Cancer in the United States, 2009

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimated New Cases</strong></td>
<td></td>
<td></td>
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<tr>
<td>Prostate</td>
<td>192,280</td>
<td>25%</td>
<td>Breast</td>
<td>192,370</td>
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<tr>
<td>Lung &amp; bronchus</td>
<td>116,090</td>
<td>15%</td>
<td>Lung &amp; bronchus</td>
<td>103,350</td>
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<tr>
<td>Colon &amp; rectum</td>
<td>75,590</td>
<td>10%</td>
<td>Colon &amp; rectum</td>
<td>71,380</td>
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<tr>
<td>Urinary bladder</td>
<td>52,810</td>
<td>7%</td>
<td>Uterine corpus</td>
<td>42,160</td>
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<tr>
<td>Melanoma of the skin</td>
<td>39,080</td>
<td>5%</td>
<td>Non-Hodgkin lymphoma</td>
<td>29,990</td>
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<tr>
<td>Non-Hodgkin lymphoma</td>
<td>35,990</td>
<td>5%</td>
<td>Melanoma of the skin</td>
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<tr>
<td>Kidney &amp; renal pelvis</td>
<td>35,430</td>
<td>5%</td>
<td>Thyroid</td>
<td>27,200</td>
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<tr>
<td>Leukemia</td>
<td>25,630</td>
<td>3%</td>
<td>Kidney &amp; renal pelvis</td>
<td>22,330</td>
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<tr>
<td>Oral cavity &amp; pharynx</td>
<td>25,240</td>
<td>3%</td>
<td>Ovary</td>
<td>21,550</td>
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<tr>
<td>Pancreas</td>
<td>21,050</td>
<td>3%</td>
<td>Pancreas</td>
<td>21,420</td>
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<tr>
<td>All Sites</td>
<td>766,130</td>
<td>100%</td>
<td>All Sites</td>
<td>713,220</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th></th>
<th>Females</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung &amp; bronchus</td>
<td>88,900</td>
<td>30%</td>
<td>Lung &amp; bronchus</td>
<td>70,490</td>
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<tr>
<td>Prostate</td>
<td>27,360</td>
<td>9%</td>
<td>Breast</td>
<td>46,170</td>
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<tr>
<td>Colon &amp; rectum</td>
<td>25,240</td>
<td>9%</td>
<td>Colon &amp; rectum</td>
<td>24,680</td>
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<tr>
<td>Pancreas</td>
<td>18,030</td>
<td>6%</td>
<td>Pancreas</td>
<td>17,210</td>
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<tr>
<td>Leukemia</td>
<td>12,590</td>
<td>4%</td>
<td>Ovary</td>
<td>14,600</td>
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<tr>
<td>Liver &amp; intrahepatic bile duct</td>
<td>12,090</td>
<td>4%</td>
<td>Non-Hodgkin lymphoma</td>
<td>9,870</td>
</tr>
<tr>
<td>Esophagus</td>
<td>11,490</td>
<td>4%</td>
<td>Leukemia</td>
<td>9,280</td>
</tr>
<tr>
<td>Urinary bladder</td>
<td>10,180</td>
<td>3%</td>
<td>Uterine Corpus</td>
<td>7,780</td>
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<tr>
<td>Non-Hodgkin lymphoma</td>
<td>9,830</td>
<td>3%</td>
<td>Liver &amp; intrahepatic bile duct</td>
<td>6,070</td>
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<tr>
<td>Kidney &amp; renal pelvis</td>
<td>8,160</td>
<td>3%</td>
<td>Brain &amp; other nervous system</td>
<td>5,590</td>
</tr>
<tr>
<td>All Sites</td>
<td>229,540</td>
<td>100%</td>
<td>All Sites</td>
<td>268,800</td>
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</tbody>
</table>

Lung Cancer in the United States

Annual Cancer Deaths

- NSCLC (156,380)
- Colorectal (56,887)
- Breast (41,394)
- Prostate (30,719)
- Pancreas (29,802)
- NHL (22,123)
- Leukaemia (21,451)
- Ovarian (14,800)

Nature Reviews | Drug Discovery
The Scheme: From Nicotine Addiction to Lung Cancer

Cigarette smoking → Metabolic Activation (eg. Cytochrome P450) → Field Carcinogenesis

NICOTINE ADDICTION → CARCINOGENS (Ba-P, NNK) → DNA ADDUCTS → MUTATIONS, etc (p53, k-ras, LOH) → LUNG CANCER

Metabolic Detoxification
Glutathione S-Transferase (alpha, mu, pi, theta)

Repair

Excretion
Normal DNA
Apoptosis

Modified from Hecht JNCI; 1999
Lung Cancer Risks

- Cigarette Smoking
  - Environmental Tobacco Smoke
- Other Carcinogens
  - Asbestos, Arsenic, Radon,
  - Bis(chloromethyl) ether, Chromium, Foundry fumes, nickel, mustard gas, coke oven emissions
- Air Pollution (foundries, diesel exhaust)
- Family History
- Diet (Vitamins A, C, E and selenium “protective”)

Overall Incidence

Rates per 100,000, age-adjusted

Source: SEER
Lung Cancer Death Rates, US 1930-2005

Rates per 100,000, age-adjusted

Source: SEER
Smoking Prevalence Rates, US

*Surgeon General’s Report

Garfinkel, Prev Med 26:447, CDC MMWR 56:1157
Percentage of High School Students Who Reported Current Cigarette Smoking

Youth Behavior Survey, MMWR 2000; 49
Presentation of Lung Cancer

- Local Symptoms
  - Cough
  - Dyspnea
  - Hemoptysis
  - Chest Pain
  - SVC Syndrome
  - Wheezing

- Systemic Symptoms
  - Constitutional
  - Skeletal
    - Clubbing
    - Hypertrophic Pulmonary Osteoarthropathy
  - Endocrine
    - SIADH (sclc)
    - Hypercalcemia (squamous)
    - Cushings Syndrome (sclc)
  - Neurologic
    - Horners Syndrome
    - Eaton-Lambert syndrome (sclc)
  Vascular
    - Thrombophlebitis, DIC
Differential Diagnosis

- Benign
  - Granuloma
  - Hamartoma

- Malignant
  - Metastasis
  - Primary Lung Ca
    - Small Cell
    - Carcinoid
    - Non-small Cell
      - Adenocarcinoma
      - Squamous
      - Large Cell
Pathologic diagnosis: specimen types

- Transbronchial biopsy
- Transthoracic needle biopsy
- Cytology
  - Bronchial brushing
  - Lavage
  - Aspiration (transthoracic or transbronchial)
- Surgical Resection-Thoracotomy/VATS
The majority of pulmonary neoplasms are malignant.

Benign tumors/lesions:
- Hamartoma (most common)
- Mesenchymal- leiomyoma, lipoma, chondroma (all unusual)
- Alveolar adenoma (rare)
Hamartoma

Likely a misnomer as these are probably true benign neoplasms, with common chromosomal abnormality (6p21 or 12q14-15).
Malignant tumors - classification

Lung Tumor Classification

Malignant epithelial tumors

- Small cell carcinoma
- Non small cell carcinoma
- Carcinoids
  - Atypical carcinoids

  - Adenocarcinoma
    - Bronchioloalveolar
  - Squamous Ca
    - Various subtypes
  - Large cell CA
    - Various subtypes
Small cell carcinoma

- Usually hilar/central tumor
- The majority have extrapulmonary spread at time of presentation.
- Only 5% present as early stage disease.
- Critical divide between small cell and non-small cell carcinoma
  - Small cell carcinoma staged differently, treated with chemoradiation not surgery.
Small cell carcinoma

- High grade tumor
- Small cells with high nuclear to cytoplasmic ratio
- Nuclear molding with stippled, salt and pepper chromatin
- Frequent mitosis and apoptosis
- “Crush” artifact - very fragile cells
- Neuroendocrine differentiation can be demonstrated by electron microscopy and immunohistochemistry (few neurosecretory granules due to poor differentiation)
Small Cell
Malignant tumors - classification

Lung Tumor Classification

- Malignant epithelial tumors
  - Small cell carcinoma
  - Non small cell carcinoma
    - Adenocarcinoma
      - Bronchioloalveolar
    - Squamous Ca
      - Various subtypes
    - Large cell CA
      - Various subtypes
  - Carcinoids
    - Atypical carcinoids
      - Various subtypes
Atypical adenomatous hyperplasia-adenocarcinoma precursor

- Focal, 5.0 mm or less, with defined borders
- Alveoli lined by cuboidal to low columnar cells with variable atypia
- Alveolar walls may be slightly thickened
- Non-mucinous
- Clinical significance unclear (?time to progression to carcinoma)
Adenocarcinoma

- Most often a peripheral tumor
- Many are near pleura and cause pleural puckering.
- Cut surface can be mucoid or firm, depending on degree of fibrosis and mucin production
- Small tumors can be associated with lymph node and distant metastasis.
Adenocarcinoma
Adenocarcinoma

- Histologic varieties are multiple, including solid, acinar, papillary, mucinous types even within the same tumor
- Rarer types include signet ring morphology
- Differentiation can recapitulate goblet cell, Clara cell or type II pneumocyte differentiation
- Bronchial glands can produce a distinct subtype mimicking salivary gland type tumors
  - These unusual tumors are central and in younger patients
Adenocarcinoma
Adenocarcinoma - Bronchioloalveolar

- Distinct morphologic and clinical variant
- Grows along pre-existing alveoli and terminal bronchioles without stromal invasion
- Grossly can form a nodule, but can also produce diffuse disease mimicking pneumonia
- Can be mucinous or non-mucinous.
- Often multifocal
Adenocarcinoma/”BAC features”

Combined non-invasive and invasive carcinoma
Is there a meaning to the histologic diversity of adenocarcinoma?

- Studies examining response to gefitinib (EGFR targeting tyrosine kinase inhibitor) found activating EGFR mutations in patients with favorable response.
- Gene profiling studies found distinct subclasses of adenocarcinoma.
Biotin-labeled cRNA transcript

Cells

Poly (A)^+ RNA
Or Total RNA

IVT

Biotin-UTP Biotin-CTP

cDNA

Hybridize

Wash & Stain

Scan
Gene expression profiling in lung adenocarcinoma
Are these observations relevant?

- EGFR mutation and amplification correlates with response to EGFR targeted agents (tyrosine kinase inhibitors gefitinib and erlotinib).
  - This subgroup of patients are also more likely to be women, non-smokers, and of Asian descent but not exclusively so.
- Activating K-ras mutations indicate resistance to these agents (about 30% of lung adenocarcinomas)
- Few, if any, lung adenocarcinomas have both activating K-ras and EGFR mutations in the same tumor.
Malignant tumors - classification

Lung Tumor Classification

Malignant epithelial tumors

Small cell carcinoma

Non small cell carcinoma

Carcinoids

Atypical carcinoids

Adenocarcinoma

Squamous Ca

Large cell CA

Bronchioloalveolar Various subtypes Various subtypes Various subtypes
Squamous precursors

- Squamous metaplasia, dysplasia and carcinoma in situ in lung progresses in a sequence similar to the changes described in the head and neck and cervix.

- Koilocytosis is not common; this HPV viral cytopathic change is seen in papillomatosis of larynx and trachea (HPV 6/11)
Squamous carcinoma

- Usually of bronchogenic origin; however can also arise from peripheral areas of squamous metaplasia
- Frequently have central necrosis
- Faster doubling time than adenocarcinoma; often larger at presentation
- Metastasis in relation to tumor size may occur later than adenocarcinoma
Squamous carcinoma
Large cell carcinoma

- This subtype shows no differentiation towards either squamous or adenocarcinoma
- Aggressive tumors with poor prognosis
- If subjected to ultrastructural examination, many of these tumors show either glandular or squamous differentiation.
- Nevertheless, these tumors are separated out because of their high grade and poor prognosis
Large cell carcinoma
Large cell/ Giant cell carcinoma
Carcinoids

- Malignant neoplasm of neuroendocrine cell origin
- Can be central or peripheral; central lesions can cause bronchial obstruction
- Project into bronchial lumen but often have intact mucosa above them (grow under the mucosa)
- Typical carcinoids are low grade malignancies; atypical carcinoids (mitoses and necrosis) are intermediate grade when compared to non-small cell carcinomas
Endobronchial carcinoid
Carcinoids

• Histologic features
  – Nests and cords surrounded by delicate stroma
  – Uniform cells with salt and pepper chromatin
  – Neurosecretory granules are abundant and easily demonstrated by electron microscopy or immunohistochemistry (well differentiated tumors)
CARCINOID
• The lung is a frequent site of metastatic tumor, both from extrapulmonary and intrapulmonary primaries.
• In autopsy series, between 20 and 50% of patients that expire from extra-pulmonary primaries have lung metastasis.
• Melanoma, sarcomas, renal cell carcinoma, germ cell tumors, breast carcinoma as well as carcinomas of bladder, larynx, thyroid and prostate
Metastasis
Lung Cancer Staging

- Small Cell Carcinoma
  Limited- confined to hemithorax
  Extensive

- Non-small Cell Carcinoma
  - T, N, M– Clinical Stage 1-4
Therapy - small cell

- Limited
  - Chemotherapy + Radiation
- Extensive
  - Chemotherapy
# International Staging System, Revised 2009

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<tr>
<th>T/M 6&lt;sup&gt;th&lt;/sup&gt; ed.</th>
<th>T/M 7&lt;sup&gt;th&lt;/sup&gt; ed.</th>
<th>N0</th>
<th>N1</th>
<th>N2</th>
<th>M3</th>
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<tbody>
<tr>
<td>T1 (≤ 2 cm )</td>
<td>T1a</td>
<td>IA</td>
<td>IIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T1 (&gt; 2-3 cm )</td>
<td>T1b</td>
<td>IA</td>
<td>IIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T2 (&gt; 2-3 cm )</td>
<td>T2a</td>
<td>IB</td>
<td>IIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T2 (≤ 5 cm )</td>
<td>T2b</td>
<td>IB</td>
<td>IIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T2 (5-7 cm )</td>
<td>T2b</td>
<td>IIA</td>
<td>IIB</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T2 (&gt; 7 cm )</td>
<td>T3</td>
<td>IIB</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T3 invasion</td>
<td>T3</td>
<td>IIB</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T4 (same lobe nodules)</td>
<td>T3</td>
<td>IIB</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
</tr>
<tr>
<td>T4 (extension)</td>
<td>T4</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
<td>IIIB</td>
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<td>M1 (ipsilateral lung nodules)</td>
<td>T4</td>
<td>IIIA</td>
<td>IIIA</td>
<td>IIIB</td>
<td>IIIB</td>
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<tr>
<td>T4 (pleural effusion)</td>
<td>M1a</td>
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<td>M1 (contralateral lung)</td>
<td>M1a</td>
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<td>IV</td>
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<tr>
<td>M1 (distant)</td>
<td>M1b</td>
<td>IV</td>
<td>IV</td>
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SURVIVAL BY PATHOLOGICAL STAGE

Therapy- Non-small Cell Lung Cancer

- Stage I, II
  - Lobectomy +/- adjuvant chemotherapy
- Stage IIIa
  - Neoadjuvant chemotherapy, radiation, surgery
- Stage IIIb
  - Chemotherapy +/- radiation
- Stage IV
  - Chemotherapy
Kaplan-Meier Estimates of Survival among Patients Who Received Adjuvant Vinorelbine plus Cisplatin and Those Who Underwent Observation Alone

Death despite chemotherapy

Survive without chemotherapy

PERSONALIZED THERAPY

- **Morphology**
  - Small cell: Squamous
  - Non-small cell: Adeno (BAC, Invasive) Large cell

- **Prediction:** Response to therapy - EGFR mutation

- **Prognosis:** Recurrence propensity - Gene expression
EGFR MUTATION STATUS PREDICTS RESPONSE TO TYROSINE KINASE INHIBITOR THERAPY

Genomic Signatures of Resected Tumors Predict Outcome

A Genomic Strategy to Refine Prognosis in Early-Stage Non-Small-Cell Lung Cancer

Anil Potti, M.D., Sayan Mukherjee, Ph.D., Rebecca Petersen, M.D., Holly K. Dressman, Ph.D., Andrea Bild, Ph.D., Jason Koontz, M.D., Robert Kraszke, M.D., Mark A. Watson, M.D., Ph.D., Michael Kelley, M.D., Geoffrey S. Ginsburg, M.D., Ph.D., Mike West, Ph.D., David H. Harpole, Jr., M.D., and Joseph R. Nevins, Ph.D.
