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**Chest CT in Testicular Mass Evaluation: A Stepwise Approach to Minimize Radiation Exposure**

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**ABSTRACT**
**Introduction:**
Chest computed tomography (CT) is commonly obtained for initial staging of testicular cancer. Since pulmonary metastases are rare in the absence of retroperitoneal disease or elevated tumor markers, a selective imaging approach may be justified, as routine chest CT can lead to unnecessary radiation exposure to the thorax.
**Methods:**
We conducted a retrospective cohort study of men evaluated for a newly diagnosed testicular mass at a tertiary medical center between 2011 and 2025. According to institutional protocol, all patients underwent abdominal

and chest CT prior to radical orchiectomy. A risk-stratified approach was then assessed, assuming that chest CT would have been omitted if both serum tumor markers and abdominal CT were negative for metastasis. The primary outcome was the false-negative rate for thoracic metastases among patients who would have been triaged to omit chest CT, and the key secondary outcome was the proportion of chest CT examinations that could have been avoided.

**Results:**

Among 183 eligible patients (mean age 34.3 ± 11.1 years), 174 (95.0%) had germ-cell tumors, including 107 (61.4%) seminomas. Chest metastases were identified in 10 patients (5.5%). Nine (90%) had positive tumor markers and seven (70%) had retroperitoneal nodal involvement. Using the prespecified rule (perform chest CT if either markers or retroperitoneal nodes were abnormal), no metastatic cases would have been missed, yielding sensitivity 100% (95% CI 69.2–100.0) and negative predictive value 100.0% (95% CI 95.7–100). Specificity was 48.0% (95% CI 40.3–55.7), and application of the rule would have avoided 45.4% (95% CI 38.0–52.9) of chest CTs.

**Conclusions:**

Integrating serum tumor markers with abdominal CT before deciding on chest CT may safely reduce radiation exposure without compromising diagnostic accuracy in the workup of men with a testicular mass. External validation is warranted before clinical implementation.





## 1. INTRODUCTION

Testicular cancer primarily affects young men at the peak of their reproductive years. With modern treatment approaches, long-term survival rates are excellent. [1] Consequently, treatment goals have shifted from cure alone to also minimizing the late harms of care.[2] Among these, cumulative radiation exposure from serial imaging represents a preventable risk associated with increased incidence of secondary malignancies.[3] In line with the ALARA (As Low As Reasonably Achievable) principle, imaging should be optimized to obtain necessary diagnostic information while avoiding unnecessary exposure.[4]

At diagnosis, approximately 11% of patients present with metastatic disease, most commonly to the lungs. [5] Accordingly, thoracic imaging forms part of the initial evaluation.[6,7] Chest computed tomography (CT) offers higher sensitivity than radiography for detecting pulmonary metastases, though at the cost of greater radiation dose, [7] roughly equivalent to about 70 chest radiographs.[8]

In seminoma, skip thoracic metastasis - that is, positive chest involvement with a negative retroperitoneum - is exceedingly uncommon,[9] suggesting that a stepwise anatomical approach, in which chest CT is performed only when retroperitoneal lymph nodes are enlarged, may be sufficient. In contrast, nonseminomatous germ-cell tumors (NSGCT) show more frequent hematogenous spread,[10] although these cases also typically exhibit elevated tumor markers that correlate with disease burden.[11]

The primary objective of this study was to assess whether a combined serum tumor marker and retroperitoneal CT–based gatekeeping approach could decrease baseline thoracic CT utilization while preserving a low false-negative rate for thoracic metastasis when applied as a clinical triage strategy. We hypothesized that patients with normal tumor markers and no retroperitoneal lymphadenopathy could safely omit baseline chest CT without loss of staging accuracy.

## 2. METHODS

### 2.1. Study Design and Setting

A retrospective cohort study conducted in a tertiary cancer referral medical center. All patients evaluated for a newly diagnosed testicular mass between January 2011 and December 2025 were reviewed. The study was approved by the institutional review board (IRB –0254-16). Informed consent was waived owing to de identified data collection and retrospective design.

### 2.2. Patient Population

Eligible patients were those with a testicular mass confirmed on physical examination and scrotal ultrasonography. At our institution, the standard evaluation of a testicular mass includes prompt scrotal ultrasonography, serum tumor marker assessment (alpha-fetoprotein [AFP], beta-human chorionic gonadotropin [β-hCG], and lactate dehydrogenase [LDH]), preoperative chest and abdominopelvic CT imaging, and sperm preservation, and radical inguinal orchiectomy, all typically completed within one week. The Demographic clinical, laboratory, and imaging data was retrospectively collected from the electronic medical record.

### 2.3. Definitions

Histologic subtype was recorded as reported in the original pathology report. Tumors were grouped into standard testicular tumor categories, consistent with contemporary classification frameworks.[12] Serum tumor markers (AFP, β-hCG, and LDH) were recorded as the first preoperative values. Retroperitoneal and thoracic metastases were determined based on the interpreting radiologist's final report. When reported, nodal size and lesion measurements followed RECIST 1.1 conventions (short-axis lymph node ≥10 mm considered pathologic), although clinical interpretation incorporated overall radiologic assessment.[13]

### 2.4 Screening Algorithm

The screening algorithm followed a prespecified and previously tested institutional protocol aimed at minimizing unnecessary chest CT imaging. Patients were classified as test-positive if either serum tumor markers (AFP, β-hCG, or LDH) were elevated above institutional reference ranges or if abdominal CT demonstrated retroperitoneal lymph nodes suspicious for metastasis. Patients classified as test-negative under this rule would, according to the algorithm, forgo chest CT evaluation.

### 2.5 Study Outcomes

The primary outcome was the false-negative rate (FNR) for thoracic metastasis among patients triaged by the tool to omit chest CT. The secondary outcome was the proportion of chest CT examinations potentially avoided in the overall cohort.

### 2.6 Statistical Analysis

To limit bias, consecutive eligible patients were included using prespecified criteria and standardized abstraction procedures. Study size was determined by all consecutive eligible patients (n = 183); no a priori sample-size calculation was performed.

Baseline characteristics were summarized overall and stratified by the presence of thoracic metastasis. Diagnostic performance of the screening rule was assessed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and the proportion of chest CTs avoided. Two-sided 95% confidence intervals (CIs) were calculated using the exact binomial (Clopper–Pearson) method. All analyses were performed using R© statistics version 4.5.0 (R Foundation for Statistical Computing, Vienna, Austria).

## 3.RESULTS

### 3.1 Patients

A total of 183 patients met the inclusion criteria. Baseline characteristics are summarized in ***Table 1*** (overall cohort and stratified by presence of chest metastasis).
The mean age was 34.3 ± 11.1 years. At presentation, 79 patients (43.1%) had positive serum tumor markers and 46 (25.1%) had retroperitoneal lymph-node involvement on abdominal CT. On final pathology, 174 (95.0%) were germ-cell tumors (GCT), including 107 (61.4%) pure seminomas. Overall, 140 patients (76.5%) had pathologic stage T1 disease. The most common histologic component was seminoma (present in 129 patients [70.4%]), followed by embryonal carcinoma (60 [32.7%]).
Among the 10 patients (5.5%) with chest metastasis at diagnosis, 9 (90%) had positive tumor markers and 7 (70%) had retroperitoneal nodal involvement. Histology was predominantly nonseminomatous (8/10, 80%). The two seminoma cases had no retroperitoneal nodal disease. Detailed characteristics of metastatic cases are presented in ***Table 2***.

### 3.2 Primary Analysis

Using the prespecified rule (test-positive if either tumor markers or retroperitoneal nodes were positive), there were no false negatives: sensitivity 100% (95% CI, 69.2%–100.0%) and negative predictive value 100% (95% CI, 95.7%–100.0%). ***Table 3*** summarizes the diagnostic performance of the rule.

### 3.3 Secondary Analysis

The specificity of the rule was 48.0% (95% CI, 40.3–55.7) and the positive predictive value was 10.0% (95% CI, 4.9–17.6). If implemented, the rule would have avoided 45.4% (95% CI, 38.0–52.9) of chest CT examinations in the cohort (Table 3).

## 4. DISCUSSION:

One chest CT exposes men with newly diagnosed testicular cancer to approximately 7 mSv roughly equivalent to 70 chest radiographs,[8] and delivers a dose higher than the average annual radiation exposure in the United States (~6.2 mSv) from natural and medical sources combined.[14] In line with statements from major radiology societies, including the American College of Radiology, that advocate for justification and dose optimization for CT[15] we sought to reduce low-value chest CT at baseline staging. This aim is particularly important in testicular cancer, which typically effects young men who may accrue substantial cumulative radiation exposure over prolonged surveillance.[16]
Beyond radiation exposure, routine chest CT also carries a real risk of false positives. In seminoma, Horan et al. reported a false-positive rate of up to 10%.[17] Such findings can set off a cascade: repeat CT scans with additional dose and extra clinic visits. For some patients, this escalates to unnecessary procedures or even chemotherapy. The result is not only avoidable medical intervention but also substantial anxiety for patients and families, along with added cost and disruption to care.
Nonetheless, about 11.4% of patients present with metastatic disease at diagnosis, most often to the lungs,[5] therefore imaging cannot be omitted for everyone. We propose a simple stepwise approach: obtain chest CT only when serum tumor markers are positive or retroperitoneal lymph nodes are abnormal on abdominal CT. This strategy reflects an intentional safety-focused trade-off: prioritizing the avoidance of missed metastatic disease by maintaining high sensitivity while reducing low-yield thoracic CT in patients with reassuring biological and anatomical features. Tumor markers and retroperitoneal imaging were selected as gatekeepers because they capture complementary pathways of metastatic spread, allowing risk stratification without abandoning established staging principles. The key safety question was whether any patient would have chest metastasis despite negative markers and no retroperitoneal lymphadenopathy; in our cohort, none did. The rule achieved sensitivity 100.0% (95% CI, 69.2% to 100.0%) and negative predictive value 100.0% (95% CI, 95.7% to 100.0%).
Prior studies have suggested that when abdominal CT shows no retroperitoneal lymphadenopathy, baseline chest CT can often be deferred in favor of chest radiography.[17,18] This approach fits the known biology of testicular cancer: spread follows a predictable lymphatic route with side-specific drainage to the retroperitoneal nodes (right to interaortocaval/paracaval, left to para-aortic)[19] . Pulmonary metastases usually result from hematogenous dissemination, with the presence of a choriocarcinoma component within the primary lesion representing the principal risk factor for early blood-borne spread. [10] However, lymphatic spread via the thoracic duct to the left supraclavicular nodes and into to the lungs is also possible.[20] Furthemore, intrathoracic metastases are far less common in seminoma than in NSGCT,[20] supporting a more conservative chest imaging strategy in pure seminoma.

Previously published data align with this clinical rationale. In a 245-patient series, Fernandez et al. found that chest CT added no useful information when abdominal CT was negative; only 2.2% of such patients had chest metastases, and all were detected on chest radiography.[18] Horan et al. reported similar findings in seminoma: among patients with normal abdominal CT and a normal chest radiograph, abnormalities seen only on chest CT proved incidental on follow-up.[17]

In light of this evidence, the American Urological Association (AUA) recommend chest radiography rather than chest CT for initial staging in seminoma, whereas in NSGCT, the AUA guidelines advise chest CT for patients proceeding to further treatment.[7] However, the European Association of Urology (EAU) guideline do not distinguish between histologic subtypes and recommends routine chest CT at initial diagnosis.[6]

Relying on normal abdominal CT alone to exclude the need to perform chest CT was found to be insufficient in our cohort. Although only 5.5% of patients had chest metastasis at diagnosis, an abdomen-only strategy would have missed 3 of 10 metastatic cases (30%). Of note, two of the missed cases harbored pure seminoma in the orchiectomy specimen, both with elevated β-hCG (207 and 133,120 IU/L, respectively). The third case was an NSGCT (embryonal carcinoma–predominant) with normal serum tumor markers but isolated pulmonary metastasis (patients 2, 4, and 9 in Table 3). Whether these three cases reflect early hematogenous dissemination or micrometastatic retroperitoneal disease below the CT detection threshold is uncertain, however, the practical implication remains the same; The abdominal CT was interpreted as normal retroperitoneal lymph nodes, and without chest CT these patients would have been under-staged and managed accordingly.

The combined use of serum tumor markers with abdominal CT overcame this limitation in our cohort and identified all metastatic cases In testicular cancer, tumor markers are crucial for proper risk stratification and surveillance, with post-orchiectomy values carrying the greatest prognostic weight.[21,22] As markers are incorporated into the staging system in addition to the anatomic Tumor, Node, Metastasis (TNM), [23] We extend this role by using baseline marker status to guide the initial imaging decision - whether to obtain a chest CT. This strategy has a clear biological rationale: marker elevation reflects tumor burden and, by extension, a higher risk of thoracic metastasis.[11]

Although our rule would have spared nearly half of the patients a chest CT without loss of staging accuracy, the cohort may be too small to exclude very rare presentations of chest metastases with negative markers and no retroperitoneal lymphadenopathy. Accordingly, we recommend pairing the rule with a baseline chest radiograph and reserving chest CT for patients with positive markers, abnormal retroperitoneal nodes, or abnormalities on the radiograph.

This study has several limitations. It is retrospective and single-center, which limits causal inference and generalizability, particularly given the tertiary referral setting and the relatively high proportion of nonseminomatous tumors, which may not reflect case mixes in other clinical environments. Outcome ascertainment relied on the final clinical radiology report without blinded reinterpretation, so misclassification is possible. The number of metastatic events was small (n=10), leading to wide confidence intervals. Accordingly, although no false negatives were observed, the sensitivity estimate remains imprecise and rare presentations of thoracic metastasis with negative markers and normal retroperitoneal imaging cannot be excluded with high confidence. Because the rule was derived and evaluated within the same cohort, optimism bias cannot be excluded and the reported performance may be overestimated. We did not prespecify a sample size, and external validation in independent and more diverse populations is required before broader clinical implementation.

## 5. CONCLUSIONS:

Adopting a simple stepwise strategy that integrates serum tumor markers with abdominal CT before deciding on chest CT may represent a promising risk-stratified strategy to reduce radiation exposure and false-positive chest CT findings in both seminoma and nonseminoma patients. External validation is warranted before broad implementation.

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None

## STATEMENTS AND DECLARATIONS:

**Ethical approval:**

This study protocol was reviewed and approved by the Rambam Health Care Campus Institutional Review Board (Helsinki Committee), Rambam Health Care Campus, Haifa, Israel (approval number RMB-0254-16). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki.

**Consent to participate:**

The requirement for written informed consent was waived by the Rambam Health Care Campus Institutional Review Board (Helsinki Committee), Rambam Health Care Campus, Haifa, Israel, due to the retrospective design of the study and the use of de-identified patient data.

**Conflict of Interest:**

The authors have no conflicts of interest to declare.

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**Author Contributions:**

- Etan Eigner - Was involved in data acquisition and served as the primary author of the manuscript.
- Kamil Malshy - Contributed through critical discussions and provided general guidance during the development of the study, in addition to critical revision of the manuscript.
- Nicola Fazaa – Assisted in drafting the initial version of the manuscript and contributed to various aspects of manuscript preparation and revision.
- Ameer Nsair - Contributed through critical discussions and data collection.
- Melissa Atallah - Contributed through critical discussions and data collection
- Gilad Amiel – provided intellectual input and contributed to discussions that informed the direction of the manuscript.
- Azik Hoffman – Guided the process from the initial conceptualization to critical revision of the manuscript.

**Data Availability Statement:**

The datasets generated and/or analyzed during the current study are not publicly available due to patient privacy considerations and institutional restrictions. De-identified data may be available from the corresponding author upon reasonable request and with approval from the Rambam Health Care Campus Institutional Review Board (Helsinki Committee), in accordance with institutional policies.





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***Abbreviations:***

- ALARA As Low As Reasonably Achievable
- AUA – American Urological Association
- CT – Computed Tomography
- EAU – European Association of Urology
- GCT – Germ-Cell Tumor
- NSGCT – Nonseminomatous Germ-Cell Tumor
- TNM – Tumor, Node, Metastasis

**Table 1.** Baseline characteristics of the cohort overall and by chest metastasis status

*Values are n (%) unless otherwise indicated; means are shown with SD.*

| Variable | Overall (N=183) | No chest metastasis (n = 173) | Chest metastasis (n = 10) |
|---|---|---|---|
| **Age, mean (SD)** | 34.26 (11.11) | 34.69 (11.20) | 26.70 (5.62) |
| **BMI, mean (SD)** | 26.03 (4.84) | 26.04 (4.87) | 25.78 (4.38) |
| **Side of tumor, n(%)** | | | |
| Left | 93 (50.8) | 89 (51.4%) | 4 (40.0%) |
| Right | 90 (49.1) | 84 (48.5%) | 6 (60.0%) |
| **Pre-Orchiectomy positive tumor markers, n(%)** | | | |
| No | 104 (56.8) | 103 (59.5%) | 1 (10.0%) |
| Yes | 79 (43.1) | 70 (40.5%) | 9 (90.0%) |
| **Positive retroperitoneal, nodes (cN+) , n(%)** | | | |
| No | 137 (74.8) | 134 (77.5%) | 3 (30.0%) |
| Yes | 46 (25.1) | 39 (22.5%) | 7 (70.0%) |
| **Pathologic T stage (pT) , n(%)** | | | |
| T1 | 140 (76.5) | 137 (79.2%) | 3 (30.0%) |
| T2 | 30 (16.3) | 27 (15.6%) | 3 (30.0%) |
| T3 | 11 (6.0) | 7 (4.0%) | 4 (40.0%) |
| T4 | 2 (1.0) | 2 (1.2%) | 0 (0.0%) |
| **Tumor size, mean (SD)** | 3.92 (1.96) | 3.89 (1.98) | 4.50 (1.44) |
| **Histology, n(%)** | | | |
| Seminoma | 107 (58.4) | 105 (60.7%) | 2 (20.0%) |
| Non-seminoma | 67 (36.6) | 59 (34.1%) | 8 (80.0%) |
| Sex-cord tumor | 9 (4.9) | 9 (5.2%) | 0 (0.0%) |
| **Histology subtype, n(%)** | | | |
| Embryonal carcinoma | 60 (34.4) | 54 (32.9%) | 6 (60.0%) |
| Yolk sac tumor | 33 (18.9) | 30 (18.2%) | 3 (30.0%) |
| Choriocarcinoma | 7 (4.0) | 7 (4.2%) | 0 (0.0%) |
| Teratoma | 34 (19.5) | 29 (17.6%) | 5 (50.0%) |
| Seminoma | 129 (74.1) | 125 (76.2%) | 4 (40.0%) |

*Abbreviations:* SD, standard deviation; pT, pathologic T stage; cN, clinical nodal stage

**Table 2.** Clinical characteristics of patients with Chest Metastasis at Diagnosis

| Patient | Age | AFP (ng/mL) | LDH (U/L) | β-hCG (mIU/mL) | Markers | Nodes | pT | Histology | Subtypes (NSGCT) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 20.0 | 905 | 468.0 | 79679 | + | + | T3 | NSGCT | EC+, Ter+ |
| 2 | 33.0 | Negative (≤ ULN) | 207.0 | 212 | + | - | T1 | Seminoma | |
| 3 | 23.0 | Negative (≤ ULN) | 324.0 | 6105 | + | + | T2 | NSGCT | EC+, YS+, Ter+ |
| 4 | 22.0 | 13 | 224.0 | 133120 | + | - | T1 | Seminoma | |
| 5 | 21.0 | 20.1 | 201.0 | 70 | + | + | T3 | NSGCT | EC+, Ter+ |
| 6 | 34.0 | 86 | 240.0 | Negative (≤ ULN) | + | + | T1 | NSGCT | YS+, Ter+ |
| 7 | 25.0 | Negative (≤ ULN) | 457.0 | Negative (≤ ULN) | + | + | T2 | NSGCT | EC+ |
| 8 | 24.0 | 4989 | 208.0 | 1948 | + | + | T3 | NSGCT | Ter+ |
| 9 | 33.0 | Negative (≤ ULN) | 226.0 | Negative (≤ ULN) | - | + | T2 | NSGCT | EC+ |
| 10 | 32.0 | 1145 | 357.0 | 399 | + | - | T3 | NSGCT | EC+, YS+ |

*Units: AFP in ng/mL; β-hCG in mIU/mL; LDH in U/L. Abbreviations: EC – Embryonal carcinoma; Ter – Teratoma; YS – Yolk sac tumor; LDH – Lactate dehydrogenase; AFP – Alpha-fetoprotein; β-hCG – Beta human chorionic gonadotropin; NSGCT – Nonseminomatous germ-cell tumor; pT – Pathologic tumor stage; ULN – Upper limit of normal*

**Table 3.** Performance of Stepwise Approach for Chest Imaging

| Category | Measure | Thoracic metastasis (+) | Thoracic metastasis (-) | Total Value | 95% CI |
|---|---|---|---|---|---|
| **Contingency table** | Rule positive (Chest CT recommended) | 10 (TP) | 90 (FP) | 100 | |
| | Rule negative (Chest CT omitted) | 0 (FN) | 83 (TN) | 83 | |
| | Total | 10 | 173 | 183 | |
| **Performance Metrics** | Sensitivity | | | 100.0% | 69.2%–100.0% |
| | Specificity | | | 48.0% | 40.3%–55.7% |
| | Positive predictive value (PPV) | | | 10.0% | 4.9%–17.6% |
| | Negative predictive value (NPV) | | | 100.0% | 95.7%–100.0% |
| | Chest CTs avoided | | | 45.4% | 38.0%–52.9% |

CTs avoided = proportion triaged to omit chest CT at baseline