

“CAROL DAVILA” UNIVERSITY OF MEDICINE

AND PHARMACY, BUCHAREST

DOCTORAL SCHOOL

FIELD: MEDICINE – THORACIC SURGERY

**POSTOPERATIVE IMAGING IN THORACIC
SURGERY**

– SUMMARY –

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GENERAL PART. CURRENT STATE OF KNOWLEDGE

CHAPTER I – INTRODUCTION

the context of technological progress and the development of minimally invasive methods in thoracic surgery, medical imaging has acquired a fundamental role in the postoperative evaluation of patients. Close monitoring of anatomical and functional changes in the thorax following surgical interventions has become a clinical necessity, contributing to the early detection of complications, assessment of therapeutic success, and adaptation of the therapeutic approach.

This paper aims to analyze the role of postoperative imaging in thoracic surgery, emphasizing modern diagnostic methods, the particularities of normal and pathological findings observed after interventions, and the impact of this information on patient prognosis.

CHAPTER II – THORACIC ANATOMY AND IMAGING CORRELATIONS

A detailed understanding of thoracic anatomy is essential for the correct interpretation of postoperative images. The structures involved in thoracic surgery include the pulmonary parenchyma, pleura, mediastinum, tracheobronchial tree, great vessels, and chest walls. High-resolution imaging, especially computed tomography, allows a three-dimensional evaluation of these structures and is indispensable for assessing post-surgical changes.

Postoperatively, thoracic anatomy undergoes significant alterations: atelectasis, mediastinal deviations, reconfigurations of the pleural cavity, and the presence of residual air or fluid may be observed. Distinguishing between these physiological changes and actual complications is only possible through a clinically and radiologically correlated interpretation, supported by a solid anatomical understanding.

CHAPTER III – ESSENTIAL CONCEPTS IN THORACIC SURGERY

Thoracic interventions can be classified according to the extent of resection: limited resections, lobectomies, and pneumonectomies. Each type of surgery results in a specific imaging pattern. For instance, lobectomy is associated with collapse of the resected space, which may be confused with pathological atelectasis, while pneumonectomy results in the progressive "filling" of the hemithorax with fluid and contralateral mediastinal shift.

Video-assisted thoracoscopic surgery (VATS) and robotic techniques significantly reduce tissue trauma, which is also reflected in imaging by reduced local inflammation and fewer complications compared to classic thoracotomy. These techniques require increased imaging accuracy for the identification of subtle changes.

CHAPTER IV – IMAGING TECHNIQUES USED IN THE POSTOPERATIVE PERIOD

Postoperative evolution is dynamic, and imaging must be adapted to the pathophysiological stages:

- **Immediate phase (0–72h):** Chest X-ray is used to check drain positioning, verify lung expansion, and exclude pneumothorax.
- **Early phase (3–14 days):** Thoracic CT becomes essential for detecting hematomas, abscesses, bronchopleural fistulas, or pleural collections.
- **Late phase (15 days – 3 months):** Chronic complications may become apparent, and imaging plays a role in distinguishing healing from pathology.
- **Follow-up phase (>3 months):** Tumor recurrence or pulmonary remodeling is monitored using CT and PET-CT, especially in oncologic patients.

CHAPTER V – POSTOPERATIVE IMAGING FINDINGS – NORMAL AND PATHOLOGICAL

Chest X-ray

This is the first-line method in the acute postoperative phase. Although it has lower resolution compared to CT, it is fast, accessible, and allows a general assessment of the thorax. It is useful for detecting pneumothorax, pleural effusions, or abnormal thoracic drain positions.

Computed Tomography

This is the gold standard for detailed evaluation of postoperative complications. Multidetector CT allows accurate identification of fistulas, abscesses, thromboses, and assessment of the remaining pulmonary parenchyma. Multiplanar and 3D reconstructions significantly enhance spatial understanding of changes.

Magnetic Resonance Imaging

Although less used in routine postoperative settings, MRI is valuable when iodine contrast is contraindicated or when investigating residual invasive tumors in the chest wall, spine, or mediastinum.

Thoracic Ultrasound

Extremely useful in intensive care, it enables visualization of pleural effusions, guides punctures, and monitors drainage. It is a complementary method to X-ray, especially in critical patients.

PET-CT

The combination of metabolic and morphological information offered by PET-CT is essential in oncology for differentiating between tumor recurrence and post-surgical inflammatory changes. However, it has limitations in the first 2–3 months post-surgery, when physiological inflammation may produce false-positive uptake.

CHAPTER VI – THE ROLE OF IMAGING IN POSTOPERATIVE MANAGEMENT AND CONCLUSIONS

Early Complications

- **Tension pneumothorax** – requires rapid diagnosis using chest X-ray or CT.
- **Hemothorax** – visible as a hyperdense pleural collection on CT.
- **Bronchopleural fistula** – presence of air in the pleural space and changes along the bronchial tract.
- **Subcutaneous emphysema** – seen on imaging as air in the soft tissues of the chest.

Late Complications

- **Chronic empyema** – septated pleural collection with wall thickening and post-contrast enhancement.
- **Tumor recurrence** – identifiable by mass growth or intense metabolic uptake.
- **Post-surgical bronchiectasis** – abnormal bronchial dilation visible on CT.
- **Re-expansion pulmonary syndrome** – pulmonary edema occurring after rapid drainage.

SPECIAL PART. PERSONAL CONTRIBUTION

CHAPTER VII – MOTIVATION AND OBJECTIVES OF THE STUDY

The rationale of this paper stems from the need to clarify the role of postoperative imaging as a prognostic and monitoring tool in thoracic surgery. Particularly in the case of pulmonary lobectomy, imaging has the ability not only to confirm lung re-expansion and absence of complications, but also to reveal subtle signs of persistent or recurrent pathology, such as ground-glass opacities, residual atelectasis, or organized pleural changes. Moreover, minimally invasive interventions are assumed to generate different imaging findings compared to classic thoracotomy, an aspect still insufficiently explored in rigorous clinical studies.

Beyond lobectomy, other thoracic surgeries such as esophagectomy, thymectomy, or mediastinotomy involve increased anatomical and physiological complexity. These procedures often result in postoperative changes that are difficult to differentiate from complications. In this context, a systematic and retrospective analysis of pre- and postoperative images can significantly contribute to refining postoperative monitoring algorithms.

Therefore, this research is justified both by its immediate practical value in patient care and by its contribution to developing an integrated imaging methodology with the potential for generalization in other thoracic surgery centers. The patient cohort, expanded to 227 cases, offers a solid foundation for comparative analyses, hypothesis testing, and statistically significant results.

CHAPTER VIII – MATERIALS AND METHODS

This chapter rigorously describes the methodological framework of the clinical study aimed at evaluating postoperative imaging in patients undergoing thoracic surgery. The study is observational, both retrospective and prospective, and was conducted in a university thoracic surgery center. The analyzed cohort included 227 patients.

Patient selection was based on clear inclusion and exclusion criteria. Included were patients diagnosed with operable pulmonary pathologies, predominantly bronchopulmonary tumors, who underwent lobectomy, pneumonectomy, or atypical resections. The primary focus was the postoperative imaging evaluation using thoracic CT. Exclusion criteria included patients with incomplete imaging data, decompensated comorbidities, or surgical complications that required immediate reintervention.

For each patient, demographic variables (age, sex), clinical parameters (type of intervention, tumor stage, preoperative functional status), and relevant postoperative imaging findings within the first 3 months were analyzed. The imaging techniques used included primarily thoracic CT, complemented in selected cases by chest X-ray and PET-CT. Each image was evaluated in a standardized manner by two radiologists to ensure diagnostic accuracy and avoid interpretation errors.

Data were entered into an electronic database, and statistical analysis was performed using specialized software (SPSS), applying statistical significance tests (Chi-square, Student's t-test, ANOVA) to evaluate correlations between imaging parameters and postoperative prognosis.

CHAPTER IX – RESULTS

This chapter presents a detailed analysis of the 227-patient cohort included in a clinical study focused on thoracic surgical interventions and postoperative imaging assessment. The data were collected retrospectively, and their interpretation highlights relevant correlations between the clinical profile of the patients, the type of intervention, and complications identified through imaging.

Patients were aged between 29 and 84, with a mean age of 61.7 years, confirming the predominance of thoracic conditions in the elderly. Sex distribution was balanced: 114 women and 113 men, eliminating potential gender bias in comparative postoperative outcome analysis. The most represented age group was 60–69 years (75 patients), followed by 70–79 years. This distribution accurately reflects the high incidence of thoracic oncology in the sixth and seventh decades of life. Additionally, patients over 80 brought forth therapeutic and monitoring challenges specific to this fragile category.

Associated comorbidities were frequent and varied. The most common were essential hypertension (63%), chronic cardiovascular diseases (28%), and type 2 diabetes mellitus (18.5%). Additionally, 15% had COPD, and approximately 10% had anemia or other hematologic disorders. Chronic renal failure and metabolic syndrome were also significant, with prevalences of 8% and 18%, respectively. This multimorbid profile directly influenced postoperative vulnerability and determined both the choice of intervention and the postoperative course.

In terms of procedures performed, pulmonary lobectomy was the most frequent (125 patients, 55.1%), driven by the high prevalence of operable non-small cell lung cancer. Thoracic esophagectomy was performed in 42 cases (18.5%), and 60 patients (26.4%) underwent thymectomy or mediastinotomy.

For lobectomies, two main approaches were used: classic thoracotomy and video-assisted thoracic surgery (VATS). Most patients (63.2%) underwent VATS, while 36.8% had thoracotomy. Technique selection was based on factors like tumor location, presence of adhesions, or complex anatomy. VATS was preferred for cases without lymph node invasion or tumor extension, offering clear advantages in postoperative recovery.

Regarding imaging assessment, over 70% of patients underwent at least two postoperative evaluations. All patients received a chest X-ray, and 31.7% also had a contrast-enhanced thoracic CT. Non-contrast CT was used in 16.7% of cases, mainly in patients with contrast contraindications. Thoracic MRI was not used, being irrelevant in the acute postoperative phase for visualizing the lung parenchyma or pleural space.

A severity score was used to analyze imaging changes, applied to each identified abnormality such as atelectasis, pleural effusion, pneumothorax, collections, emphysema, or signs of infection. Based on the total score, patients were categorized into three groups: low (0–4), medium (5–8), and high (9–14). Almost half of the patients (105) had a low score, indicating favorable postoperative evolution and rapid discharge. Seventy-eight patients recorded medium scores, requiring additional monitoring, while 44 patients had high scores, associated with a significant risk of complications.

The most frequent imaging complications were pleural effusion (13.6%), lobar or segmental atelectasis (9.7%), and residual pneumothorax (4%). Other notable complications included subcutaneous emphysema (3.5%), hemothorax (2.6%), and mediastinitis/thoracic abscess (3.1%). These complications correlated with higher imaging scores, longer hospital stays (12.7 days vs. 8.3 days without complications), and increased ICU admission rates.

Statistical analysis of clinical–imaging correlations showed significant relationships between imaging score and various clinical parameters. For example, a moderately strong correlation was found between total imaging score and hospital stay duration ($r = 0.48$, $p < 0.001$), and between bilateral pleural effusion and ICU admission ($r = 0.39$, $p = 0.004$). Bronchopleural fistula was associated with an increased risk of reintervention ($r = 0.53$), and elevated CRP correlated with the presence of septic collections ($r = 0.44$). Mortality was significantly higher in patients with imaging scores >9 ($p = 0.006$).

Binary logistic regression identified independent imaging predictors for unfavorable postoperative outcomes. These included imaging score ≥ 9 (OR = 3.8), persistent atelectasis beyond day three (OR = 2.5), abundant pleural effusion (>500 ml, OR = 2.1), and presence of

a septic pleural collection (OR = 3.2). These results led to the proposal of a risk stratification algorithm based on imaging, which can guide clinical decisions regarding monitoring and therapeutic intervention.

Clinical classification of patients by imaging score showed a proportional evolution in severity. The mean hospital stay increased from 6.3 days in the low-score group to 13.7 days in the high-score group. Similarly, the ICU admission risk rose from 4% to 38%, and postoperative mortality from 0% to 5.3%. These findings validate the imaging score as an objective tool for predicting clinical severity and justify its integration into current medical practice.

CHAPTER X – HYPOTHESIS TESTING

Chapter X rigorously analyzes seven hypotheses formulated to assess the relationships between postoperative imaging data and the clinical outcomes of thoracic surgery patients. The hypotheses aim to validate the utility of CT, the influence of surgical approach on complications, the correlation between imaging scores and hospitalization duration, and the prediction of severe complications.

Hypothesis 1: Superiority of Postoperative CT

Hypothesis: Postoperative chest CT is more effective than X-ray and ultrasound in detecting early complications.

Methodology: 110 patients were evaluated using CT; the others underwent only X-ray and/or ultrasound. Complications and time of detection were compared between groups.

Results:

- CT identified complications in 31.3% of cases.
- Complications were detected faster (mean 2.6 days vs. 4.3 days).
- Immediate therapeutic measures (drainage, ICU admission, reintervention) were more frequent after CT.

Conclusion: Hypothesis confirmed. CT has superior value in early detection, improves therapeutic decision-making, and reduces hospitalization duration.

Hypothesis 2: Surgical Approach Influences Imaging Complications

Hypothesis: Lobectomies performed via VATS are associated with fewer complications than those via thoracotomy.

Methodology: 79 patients operated via VATS were compared with 46 via thoracotomy.

Results:

- Imaging complication rate: 22.7% for VATS vs. 32.6% for thoracotomy.
- VATS was associated with reduced tissue trauma and lower inflammatory response.

Conclusion: Hypothesis confirmed. Minimally invasive surgery is preferable when feasible, consistent with literature findings.

Hypothesis 3: Correlation Between Imaging Score and Hospitalization Duration

Hypothesis: A more severe postoperative imaging score correlates with longer hospital stays.

Methodology: For 214 patients, the imaging score (0–14) was correlated with hospitalization duration.

Results:

- Moderate positive correlation ($r = 0.48$, $p < 0.001$).
- Mean hospitalization duration: 6.3 days (low score), 9.1 days (medium score), 13.7 days (high score).

Conclusion: Hypothesis confirmed. Imaging score is a strong predictor of hospitalization length and clinical resource utilization.

Hypothesis 4: Pleural Effusion >500 ml as a Predictor of Complications

Hypothesis: Abundant pleural effusion is associated with a higher risk of clinical complications.

Methodology: 42 patients with significant effusion were compared with the rest.

Results:

- Hospitalization duration: 12.4 days vs. 7.1 days.

- ICU admission: 38% vs. 14%.
- Reinterventions: 19% vs. 4.8%.

Conclusion: Hypothesis confirmed. Large pleural effusion is an early indicator of negative clinical evolution.

Hypothesis 5: Imaging Score >9 as a Predictor of Severe Complications

Hypothesis: Imaging score >9 is associated with a higher incidence of abscesses or cardiac arrest.

Methodology: Groups were compared based on imaging score (≤ 9 vs. >9).

Results:

- Severe complication rate: 28.9% (score >9) vs. 3.8% (score ≤ 9).
- Relative risk: 7.6 (95% CI: 3.01–18.90).

Conclusion: Hypothesis confirmed. Score >9 is a critical alert threshold with strong predictive value for severe events.

Hypothesis 6: Bronchopneumonia and Imaging Severity

Hypothesis: Patients with postoperative bronchopneumonia have more severe imaging scores.

Methodology: Imaging scores of 32 patients with bronchopneumonia were compared to 115 without.

Results:

- Mean scores: 6.82 vs. 6.27.
- Difference NOT statistically significant ($p = 0.12$).

Conclusion: Hypothesis refuted. Clinical diagnosis remains essential, as imaging signs do not always reflect bronchopneumonia severity.

Hypothesis 7: Subcutaneous Emphysema and Hospital Stay

Hypothesis: Subcutaneous emphysema prolongs hospitalization only in major pulmonary surgeries.

Methodology: Hospital stays compared in patients with/without emphysema, based on type of surgery.

Results:

- Major surgeries: emphysema → 11.4 days vs. no emphysema → 8.6 days ($p = 0.003$).
- Minor surgeries: no significant differences.

Conclusion: Hypothesis partially confirmed. Emphysema affects hospitalization duration only in the context of major surgical interventions.

Final Summary of Hypotheses Tested

No.	Hypothesis	Test Result	Significance
1	CT detects complications more effectively than X-ray	Confirmed	$p < 0.001$
2	Surgical approach influences imaging complications	Confirmed	$p = 0.002$
3	Severe imaging score = longer hospitalization	Confirmed	$r = 0.48$
4	Pleural effusion >500 ml increases complication risk	Confirmed	$p < 0.001$
5	Score >9 predicts severe complications (e.g., abscess, cardiac arrest)	Confirmed	$p < 0.001$
6	Bronchopneumonia = more severe imaging score	Refuted	$p = 0.12$
7	Emphysema increases hospital stay only in major surgeries	Partially Confirmed	$p = 0.003$ / $r = 0.48$

Chapter Conclusion

This chapter demonstrates the validity of most proposed hypotheses and emphasizes the importance of imaging evaluation in postoperative practice. Thoracic CT proves to be an essential tool for early complication detection, while the total imaging score emerges as a strong predictor of clinical evolution, especially regarding hospitalization duration, reintervention risk, and severe complications.

The type of intervention—especially the choice between VATS and thoracotomy—significantly influences the postoperative imaging profile. Large pleural effusions and imaging scores >9 should be considered red flags for intensive monitoring. Conversely, some intuitive hypotheses, such as the one related to bronchopneumonia, were not confirmed, highlighting the importance of correlating imaging with clinical presentation.

This chapter provides a solid foundation for developing risk stratification algorithms and personalizing postoperative management in thoracic surgery.

CHAPTER XI – THE POSTOPERATIVE IMAGING SCORE

This chapter introduces an innovative clinical evaluation tool – the **Postoperative Imaging Score** – designed to quantify the severity of radiological complications in the immediate period following major pulmonary interventions. This score, objectively and reproducibly applicable, provides a standardized model for interpreting postoperative images and transforms fragmented radiological data into a synthetic risk stratification system with direct impact on clinical decision-making. Its originality lies in its solid methodological foundation and its demonstrated predictive value through a high AUC coefficient in ROC analysis.

Structure and Clinical Rationale of the Score

The score was conceived as a quantitative, reproducible instrument to assess imaging complications, focusing on radiological changes easily identified by multidisciplinary evaluators (radiologists, pulmonologists, surgeons). Its goal is to stratify the risk for major complications such as respiratory failure, sepsis, or need for ventilatory support.

Each complication was quantified on a severity scale from 0 to 3:

- **Pleural effusion** (1–3),
- **Atelectasis** (1–2),
- **Pneumothorax, emphysema, infiltrates, septated collections, bronchopleural fistula.**

The total score ranges from 0 to 14 points, with a threshold of **≥9 points** identified as an indicator for high risk of severe clinical events.

The score was retrospectively applied to a cohort of 227 patients. Evaluation was independently performed by two specialists, and disagreements were resolved by consensus. The ROC curve analysis identified 9 points as the optimal threshold for predicting complications.

Key Findings:

- **In-hospital mortality:** 20.9% in patients with scores ≥ 9 vs. 3.0% in those with scores < 9 .
- **ICU admissions:** 37.1% (score ≥ 9) vs. 4.2% (score < 9).
- **Odds ratio for severe complications:** 7.61 (95% CI: 3.2–15.7).

These data validate the score as an effective tool for predicting postoperative clinical instability.

Stratification of Clinical Decisions:

- **Score < 4 :** low risk $\rightarrow$ early discharge.
- **Score 4–8:** intermediate risk $\rightarrow$ monitoring and follow-up imaging.
- **Score ≥ 9 :** high risk $\rightarrow$ ICU admission, frequent CT reevaluations, potential reintervention.

Resource Planning:

The score enables efficient ICU bed allocation and directs resources toward high-risk patients.

Imaging Follow-up Frequency:

- Selective reevaluation for low scores;
- Systematic reevaluations every 48–72 hours for scores ≥ 9 .

Hospitalization Duration:

The score guides discharge decisions and helps prevent both unnecessary prolonged hospitalization and premature discharge.

A **clinical example** (patient D.M., 55 years old, imaging score = 8) was used to demonstrate the score's utility in patient triage. Although ICU admission was not needed, the patient experienced a slow favorable evolution, requiring prolonged drainage and extended hospitalization. The score helped avoid premature discharge and supported risk-adapted clinical decisions.

Unlike descriptive approaches from the literature, the proposed score:

- Objectively quantifies imaging data;
- Has statistically validated predictive value;
- Is applicable across disciplines (radiology, surgery, ICU);
- Can be integrated into clinical algorithms and digital systems.

The score provides a common language across specialties, enabling rapid, standardized, and personalized decisions. It is also compatible with integration into EMRs and AI-assisted systems, offering potential for future developments.

CHAPTER XII – DISCUSSION

This chapter analyzes the data from the previous chapter, correlates them, and evaluates their clinical significance. It interprets the findings in the light of previously formulated hypotheses, offering possible explanations for observed phenomena – such as why certain imaging complications correlate with hospitalization duration or postoperative mortality.

Simultaneously, results are rigorously compared with data from the literature to determine whether they are confirmed by previous studies or bring new insights, divergences, or even contradictions – all contributing to external validation or identification of local particularities.

Furthermore, this section plays an essential role in translating theoretical knowledge and scientific findings into applied medical practice – the author extracts concrete recommendations for optimizing postoperative monitoring algorithms, risk stratification, and tailored management based on the imaging score.

The chapter does not avoid critical aspects. On the contrary, it honestly acknowledges the **methodological limitations** of the study: its retrospective nature, the absence of a standardized imaging protocol, and the lack of complementary clinical-functional parameters. By acknowledging these limitations, a realistic framework for interpreting conclusions is offered, and the validity of findings is clearly delimited.

Ultimately, perhaps the most valuable contribution of this chapter is that it **opens new directions for research**, proposing specific future lines of inquiry – from multicenter validations of the imaging score to its integration into composite clinico-biological scores or AI-assisted automated algorithms.

CHAPTER XIII – CONCLUSIONS

This chapter synthesizes the scientific and clinical essence of the entire research, presenting in an academic and evidence-based manner the main lessons derived from the analysis of postoperative imaging cohorts. It marks the transition from the analytical to the integrative and applicative phase, offering a panoramic view of the value of imaging investigations in modern thoracic surgery.

The study on 227 patients demonstrated that postoperative imaging is not merely a tool for confirming clinical suspicions but a **central element** in the early diagnosis of complications and anticipation of clinical evolution. One of the major conclusions was the **superiority of CT** over standard radiography, supported by the clear sensitivity gap in detecting postoperative pathological changes (97% vs. 61%).

Moreover, the type of intervention directly influenced the **severity and frequency of imaging findings**, with increased risk noted in patients undergoing major pulmonary procedures. A key contribution of the study is the introduction of a **global imaging score** – a synthetic, reproducible tool capable of correlating radiological severity with clinical parameters like hospitalization duration or ICU readmission.

Scores above 9 points were associated with severe complications and functioned as accurate indicators of postoperative instability, conferring the score the status of a potential severity marker for integration into triage and monitoring algorithms. Equally important was identifying the **predictive value of pleural effusion volume** – the 500 ml threshold proved critical in forecasting unfavorable clinical outcomes, supporting its inclusion in routine evaluation.

The chapter also reflects on **partially refuted hypotheses**, highlighting the complexity of the imaging–clinical relationship and drawing attention to the dangers of interpreting images in isolation without considering the patient's symptomatic and biological profile.

The chapter concludes with **clear, objective-based conclusions**, highlighting key achievements in relation to the declared research goal – validating imaging as an early therapeutic decision-making tool.

Finally, it proposes **concrete improvements for clinical practice**:

- Use of CT at 48–72 hours post-op for major cases;
- Introduction of the imaging score in standardized evaluations;
- Objective quantification of pleural fluid;
- Integrated clinical–imaging interpretation;
- Protocol adaptation to intervention type.

Chapter XIII is not merely the closure of the study, but a **coherent translation of findings into practical recommendations**, justifying the impact of the work on improving postoperative care protocols and advancing the personalization of modern thoracic medicine.