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Disruption of Radiological Surveillance Following a Global Health Crisis in Resected Lung Cancer

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ABSTRACT

Objectives: Radiological surveillance after curative-intent lung cancer resection is essential for early detection of recurrence and second primary tumors. Large-scale health emergencies can compromise oncologic follow-up. This study quantifies the impact of a health crisis on radiological surveillance in a national cohort of resected lung cancer patients.

Methods: A time-segmented observational cohort study was performed using data from the prospective, multicenter GEVATS registry. Surveillance density (CT/month) was evaluated across three predefined periods: pre-pandemic (baseline), state of alarm (maximum healthcare restrictions), and post-alarm (recovery phase). The population at risk was updated for each period. Subgroup analyses during the post-alarm phase assessed prioritization according to neoadjuvant treatment, pathological stage, age, and comorbidity.

Results: Among 2382 eligible patients, surveillance density declined progressively from the pre-pandemic period (0.157 ± 0.079 CT/month) to the state of alarm (0.098 ± 0.071 CT/month). In the post-alarm phase, density dropped sharply to 0.023 ± 0.018 CT/month (equivalent to one CT every 3.6 years), representing a 76.5% reduction compared with the state-of-alarm period ($p < 0.001$). This under-surveillance was generalized, with no significant differences by pathological stage ($p = 0.084$), age ($p = 0.564$), or comorbidity ($p = 0.872$). Only prior neoadjuvant therapy was associated with a slightly higher density ($p = 0.040$).

Conclusions: A prolonged health crisis resulted in a profound and persistent reduction in radiological surveillance after lung cancer resection, without evidence of risk-based prioritization. These findings support the need for contingency frameworks within clinical guidelines to preserve continuity of oncologic follow-up during future health emergencies.

1 | Introduction

Postoperative surveillance following curative-intent resection of lung cancer represents a cornerstone of oncologic care. Its primary objectives are the early detection of recurrence and the identification of second primary tumors, ultimately aiming to improve long-term survival by enabling timely administration of salvage therapies [1, 2]. Despite widespread acceptance, substantial heterogeneity persists in the recommended intensity and frequency of follow-up across clinical practice guidelines. Major societies such as the American College of Chest Physicians (CHEST), the National Comprehensive Cancer Network (NCCN), the American Society of Clinical Oncology (ASCO), the European Society for Medical Oncology (ESMO), and the Spanish Society of Thoracic Surgery (SECT) [3–7] generally recommend chest computed tomography (CT) every 6 months during the first 2–3 years, followed by annual imaging thereafter.

See Spanish Group of Video-assisted Thoracic Surgery (GEVATS) are given in Acknowledgments.

This apparent consensus is based largely on indirect and heterogeneous evidence, and the true clinical benefit of intensive surveillance strategies remains a subject of ongoing debate. Indeed, several large-scale observational studies, including a previous analysis from our own national GEVATS cohort [8], as well as others [9, 10], have questioned whether more frequent imaging universally translates into improved overall survival. These findings underscore the need to move from a "one-size-fits-all" model toward personalized, risk-stratified surveillance strategies [11], which could optimize resource allocation and focus intensive follow-up on patients at greatest risk of recurrence.

Within this complex landscape, large-scale health crises—such as the COVID-19 pandemic that emerged in March 2020—have demonstrated their profound capacity to disrupt healthcare systems worldwide [12]. Oncologic care was severely affected, characterized by diagnostic delays, postponed treatments, and significant reductions across multiple cancer screening programs [13–16]. In Spain, the declaration of a nationwide state of alarm (*Real Decreto 463/2020*) resulted in the temporary centralization of healthcare governance and a drastic reorganization of medical resources. The reassignment of personnel and suspension of non-urgent surgeries led to an unprecedented reduction in oncologic activity [17, 18].

This scenario constituted a unique "natural experiment" to evaluate not only the immediate impact of a health crisis on the continuity of radiological surveillance but, more importantly, the resilience and mid-term recovery capacity of oncologic monitoring systems.

The objective of this study is to quantify the effect of a prolonged health crisis on the intensity of radiological surveillance in a national cohort of patients with resected lung cancer. The analysis encompasses three distinct phases: pre-pandemic, state of alarm, and post-alarm period—to assess both the magnitude of disruption and the persistence of its effects.

2 | Materials and Methods

An observational cohort study segmented by time periods was conducted using data from the prospective, multicenter registry of the Spanish Video-Assisted Thoracic Surgery Group (GEVATS). The methodology of this registry has been previously described [19]. It includes audited data from patients undergoing anatomical pulmonary resections across 33 thoracic surgery departments in Spain.

From an initial cohort of 3320 patients included in the GEVATS database between December 2016 and March 2018, predefined exclusion criteria were applied: absence of primary lung cancer, residual disease after surgery, death within the first 90 postoperative days, or documented recurrence within that same period. The patient selection process is summarized in Figure 1.

The study was conducted in accordance with the Declaration of Helsinki and received approval from the coordinating ethics committee (reference number CASVE-PS-16-273).

To assess the effect of a prolonged health crisis, three distinct and non-overlapping analysis periods were pre-specified:

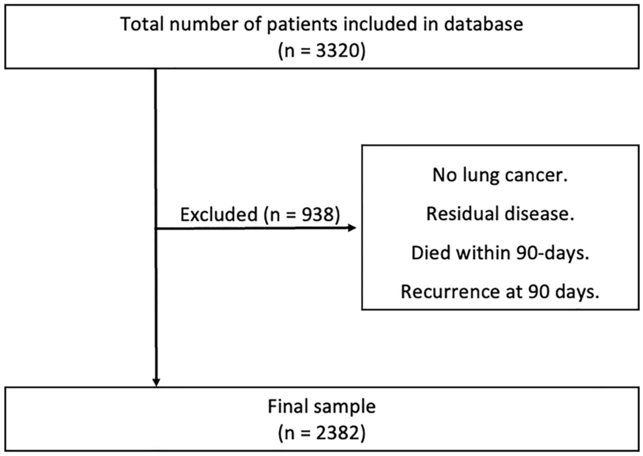

FIGURE 1 | Flowchart of patient selection for the analysis of the total number of patients in the GEVATS database.

1. *Pre-pandemic period*: From December 20, 2016 (opening date of the GEVATS database) to February 29, 2020, representing the baseline phase prior to the pandemic impact.
2. *State of alarm period*: From March 1, 2020, to May 31, 2021, corresponding to the phase of maximal healthcare strain and sanitary restrictions in Spain.
3. *Post-alarm period*: From June 1, 2021, to the end of follow-up on September 30, 2022.

The primary variable was radiological surveillance density (CT/month), defined as the number of follow-up chest CT scans divided by the total time (in months) each patient remained under oncologic follow-up. The population at risk was updated for each period, censoring (excluding) patients who experienced an event (oncologic recurrence, death, or loss to follow-up) during the preceding phase.

Additionally, an equivalent interval was calculated, defined as the theoretical conversion of population-level density (12/[CT/year]) to express the mean interval between imaging studies (in months). This measure does not represent the actual patient-level follow-up interval but rather a population-based estimate derived from the observed mean density.

The cohort chronology (latest surgery in March 2018) confirms that all patients had completed at least 24 months of follow-up at the onset of the state of alarm. Therefore, the pre-pandemic period corresponded to the phase when semiannual radiological surveillance was recommended, whereas during the state of alarm and post-alarm periods, annual surveillance was considered standard (minimum expected density: 0.083 CT/month).

Predefined subgroup analyses were conducted to evaluate prioritization trends in surveillance exclusively within the post-alarm cohort ($N = 1135$), as this group exhibited substantial changes in follow-up patterns.

The stratification variables analyzed included: neoadjuvant treatment; pathological stage grouped as stage I–II vs. III–IV

(AJCC 8th Edition); age (analyzed as a continuous variable); and comorbidity (categorized as 0, 1, or ≥2 comorbidities), defined by the sum of hypertension, heart failure, ischemic heart disease, arrhythmia, stroke, and peripheral vascular disease.

2.1 | Statistical Analysis

Quantitative variables were expressed as mean ± standard deviation (SD). The primary statistical analysis consisted of a direct comparison (Mann–Whitney *U* test) of radiological surveillance density between the state-of-alarm and post-alarm periods, as both shared the same recommended annual follow-up standard.

Subgroup analyses (Table 2) within the post-alarm cohort were performed using Welch's *t*-test, the Kruskal–Wallis test, the Mann–Whitney *U* test, and Pearson's correlation coefficient. A *p*-value < 0.05 was considered statistically significant. All analyses were conducted using IBM SPSS Statistics software, version 24.0.

3 | Results

From an initial cohort of 3320 patients who underwent surgery between December 2016 and March 2018, 938 patients were excluded for not meeting inclusion criteria. The final baseline cohort included 2382 patients. Baseline characteristics and audit methodology for this registry have been previously described in detail by Embún et al. [19] and more recently by our group [8]. In the present analysis, only variables related to postoperative radiological surveillance were evaluated. No additional clinical comparisons were performed, as the demographic and oncologic characterization of this cohort has already been comprehensively analyzed in the aforementioned publications.

3.1 | Evolution of Radiological Surveillance Density

Radiological follow-up density was analyzed among patients who remained under active surveillance during each of the three defined periods.

- *Pre-pandemic period (Baseline)*: In this phase ($n = 2382$), the mean surveillance density was 0.157 ± 0.079 CT/month (equivalent to one CT every 6.4 months), consistent with the recommended semiannual protocol (0.167 CT/month).
- *State-of-alarm period*: During this phase ($n = 1532$), the expected follow-up standard was annual (0.083 CT/month). The observed density was 0.098 ± 0.071 CT/month (equivalent to one CT every 10.2 months).
- *Post-alarm period*: In the final phase ($n = 1135$), mean surveillance density dropped sharply to 0.023 ± 0.018 CT/month (equivalent to one CT every 3.6 years), despite the annual follow-up recommendation remaining unchanged (0.083 CT/month).

Comparison between the two periods with identical recommended surveillance frequency (state of alarm vs. post-alarm) demonstrated a statistically significant 76.5% reduction in surveillance density (0.098 vs. 0.023 CT/month, respectively; $p < 0.001$, Mann–Whitney *U* test) (Table 1 and Figure 2).

3.2 | Subanalysis of Surveillance Density During the Post-Alarm Period

Radiological surveillance density during the post-alarm period ($n = 1135$) was analyzed according to clinical variables:

- *Neoadjuvant treatment*: A significantly higher follow-up density was observed among patients who received induction therapy (mean: 0.0278 CT/month) compared with those who did not (mean: 0.0226 CT/month; $p = 0.040$).
- *Comorbidity index*: No statistically significant differences were found across comorbidity groups (0: 0.027 CT/month; 1: 0.026 CT/month; ≥2: 0.026 CT/month; $p = 0.872$).
- *Grouped stage*: No significant differences were observed when comparing early-stage (I–II: 0.0276 CT/month) versus advanced-stage (III–IV: 0.0249 CT/month) disease ($p = 0.084$).
- *Age correlation*: Pearson's correlation between patient age and radiological follow-up density during the post-alarm period ($r = -0.017$; $p = 0.564$) showed no statistical significance, suggesting that the reduction in surveillance affected all age groups uniformly (Table 2).

4 | Discussion

This multicenter national cohort study demonstrates a marked and sustained decline in the intensity of radiological surveillance following curative-intent lung cancer surgery in Spain,

TABLE 1 | Temporal evolution of radiological surveillance density.

Study period	Patients under follow-up (*n*)	Mean surveillance density (CT/month ± SD)	CT/year (λ)[a]	Equivalent interval[b]
Pre-pandemic	2382	0.157 ± 0.079	1.88	6.4 months
State-of-alarm	1532	0.098 ± 0.071	1.18	10.2 months
Post-alarm	1135	0.023 ± 0.018	0.28	3.6 years

Note: The equivalent interval represents a theoretical conversion of population-level surveillance density and does not reflect the actual follow-up interval for individual patients.
[a]CT/year = 12 × (CT/month).
[b]Equivalent interval = 12/(CT/year).

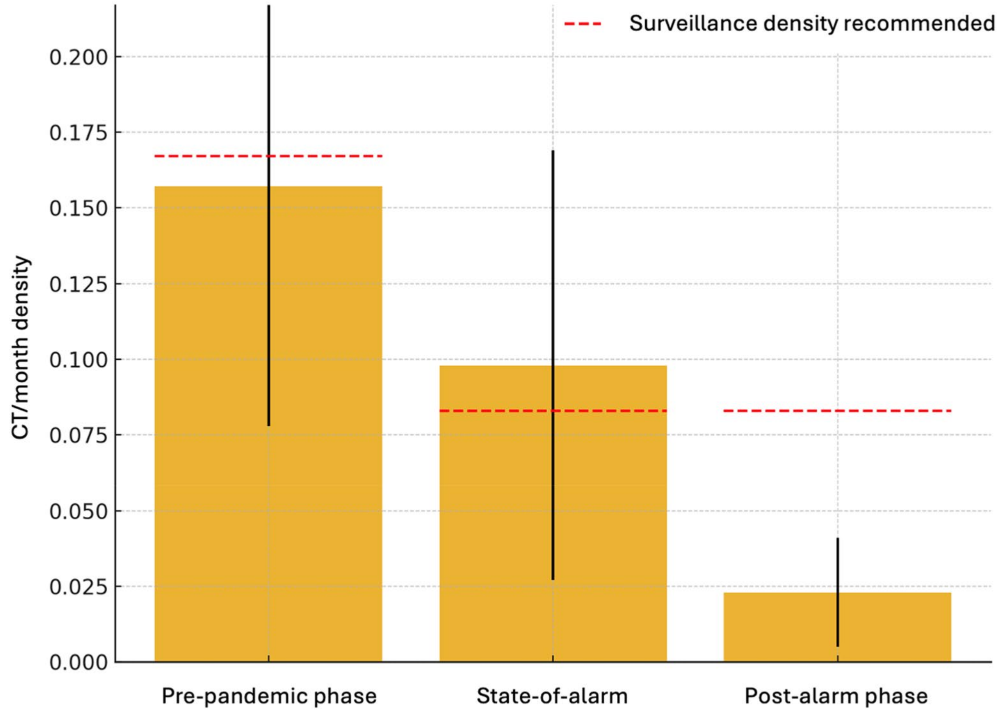

FIGURE 2 | Mean density of computed tomography scans per month (CT/month) during postoperative follow-up of patients with resected lung cancer across the three defined study periods. Red dashed lines indicate the surveillance density recommended by clinical guidelines for each period: 0.167 CT/month (one CT every 6 months) during the pre-pandemic phase, and 0.083 CT/month (one annual CT) during the state-of-alarm and post-alarm periods. Error bars represent the standard error of the mean.

TABLE 2 | Subanalysis of radiological follow-up density (CT/month) in the post-pandemic cohort.

Variable	Subgroup	*N*	Mean (CT/month)	Statistical test	*p*
Neoadjuvant treatment	No	1.056	0.023	Welch *t*	0.04
	Yes	79	0.028		
Comorbidity[a]	0	405	0.027	Kruskal–Wallis	0.87
	1	384	0.026		
	≥ 2	346	0.026		
Grouped stage (AJCC 8th edition)	I–II	960	0.028	Mann–Whitney *U*	0.08
	III–IV	130	0.025		

Abbreviation: CT, computed tomography.
[a]Comorbidity (categorized as 0, 1, and ≥ 2 comorbidities), defined as the sum of arterial hypertension, heart failure, ischemic heart disease, arrhythmia, stroke, and peripheral vascular disease.

temporally associated with the impact of a prolonged health crisis and the subsequent healthcare restrictions.

During the state-of-alarm period, a decrease in surveillance density was observed compared with the pre-pandemic phase; however, this reduction was expected, as all patients had surpassed the first two postoperative years and therefore transitioned from a recommended semiannual to an annual radiological follow-up protocol.

The most relevant finding is that, in the post-alarm period, radiological surveillance density continued to decrease significantly (0.023 CT/month), falling well below the recommended annual standard (0.083 CT/month) without evidence of progressive recovery in follow-up activity. This suggests a persistent attenuation of surveillance intensity beyond the critical phase of the pandemic, not explained merely by the natural temporal evolution of the cohort.

The mean interval between follow-up CT scans lengthened from approximately 10.2 months during the pandemic (0.098 CT/month)—consistent with the annual surveillance frequency recommended by clinical guidelines—to an alarming 3.6 years (0.023 CT/month vs. the recommended 0.083 CT/month) during the post-alarm period. It must be emphasized that this equivalent interval of 3.6 years represents a theoretical temporal conversion derived from population-level density and does not correspond to individual patient scheduling. Rather, it should be interpreted as an indicator of the accumulated population-level deficit in imaging activity.

This 76.5% reduction ($p < 0.001$) compared with the state-of-alarm period (0.098 CT/month) constitutes a profound under-surveillance relative to the standards established by major societies such as CHEST, ASCO, NCCN, ESMO, and SECT [3–7]. This finding reflects a structural failure in the recovery of oncologic follow-up activity after the acute pandemic phase.

Perhaps the most concerning and clinically relevant finding is the largely non-selective nature of this under-surveillance.

We specifically analyzed the influence of age and comorbidity (Table 2), based on the hypothesis that these factors might have biased follow-up practices. It could be expected that older patients or those with greater multimorbidity—considered high-risk populations for severe COVID-19—might have attended oncologic follow-ups less frequently, whether due to imposed restrictions or fear of infection. However, our findings refute this hypothesis. No statistically significant differences were found in follow-up density across comorbidity strata ($p = 0.872$), nor was any correlation observed with age ($p = 0.564$). This suggests that the reduction in surveillance was a generalized phenomenon, not the result of selective barriers affecting the most vulnerable patients.

More critically, the analysis revealed a systemic failure in the prioritization of high-risk oncologic patients. Individuals with advanced pathological stages (III–IV) were not prioritized, showing follow-up densities comparable to those with early-stage disease (I–II: 0.0276 vs. 0.0249 CT/month; $p = 0.084$). This indicates the absence of risk-based triage mechanisms to safeguard patients at higher risk of recurrence. The only statistically significant exception was among patients with a history of neoadjuvant therapy ($p = 0.040$), who maintained slightly higher follow-up density (0.0278 vs. 0.0226 CT/month). Although this might reflect a modest effort to prioritize this clinically complex subgroup—potentially influenced by more frequent oncologic (rather than surgical or pulmonary) follow-up—it does not alter the overall conclusion of a generalized collapse lacking oncologic risk stratification. A plausible explanation for this absence of oncological risk–based prioritization lies in the structural organization of radiological follow-up workflows during and after the pandemic. In many hospitals, CT scheduling during this period was constrained by available capacity, with cancelations and rescheduling frequently managed at an administrative level rather than through physician-led clinical triage. As a result, patients were rescheduled according to chronological waiting lists or generic urgency categories, rather than according to pathological stage or recurrence risk.

These results are consistent with international reports documenting the disruption of oncologic care during the pandemic. In England, Maringe et al. [13] estimated a 4.8%–5.3% increase in 5-year lung cancer mortality due to diagnostic delays. In the United States, Patt et al. [14] reported a 56% reduction in lung cancer screening, while other authors described the suspension of surveillance programs and a subsequent increase in suspicious nodules once activities resumed [15, 16].

The findings of this study have relevant clinical implications. Although available evidence, including our prior analysis of the same cohort [8], suggests that intensive radiological follow-up does not uniformly translate into improved overall survival, the magnitude of the post-alarm surveillance deficit exceeds the acceptable variability described in major clinical guidelines. Such a pronounced reduction in imaging frequency could delay the detection of potentially treatable recurrences and compromise therapeutic opportunities in selected subgroups.

This observation underscores the need for risk-adapted surveillance strategies and, more specifically, for structured contingency frameworks within international guidelines to ensure continuity of oncologic care during future health crises. The pandemic should be regarded as an opportunity to redefine more resilient surveillance models. International consortia—including ESMO [20] and NCCN [21]—have advocated for telemedicine as a cornerstone of post-COVID oncologic care. In lung cancer, the integration of digital tools, such as remote monitoring of patient-reported outcomes (ePROs), has proven not only to represent a resilient follow-up model but also to be associated with improved overall survival [22, 23]. Therefore, coordinated telesurveillance systems with automated risk prioritization should be a priority in the future redefinition of follow-up guidelines.

This study benefits from the use of a prospective, multicenter, and nationally audited cohort, strengthening the external validity of the findings. However, several limitations must be acknowledged. Although the ultimate clinical relevance of surveillance disruption lies in its impact on recurrence detection and oncological outcomes, the present study deliberately did not analyze the timing of recurrence, recurrence stage, or survival, as these variables were beyond the scope of this process-of-care–focused design and were not collected in a sufficiently uniform and prospective manner to allow for unbiased outcome analyses. This remains a critical step for future research. Second, the duration of the post-alarm period (16 months) may be insufficient to fully assess the recovery of surveillance programs. Future studies should integrate clinical, radiological, and oncologic outcome variables to determine whether the loss of surveillance observed here had a measurable effect on survival and the timely detection of treatable recurrences among patients under oncologic follow-up during and after the COVID-19 pandemic.

5 | Conclusion

Large-scale health crises can lead to a profound and sustained reduction in the intensity of radiological surveillance among patients with resected lung cancer. In the analyzed cohort, surveillance intensity decreased by 76.5%, reflecting an incomplete recovery of activity even after the normalization of healthcare services.

The observed under-surveillance was widespread, with no significant differences according to age, comorbidity, or tumor stage, indicating a systemic impact rather than a selective prioritization of oncologic risk.

These findings highlight the need to incorporate contingency plans and prioritization strategies into clinical guidelines to ensure continuity of oncologic follow-up during future health emergencies or structural crises within healthcare systems.

Author Contributions

Álvaro Fuentes-Martín: conceptualization, investigation, methodology, formal analysis, supervision, funding acquisition, writing – review and editing, writing – original draft, resources, project administration, visualization, validation. **Néstor J. Martínez-Hernández:** writing – review and editing. **Raul Embun:** writing – review and editing. **María Fé Muñoz Moreno:** data curation, formal analysis, investigation. **Ángel Cilleruelo Ramos:** conceptualization, methodology, investigation, data curation, writing – original draft, writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are derived from the Spanish Group of Video-assisted Thoracic Surgery (GEVATS) registry. Restrictions apply to the availability of these data, which were used under license for the current study. Requests for access to the anonymized dataset may be directed to the corresponding author or the GEVATS scientific committee, subject to ethical approval and data sharing agreements.

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