BRIEF REPORT

Brief Report: Increasing Prevalence of Ground-Glass Nodules and Semisolid Lung Lesions on Outpatient Chest Computed Tomography Scans

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ABSTRACT

Introduction: The increased use of cross-sectional imaging frequently identifies a growing number of lung nodules that require follow-up imaging studies and physician consultations. We report here the frequency of finding a ground-glass nodule (GGN) or semisolid lung lesion (SSL) in the past decade within a large academic health system.

Methods: A radiology system database review was performed on all outpatient adult chest computed tomography (CT) scans between 2013 and 2022. Radiology reports were searched for the terms "ground-glass nodule," "subsolid," and "semisolid" to identify reports with findings potentially concerning for an adenocarcinoma spectrum lesion.

Results: A total of 175,715 chest CT scans were performed between 2013 and 2022, with a steadily increasing number every year from 10,817 in 2013 to 21,916 performed in the year 2022. Identification of GGN or SSL on any outpatient CT increased from 5.9% in 2013 to 9.2% in 2022, representing a total of 2019 GGN or SSL reported on CT scans in 2022. The percentage of CT scans with a GGN or SSL finding increased during the study period in men and women and across all age groups above 50 years old.

Conclusions: The total number of CT scans performed and the percentage of chest CT scans with GGN or SSL has more than doubled between 2013 and 2022; currently, 9% of all chest CT scans report a GGN or SSL. Although not all GGN or SSL radiographic findings represent true adenocarcinoma spectrum lesions, they are a growing burden to patients and health systems, and better methods to risk stratify radiographic lesions are needed.

Keywords: Chest CT scan; Lung cancer screening; Incidental lung nodules; Lung adenocarcinoma

Introduction

The use of cross-sectional computed tomography (CT) imaging studies is increasing with 255 scans per 1000 persons performed in the United States in 2021.[1] Chest CT scans frequently identify incidental ground-glass lung nodules and adenocarcinoma spectrum lesions which lead to a growing volume of CT scan interpretations, follow-up imaging studies, and consultations with pulmonologists or thoracic surgeons.

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Lung cancer incidence in the United States has been slowly declining since a peak in 1992, and in 2020, it was newly diagnosed at a rate of 38.8 cases per 100,000 persons.[2] The National Lung Cancer Screening trial results published in 2011 revealed a 20% reduction in lung cancer mortality with low-dose screening CT scans, with a 24.2% rate of positive screening.[3] Several studies have revealed that the adoption of lung cancer screening programs does not change the incidence of lung cancer but rather causes a shift in the stage-specific incidence rates with increased number of stage I cancers diagnosed with increased lung cancer screening scans.[4] Patient selection remains an important component of successful screening. CT scan screening performed in patients with a smoking history has been revealed to find few lung cancers in situ[4]; however, when CT screening is performed on never-smoking, Asian women, the incidence of lung cancer in situ or stage I lung cancer increases from 2.3 to 14.4 per 100,000 people.[5]

Ground-glass nodules (GGNs) are defined as regions of the parenchyma with increased attenuation compared with normal lung tissue, although the bronchovascular structures can be visualized; semisolid lesions (SSLs) have a soft tissue component in addition to the ground-glass regions.[6] The increasing clinical use of chest CT scans and correlation with increasing rates of GGN and SSL has not been reported previously. We describe here the frequency with which a GGN or SSL is found on screening and nonscreening outpatient chest CT scans in a ten-year period from 2013 to 2022.

Methods

A retrospective review of a centralized radiology database was performed on all outpatient chest CT scans for a large Northeast tertiary health care network encompassing six hospitals, more than 2000 hospital beds, and more than 2.2 million annual outpatient encounters. The database mPower Clinical Analytics (Nuance Communications, Inc. Burlington, MA) is a cloud-based system that uses natural language processing to automate the extraction of data from radiology reports. All radiology reports in our system seem automatically in this database. A review was performed for the years 2013 to 2022 after the initiation of a lung cancer screening program in 2013. For the radiology database query, only outpatient CT scans were included. Eligible studies included contrast, noncontrast, low-dose, initial lung cancer screening, and subsequent lung cancer screening CT scans for all adults aged 35 to 99 years old. All screening chest CT scans were performed with slice thickness of 0.625 to 1.0 mm. Age above 35 years old was used as a cutoff on the basis of the Fleischner Society Guidelines[7] (Supplementary Fig. 1).

Search terms of "ground-glass nodule," "subsolid," and "semisolid" were used to identify patients suspected of having a diagnosis of a GGN or a semisolid lung adenocarcinoma spectrum lesion (GGN or SSL). Other search terms were tested and seen in less than 1% of the reports. Our search terms were chosen over the use of words such as "ground-glass" and "ground-glass opacity," which are often used to describe opacified lung regions thought to be infectious or inflammatory. Demographic patient information including sex and age was also collected in addition to the type of CT scan performed.

A Mann-Kendall (MK) test and an alpha of 0.05 were used to test for presence of a trend within the overall cohort and associated subgroups. Chi-squared test was used when comparing percentages between 2013 and 2022. Statistical analysis was performed using Excel with the data analysis plug-in. This study was approved by the Yale Institutional Review Board #2000032675 and by design is exempt from informed consent.

Results

A total of 175,715 chest CT scans were performed between 2013 and 2022, which increased in number every year from 10,817 in 2013 to 21,916 performed in the year 2022, representing a 102.6% increase in total scan volume over the study period (MK $p < 0.001$). There were similar rates of growth in the number of CT scans performed with a 108.2% increase in the number of chest CT scans performed in women and a 96.1% increase among men. By age, the largest growth in the total number of CT scans performed was found among patients in their 70s (172.5% increase), 80s (116.3% increase), and 90s (182.9% increase) (Table 1).

CT scans that reported GGN or SSL findings steadily increased both in number and as a proportion of all chest CTs performed going from 637 scans (5.9% of all chest CT) in 2013 to 2019 scans (9.2% of all chest CT) in 2022 (MK $p < 0.001$). This translates to a 56.4% increase (2013 = 5.9% to 2022 = 9.2%, chi-square $p < 0.001$) in the prevalence of GGN or SSSL findings on CT scan in the ten-year study period, with a total of 7,326 unique patients diagnosed with a GGN or SSL during this time. The annual number of unique patients with GGN or SSL increased from 562 in 2013 to 1,614 in 2022 (MK $p < 0.001$). The absolute number and overall proportion of CT scans reporting GGN or SSL findings increased in both women and men. In the ten-year study period, GGN or SSL findings in women increased by 47.7% and were reported in 10.2% of all CT scans in 2022 (MK $p = 0.001$). In men, GGN or SSL findings increased 48.2% and are now found in 7.0% of all chest CT scans (MK $p = 0.001$) (Table 1, Fig. 1*A* and *B*). The sex ratio among

Table 1. Increasing Chest CT With a Report of GGN or SSL

Table 1. Growth of GGN and SSL as Findings on Outpatient CT Scans

CT Scan Total Number	2013	2022	% Change	MK Trend Test *p* Value
Total outpatient CT scans	10,817	21,916	102.6	0.001
Nonscreening CT scans	10,794	19,731	82.8	<0.001
Lung cancer screening CT	23	2185	9400	<0.001
Sex distribution				
Female	5799	12,074	108.2	0.003
Male	5018	9842	96.1	0.001
Age distribution, y				
35-39	220	327	48.6	0.473
40-49	1044	1295	24.0	0.720
50-59	2483	3760	51.4	0.007
60-69	3366	7081	110.3	0.001
70-79	2435	6636	172.5	<0.001
80-89	1163	2516	116.3	0.001
90-99	105	297	182.9	0.001
Scans With GGN or SSL Findings	2013 # (% of All CT)	2022 # (% of All CT)	% Change of Prevalence of CT Finding	MK Trend Test % of All CT *p* Value
Total GGN or SSL in outpatient CT	637 (5.9)	2019 (9.2)	56.4	0.001
In nonscreening CT scans	636 (5.9)	1828 (9.3)	57.2	0.001
In lung cancer screening CT	1 (4.3)	191 (8.7)	101.1	0.001
Sex distribution of GGN or SSL				
Female	401 (6.9)	1233 (10.2)	47.7	0.001
Male	236 (4.7)	686 (7.0)	48.2	0.007
Age distribution of GGN or SSL, y				
35-39	7 (3.2)	20 (6.1)	92.2	0.003
40-49	47 (4.5)	71 (5.5)	21.8	0.073
50-59	138 (5.6)	251 (6.7)	20.1	0.004
60-69	205 (6.1%)	612 (8.6)	41.9	0.004
70-79	148 (6.1)	720 (10.8)	78.5	0.004
80-89	89 (7.7)	315 (12.5)	63.6	0.019
90-99	3 (2.9)	30 (10.1)	253.5	0.007

Note: An MK test and an α of 0.05 were used to test for presence of a trend within the overall cohort and associated subgroups.
#, number; CT, computed tomography; GGN, ground-glass nodule; MK, Mann-Kendall; SSL, semisolid lung lesion.

scans with GGN or SSL has remained stable during the study period with 61% of GGN or SSL found in women and 39% GGN or SSL found in men in 2022 (Fig. 2*A*).

Increases in GGN or SSL findings on CT scan occurred across all age groups, but most significantly in older patients. MK trend test revealed significant increases in both the number of GGN or SSL and the percent of scans with this finding for all age groups above 50 years old. In 2022, patients in their 70s had a 10.8% chance of a GGN or SSL finding and patients in their 80s had a 12.5% chance of GGN or SSL finding on a chest CT (Table 1 and Fig. 1*C* and *D*). Overall, the age distribution of patients with GGN or SSL findings shifted with patients aged 60 to 79 years old comprising 66.0% of the GGN or SSL findings in 2022 and increased from 55.4% in 2013 (chi-square $p < 0.001$) (Fig. 2*B*).

The number of lung cancer screening CT scans performed in 2022 was 2185, a 9400% increase since the 23 scans done in the first year of the program in 2013, with either initial or subsequent lung cancer screening CT scans comprising 10.0% of all outpatient studies performed in 2022. Outpatient, nonscreening chest CT scans were similarly likely to describe a finding of a GGN or SSL as lung cancer screening CT scans, all at approximately 9% (Table 1, Fig. 1*E* and *F*). The number of screening CT over time (MK $p < 0.001$), the number of screening CT that had a GGN or SSL (MK $p < 0.001$), and the percent of screening CT that contained a GGN or SSL (MK $p < 0.001$) all significantly increased over the study period.

Discussion

This retrospective review is the first to quantify the increased frequency of GGN and SSL findings on outpatient CT scans, which more than doubled in the study

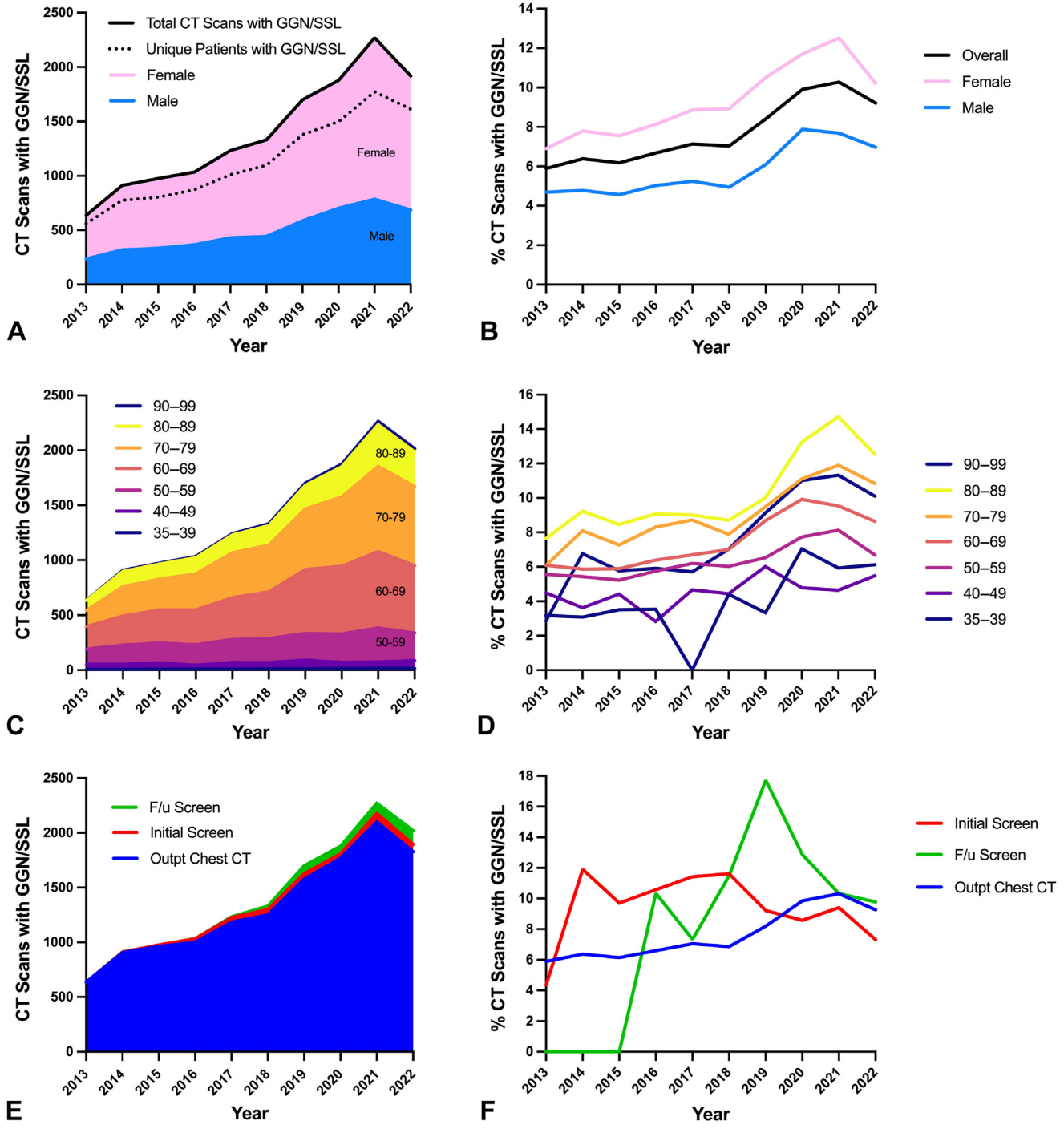

Figure 1. Chest CT scans with GGN or SSL findings over time. (*A*) Increasing total number of chest CT with GGN or SSL (solid line) and increasing number of unique patients (dotted line) with breakdown on the basis of sex, sex data stacked to reveal the proportional breakdown by sex. (*B*) Increasing percentage of CT scans with GGN or SSL findings, data not stacked, sex plotted separately. (*C*) Increasing number of chest CT scans with GGN or SSL findings with breakdown by age, age data stacked to reveal the proportional breakdown. (*D*) Increasing percentage of CT scans with GGN or SSL findings with breakdown by age, data not stacked. (*E*) Increasing number of CT scans with GGN or SSL findings on the basis of outpatient scans versus screening CT scans, data stacked. (*F*) Increasing percentage of CT scans on the basis of outpatient scans versus screening CT scans, data not stacked. A Mann-Kendall test for a statistically significant increasing trend over time was significant with p value less than 0.05, for all the groups found in this figure (overall, for individual patients, for women, for men, and for all age subgroups) except ages 40 to 49 years. CT, computed tomography; GGN, ground-glass nodule; SSL, semisolid lung lesion.

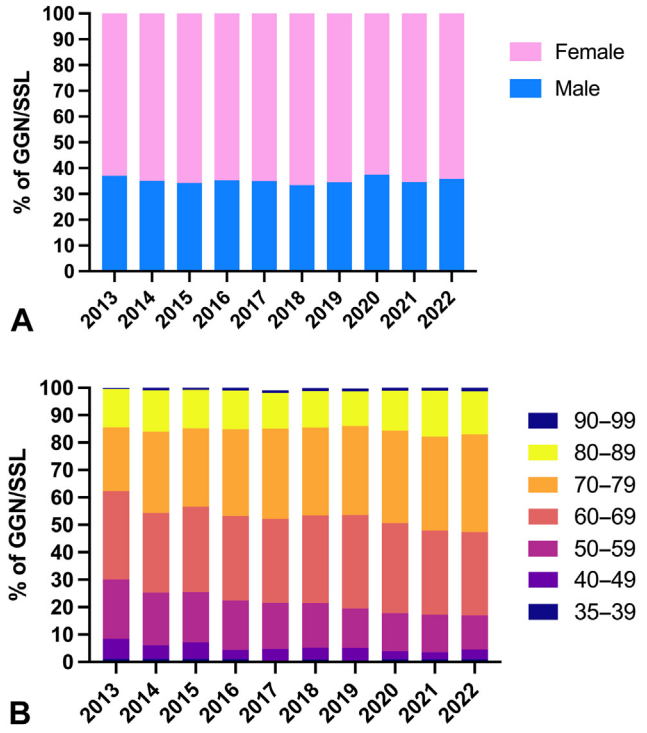

Figure 2. Demographics over time of patients with GGN or SSL. (*A*) No major shifts occurred over 10 years in the female vs male distribution of GGN or SSL. (*B*) The age distribution of patients with GGN or SSL findings shifted with patients aged 60 to 79 years old comprising a greater proportion of patients in 2022 compared with 2013 (66.0% versus 55.4%, chi-square $p < 0.001$). GGN, ground-glass nodule; SSL, semisolid lung lesion.

period between 2013 and 2022. The increasing use of the terms "ground-glass nodule," "subsolid," and "semisolid" in radiology reports in the past decade generates additional needs for physician interpretation, consultation, and subsequent CT scans. Only some of these lesions may persist on imaging over time, and even fewer require treatment. Nevertheless, the increased reporting of GGN and SSL on chest CT scans reflects the growing burden of this problem. The peak, observed in the year 2021, was likely driven in part by an increase in CT scans overall associated with the coronavirus pandemic. Our final numbers for the year 2022, although less than those in 2021, are in line with the overall growth trend trajectory before the pandemic.

A similar correlation between increase in CT scan use and increased diagnosis of incidental stage IA lung cancer was found in a review of the Danish Lung Cancer Registry from 2013 to 2020, in which the relative increase in chest CT scans for reasons other than lung cancer suspicion or screening correlated with the fraction of stage IA lung cancer diagnosed in a particular region.[8]

Though outside of the scope of this study, it is unclear whether these increases in reporting represent a true change in the prevalence of GGN and SSL or an increase in awareness and reporting by radiologists. Improvements in CT imaging technology with better quality images of more subtle findings are also likely to contribute. The question also remains on how many of these lesions identified on CT scan represent true lung adenocarcinoma, though prior data have revealed that semisolid nodules found on screening CT are more likely than solid nodules to be malignant.[9] Although the histologic diagnosis may be unknown, the presence of a GGN or SSL finding has real implications for the patient, including at the very least a repeat CT scan and a discussion with a health care provider. Many patients will have a semisolid lesion followed for years with serial CT scans generating patient stress and repeated health care visits. These additional annual chest CT scans to follow stable or slowly enlarging lesions contribute to the growing number of patients living with GGN and SSL and the steady increase we observed in the volume and percentage of chest CT scans that contain GGN and SSL findings.

The frequency of GGN and SSL on chest CT done for any reason and the need for treatment or follow-up imaging reveal the burden these lesions pose to patients, clinicians, and the health system and the need for lung nodule programs to follow known lesions. Lung nodule programs improve early detection of lung cancer among patients who might not otherwise qualify for screening CT scans,[10] and our data reveal that we should expect increasing demand for these services. Furthermore, the data highlight the need for better methods, potentially aided by artificial intelligence algorithms and tissue- or blood-based biomarkers, to risk stratify GGN and SSL found on CT scan.

CRediT Authorship Contribution Statement

Gavitt A. Woodard: Conceptualization, Data curation, Data analysis, Writing—original draft, Final approval.

Samantha R. Prince: Data curation, Writing—reviewing and editing, Final approval.

Justin D. Blasberg: Data analysis, Writing—reviewing and editing, Final approval.

Andrew P. Dhanasopon: Data analysis, Writing—reviewing and editing, Final approval.

Brooks V. Udelsman: Data analysis, Writing—reviewing and editing, Final approval.

Christopher P. Gange, Jr.: Data analysis, Writing—reviewing and editing, Final approval.

Leah Traube: Data analysis, Writing—reviewing and editing, Final approval.

Vincent J. Mase: Data analysis, Writing—reviewing and editing, Final approval.

Daniel J. Boffa: Data analysis, Writing—reviewing and editing, Final approval.

Frank C. Detterbeck: Data analysis, Writing—reviewing and editing, Final approval.

Anna S. Bader: Conceptualization, Data curation, Data analysis, Writing—reviewing and editing, Final approval.

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Supplementary Data

Note: To access the supplementary material accompanying this article, visit the online version of the *JTO Clinical and Research Reports* at www.jtocrr.org and at https://doi.org/10.1016/j.jtocrr.2023.100583.

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