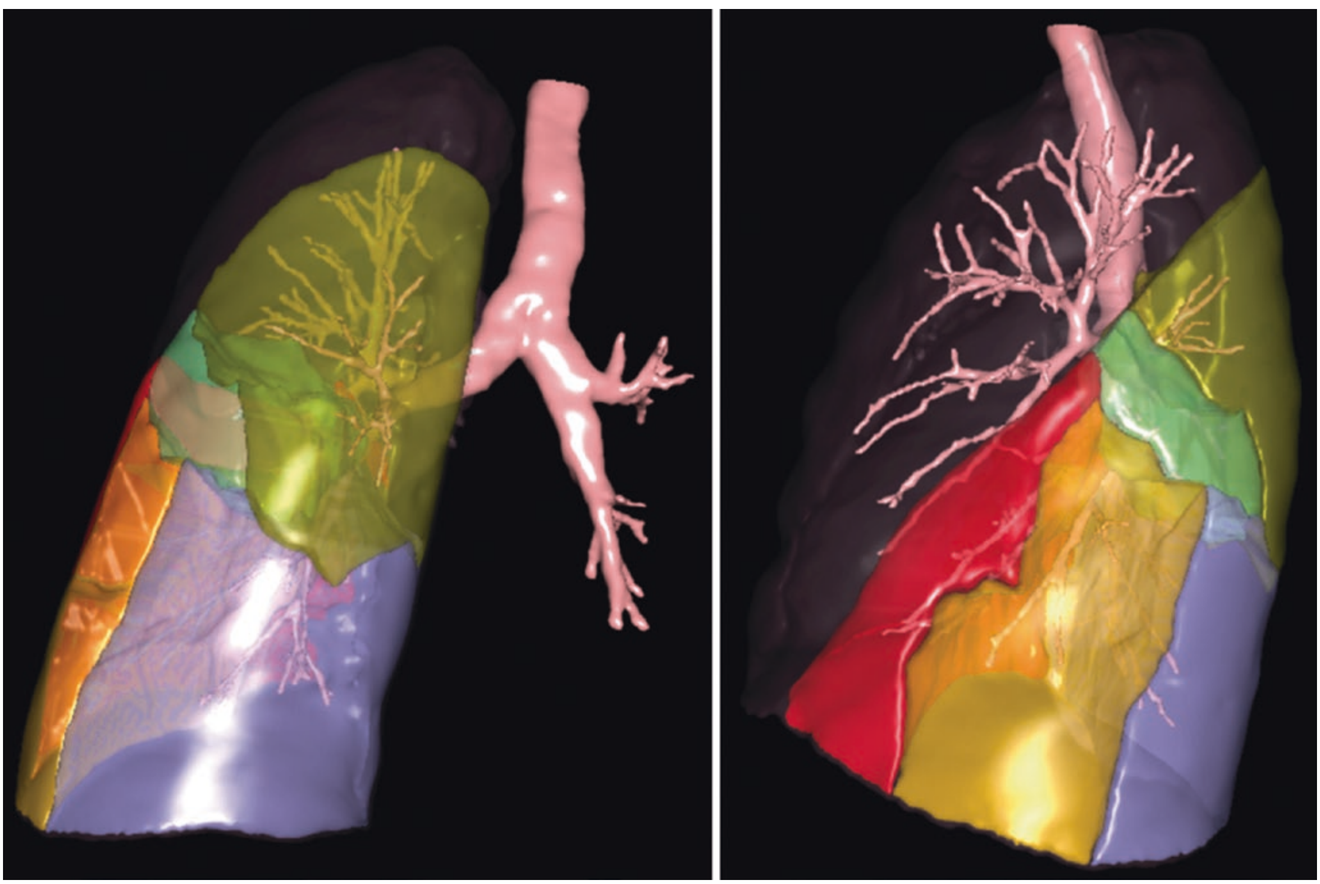

Fig. 2.2 Left lung segmental anatomy created by software from a CT scan. A subsuperior segment is seen below the segment 6 in the left lower lobe

communication and management of medical imaging information. Surely, in the near future widely available, more user-friendly software should be developed with one-click or even automatic segmentation of desired structures and the whole lung and, perhaps, there should be a generalization of navigation systems [9] as occurs in other parts of the body [10], with imaging playing a central role to aid the surgeon to perform effective and safe procedures [11].

2.3 Understanding Segmental Anatomy at CT

Even with the use of 3D reconstructions, interpretation and recognition of segmental anatomy relies on the identification on native thin-sliced CT scans of the major anatomic landmarks of each segment. A study comparing 3D reconstructions with thin section multiplanar reconstruction (MPR) found that MPR contributes more to the evaluation of smaller branches of the right upper lobe [12]. In our experience, use of 5–10 mm maximum intensity projection images with MPR allows the identification of vascular structures either in axial or other customized orientation according to the vessels being evaluated.

Although each one has a different morphology, we must think of the pulmonary segment as a roughly pyramidal shaped part of the lung, with the bronchial and arterial structures at their apex.

For their delimitation, the first step is to identify the different bronchial structures during upward and downward navigation through the axial sections. By doing this, we can easily identify bronchial division anomalies.

Arteries have a more complex branching pattern than bronchi, and frequently we can find more than one artery for a single segment. They can be identified by following them from their origin in the corresponding major artery and for their location, usually next to its bronchus and, frequently, peripheral to it [13].

Regarding the veins, although anatomically more complex, they are the key for identification of the segment's boundaries, so the venous anatomy of the segment we are willing to resect and of the adjacent segments being preserved must be identified [2, 14–16]. There are intrasegmental and intersegmental veins, the latter being important landmarks to perform segmental dissection [2], and sometimes they serve as dissecting planes to reach the hilum that ease the segmentectomy [17]. As for arteries, they can be identified at consecutive axial CT images by following them in an outward direction from the major pulmonary veins. In Fig. 2.3, Video 1 you can find a whole CT scan with demarcated segments.

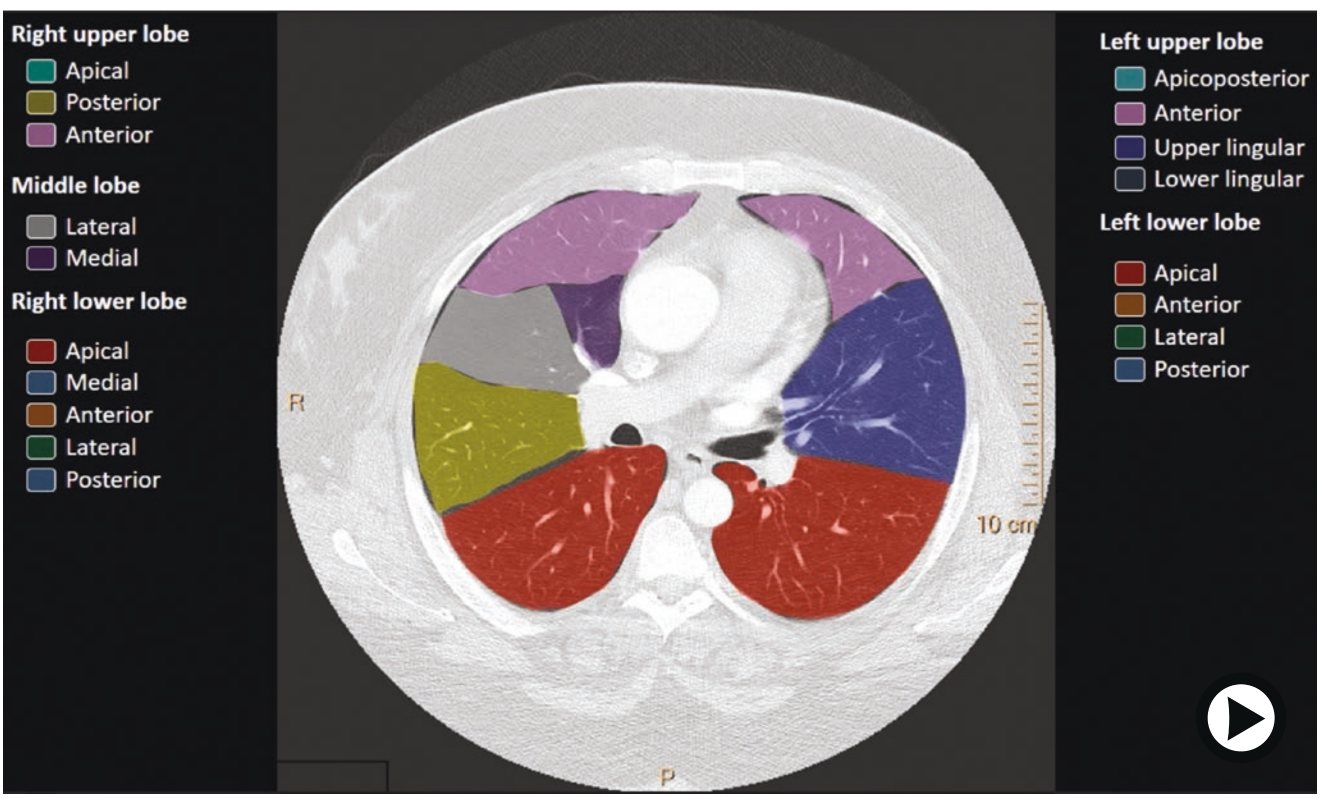

Fig. 2.3 Sequential images of a chest CT in lung window showing the anatomy of lung segments demarcated by colors (▶ https://doi.org/10.1007/000-aae)

2.4 Segmental Anatomy by Lobe

Before the adoption of a classification scheme for the segmental anatomy of the lungs, the readers must be aware that the classification and nomenclature of the bronchopulmonary segments has suffered from variations and controversy in the literature along its history [14, 18–20]. This is due to the variable size of some of the segments (such as the frequently absent or small medial segment of the left lower lobe), the frequent existence of common branches (such as the apicoposterior of the left upper lobe), and the different view of the anatomy at bronchography, bronchoscopy, and surgery, that leads to consider anterior segment of the upper lobe as the second (B^2) instead of the posterior segment (then called B^3) [18]. The latter confusion still persists, and we can find books and relatively recent radiological publications [21] showing this nomenclature, although for the vast majority of surgeons B^2 and B^3 are the posterior and anterior segments, respectively. This is important when treating patients coming with medical reports from other institutions, where a different nomenclature can be used. In the author's opinion, numbering of anterior and posterior segments of the upper lobes should be avoided; conversely, it is recommended the use of its description to prevent mistakes. In this video-atlas, the posterior and apicoposterior segments should be regarded as segments 2 and 1 + 2, respectively, and the anterior segments should be named as 3.

Normally, there are 3 lobes in the right lung and 2 in the left lung. The oblique fissure separates the lower lobe from the upper lobe in the left, and from the upper and middle lobes in the right. The minor fissure separates the upper and middle lobes in the right. These fissures are covered by visceral pleura continuing from the upper surface of the lung and reflexing at the pulmonary hilum. However, fissures are incomplete in around one third of the right oblique, one in five of the left oblique, and 62–74% of the horizontal fissures [22, 23]. Accessory fissures can be mainly seen between the medial and anterior basal segments (inferior accessory fissure, shown in Fig. 2.4), separating segment 6 from segment 10 (superior accessory fissure), and separating the lingula from the culmen (horizontal accessory fissure) [21–23].

Next, we will review the most common anatomic configuration and variations of each segment, discussing the bronchial, arterial, and venous anatomy. They will be named as "B" for bronchi, "A" for the arteries, and "V" for the veins, followed by the number of the corresponding segment, and occasionally a letter of a subdivision. Nomenclature and most frequent anatomic appearance is presented following classic anatomic publications and most recent radiological descriptions [24–33]. Most frequent anatomic configuration with their respective range of frequencies according to the literature is summarized in Tables 2.1 and 2.2.

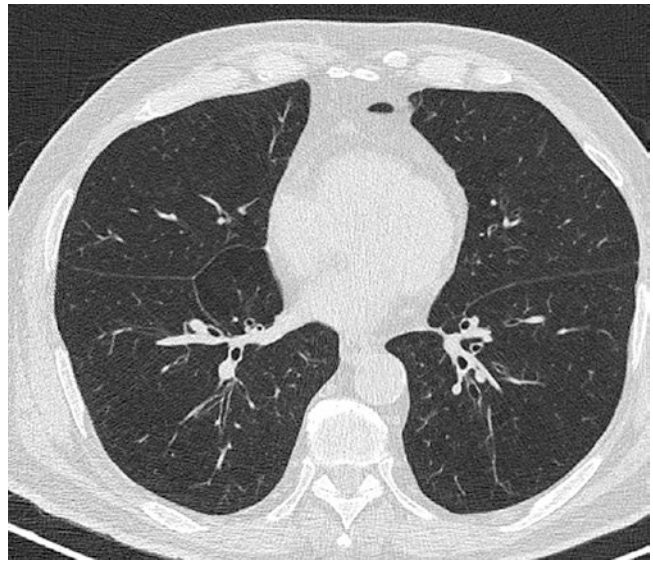

Fig. 2.4 Accessory fissure separating segment 7 from segment 8 of the right lower lobe. The segment 7 in this case is only anteriorly to the left lower lobe vein (type Ia)

Table 2.1 Frequencies of most relevant anatomic configurations of bronchial, arterial, and venous branching in the right upper and lower lobes

Right upper lobe		
Bronchi	Three branches B^1, B^2, B^3	30–44%
	Two branches, either B^{1+3}, B^{1+2}, B^{2+3}	29–48%
	Four branches	1–12%
Arteries	A^1 from trunk superior ± other branches	~100%
	A^2 from recurrent artery from the trunk superior ± other branches	~80%
	A^3 from trunk superior ± other branches	~100%
	Common branches with right lower lobe or middle lobe	~13%
Veins	Anterior with central type	70–88%
	Anterior type	9–22%
	Central type	7–8%
Right lower lobe		
Bronchi	Subsuperior segment	20–56%
	B^{7a} type	22–75%
	B^{7ab} type	15–58%
	B^8 and B^{9+10}	80–94%
	B^{8+9} and B^{10}	8–15%
	B^8, B^9, and B^{10}	4–6%
Arteries	A^6 one single branch	~80%
	A^6 two branches	~20%
	A^6 three branches	<3%
	A* single branch for subsuperior segment	>90%
	A^{7+8}	29–60%
	A^8 and A^{9+10}	~90%
Veins	Inferior pulmonary vein formed by V^6 and common basal vein	>80%
	V^6 into superior pulmonary vein	<2%
	Right middle lobe vein into inferior pulmonary vein	2–8%