

# Incidental Pulmonary Nodules Found on Shoulder Arthroplasty Preoperative CT Scans

Journal of Shoulder and Elbow Arthroplasty  
Volume 6: 1–8  
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DOI: 10.1177/24715492221090762  
journals.sagepub.com/home/sea



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## Abstract

With current emphasis on preoperative templating of anatomical and reverse shoulder arthroplasty (aTSA and rTSA, respectively), patients often receive thin slice (<1.0 mm) computerized tomography (CT) scans of the operative shoulder, which includes about two-thirds of the ipsilateral lung. The purpose of this study is to evaluate the prevalence and management of incidentally detected pulmonary nodules on preoperative CT scans for shoulder arthroplasty. In this single-center retrospective study, we queried records of aTSA and rTSA patients from 2015 to 2020 who received preoperative CT imaging of the shoulder. Compared to patients with negative CT findings, there were significantly more females (63.8% vs. 46.4%;  $P = .011$ ), COPD (13.0% vs. 4.7%;  $P = .015$ ), and asthma (18.8% vs. 6.9%;  $P = .003$ ) among the patients with incidental nodules on CT. Binary logistic regression confirmed that female sex (odds ratio = 2.00; 95% CI = 1.04 to 3.88;  $P = .037$ ), COPD history (OR = 3.02; 95% CI = 1.05 to 8.65;  $P = .040$ ), and asthma history (OR = 3.17; 95% CI = 1.30 to 7.77;  $P = .011$ ) were significantly associated with an incidental nodule finding. Incidental pulmonary nodules found on shoulder arthroplasty preoperative CT scans are often low risk in size with low risk of malignancy, and do not require further workup. This study may provide guidance to orthopedic surgeons on how to manage patients with incidental pulmonary nodules to increase chances of early cancer detection, avoid unnecessary referrals, reduce potentially harmful radiation exposure of serial CT scans, and improve cost efficiency.

## Keywords

incidental finding, pulmonary nodule, preoperative imaging, cancer, total shoulder arthroplasty, reverse shoulder arthroplasty, computerized tomography scan, CT scan

Date received: 29 December 2021; revised: 15 February 2022; accepted: 12 March 2022

## Introduction

Incidentally discovered pulmonary nodules on preoperative computerized tomography (CT) scans of the shoulder can be a cause of uncertainty and anxiety for surgeons, patients and families. Although lung cancer is a leading cause of mortality in the United States, early detection of a lung tumor increases the chances of a favorable prognosis.<sup>1</sup> Pulmonary nodules are common, with an average prevalence of 10% detected on chest CT scans done for reasons other than cancer screening, and reported incidences may range up to 70% among the elderly and smokers.<sup>2</sup> As the volume of total shoulder arthroplasty procedures in the US has increased by four-fold over the last two

decades,<sup>3</sup> and preoperative CT imaging has become a popular tool to better understand glenoid deformities and to improve accuracy on component positioning,<sup>4</sup> orthopedic surgeons should become aware of how to counsel and manage patients with incidental pulmonary nodules.<sup>5</sup>

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Despite over 95% of incidental pulmonary nodules being associated with benign causes such as respiratory infections, lymph nodes, atelectasis, and arteriovenous malformations,<sup>6</sup> nodule risk stratification for malignancy is complex and relies on size, location, density, and patient risk factors, with a 6-mm size as the common threshold for concern.<sup>7</sup> The 2017 Fleischner Society guidelines standardized the management of incidentally discovered pulmonary nodules on CT images,<sup>7</sup> but low compliance to these guidelines have been reported among radiologists.<sup>8,9</sup> Inconsistent strategies and follow-up management of pulmonary nodules have been reported for different patient populations based on age and past medical history; especially for patients who are immunocompromised, have a history of malignancy actively under treatment or follow-up, or have existing pulmonary symptoms.<sup>10-12</sup> In addition, over-management of incidental pulmonary nodules has been shown to substantially increase the downstream health care costs of treating these patients.<sup>13</sup>

Given a paucity of data in the literature regarding pulmonary nodules incidentally found on shoulder CT scans, unanswered questions remain. They include whether a nodule found on an incomplete thoracic scan is relevant, how to determine malignancy risk, how the thickness of CT sections intervene in nodule characterization, if a referral to a lung specialist or a complete high-resolution lung CT scan should be performed in such instances, and if the orthopedic surgery should be cancelled, delayed or postponed to focus on nodule workup. The purpose of this retrospective study is to investigate the prevalence and the current management of incidental pulmonary nodules on preoperative CT scans for shoulder arthroplasty, with the goal of providing guidance to orthopedic surgeons on how to adequately manage patients with incidental pulmonary nodules. Such guidance may help increase chances of early cancer detection, avoid unnecessary and inconvenient referrals, reduce potentially harmful radiation exposure of serial tomographic scans, and improve cost-efficiency. We hypothesize that the prevalence of pulmonary nodules on preoperative CT scans is associated with concomitant and confounding factors that, although might not play a role in determining the patients eligibility for shoulder arthroplasty, would help orthopedic surgeons in managing appropriate follow-up with physicians in medical disciplines that can elucidate the severity of the incidental finding further if need be.

## Materials and Methods

### Study Design

In this single-center retrospective study, we queried records of anatomic total shoulder arthroplasty (aTSA) and reverse total shoulder arthroplasty (rTSA) patients from 2017 to 2020 who received preoperative CT imaging of the shoulder. As a large, urban university hospital with affiliations to multiple satellite locations, this center offers multidisciplinary treatment options for patients, including a

“Comprehensive” Cancer Center. Patients were included if they received CT scans before primary total shoulder arthroplasty surgery and if documentation showed a radiologist’s report of the nodule findings, in addition to orthopedic provider notes indicating if the patient proceeded to surgery or if surgical plans changed. Patients were excluded if they did not receive preoperative CT or if pertinent documentation (radiologist’s report noting nodule findings and/or provider notes on acknowledgement of incidence) was not available. Patients demographic information (age, sex, smoking history), pertinent medical history (orthopedic preoperative diagnosis, chronic obstructive pulmonary disease - COPD, asthma, American Society of Anesthesiologists classification, personal and family history of cancer), CT radiology reports (section thickness, nodule size, location and characteristics, Fleischner Society guidelines, and recommendations), orthopedic surgical plan at the time of pulmonary nodule discovery (aTSA or rTSA), clinical notes pertinent to the evaluation of the identified nodules at the discretion of the orthopedic surgeon, and subsequent outcome of nodule on the orthopedic surgical plan (proceed, delay, or cancel surgery) were also collected. Management of the pulmonary nodule was directed by the orthopedic surgeon, based on recommendations by the radiologist, if provided. However, there was not a standard protocol and management varied by provider. Patients found to have incidental pulmonary nodules on CT, as indicated by a radiologist, were included in further review to determine the subsequent course of action (complete chest CT scan, referral to a lung specialist, follow-up with a high-resolution thin-cut complete chest CT scan, and/or invasive procedures) by reviewing orthopedic clinical follow-up and referral notes. IRB approval was obtained for this study.

### Statistical Analysis

An *a priori* power analysis revealed that for a significance level of 0.05 (type-I error), a sample size of 300 patients would be sufficient to power the analysis at 80% and to minimize the risk of a type II error of the null hypothesis, based on previously reported pulmonary nodule incidence. Unpaired t-tests and multivariate binary logistic regression analysis were performed to examine predictive factors (demographic variables and medical comorbidities) associated with an incidental nodule finding on CT. Statistical significance was set at  $P < .05$ . All analyzes were performed in Stata (version 16.1 – Stata Corporation; College Station, TX, USA).

**Table 1.** Patient Characteristics.<sup>1</sup>

Demographics	n	%
Total Patients (n)	302	100
Avg. Age (years)		70.7 ± 12.4
Male : Females (n, %)	150 : 152	49.7% : 50.3%
aTSA : rTSA (n, %)	171 : 131	56.6% : 43.4%

**Table 2.** Preoperative Diagnosis.<sup>2</sup>

Orthop Preop Diagnosis	Patients (n)	%
OA	209	69.2%
Cuff Tear Arthroplasty	54	17.9%
Fracture	18	6.0%
Rotator Cuff Tear	15	5.0%
Malunion	3	1.0%
AVN	3	1.0%

**Table 3.** Patient Risk Factors.<sup>3</sup>

Risk Factors	Patients (n)	%
Smoking History	126	41.7%
Personal or Family History of Cancer	109	36.1%
Asthma	29	9.6%
COPD	20	6.6%
ASA Class 1	17	5.6%
ASA Class 2	176	58.3%
ASA Class 3	102	33.8%
ASA Class 4	0	0.0%

## Results

There were 302 total shoulder arthroplasty patients with a mean age at time of preoperative evaluation of  $70.7 \pm 12.4$  years, of which 50.3% were female (Table 1). A total of 131 patients (43.4%) underwent rTSA and 171 patients (56.6%) underwent aTSA, with varying orthopedic preoperative diagnoses reported (Table 2). Pertinent risk factors for pulmonary nodules identified on medical history are reported on Table 3, with 41.7% of patients reporting history of smoking, and 36.1% personal or family history of cancer. Evaluation of preoperative American Society of Anesthesiologists (ASA) classification revealed that 63.9% of patients were ASA Class 1 or 2 (Table 3).

Out of the total of 302 TSA patients, 69 (22.8%) had an incidental pulmonary nodule detected on the shoulder preoperative CT imaging, with an average nodule size of  $3.8 \pm 2.3$  mm (Table 4). The majority of nodules were  $\leq 5$  mm (84.1%) and only 6 patients had nodules larger than 8 mm. Eighteen nodules were smaller than 1 mm. Thirty-seven out of the 69 patients (53.6%) had multiple nodules on CT, 68.1% of the nodules were located on the superior lobe, and 26.1% of nodules presented calcifications. In addition, 67 out of the 69 patients (97.1%) with nodule findings had high-resolution thin-slice ( $<1.0$  mm) CT scans which were ordered for three-dimensional CT reconstruction (Table 4).

Eight out of 69 patients (11.6%) had previous diagnosis of cancer, including breast cancer, non-Hodgkin's lymphoma, renal cell carcinoma, salivary gland carcinoma, and laryngeal carcinoma, and 15 patients (21.7%) reported family history of cancer. Only 20 out of 69 radiology reports (29.0%) mentioned Fleischner guidelines, and the reviewing radiologist

**Table 4.** Preoperative CT Findings and Results.

Findings/Results	Patients (n)	%
Nodule Detected on Shoulder CT Scan	69	22.8%
High-resolution Thin-slice ( $<1.0$ mm) CT Scan	67	97.1%
Nodule Size (mm)	$3.8 \pm 2.3$ mm	
$\leq 5$ mm	58	84.1%
6 to 8 mm	5	7.2%
$> 8$ mm	6	8.7%
Multiple Nodules vs Single Nodule	37 : 32	53.6% : 46.4%
Superior Lobe vs Other Locations	47 : 22	68.1% : 31.9%
Nodule Characteristics		
Calcification	18	26.1%
Ground-Glass	6	8.7%
Sub-Solid	2	2.9%
Spiculated Margins	1	1.4%
Radiologist Reports		
Nodule Suggested Benign	40	58.0%
Further Workup CT Recommended	20	29.0%
Fleischner Guidelines Present	20	29.0%
CT recommended against Fleischner	7	10.1%
Further Workup Done (Chest CT-scan)	12	17.4%
Invasive Procedures (Biopsy or Surgery)	2	2.9%
Cancer Diagnosis	2	2.9%
Surgery Delayed or Canceled	0	0.0%
Family History of Cancer	15	21.7%
Previous Diagnosis of Cancer	8	11.6%
Breast cancer	2	2.9%
Non-Hodgkins lymphoma	2	2.9%
Renal cell carcinoma	2	2.9%
Salivary gland carcinoma	1	1.4%
Laryngeal carcinoma	1	1.4%

recommended that 13 patients receive CT follow-up in 12 months and 7 patients receive follow-up in 3-6 months. Seven radiology reports that recommended further chest CT scan were in disagreement with the Fleischner guidelines (10.1%). After review of imaging in preparation for their orthopedic surgery and per the standard of care, all reports and recommendations from the radiologist were discussed with all patients for which incidental nodule were found regardless of nodule characterization criteria. They were subsequently advised by their orthopedic surgeon to seek further management care. Only 12 patients actually received additional work-up (3 received chest CT before surgery, 1 patient received surveillance chest CT 3 months after review of findings, 2 patients received surveillance chest CT 6 months after review, 6 patients received surveillance chest CT 12 months after review, and 2 patients were referred to a pulmonologist and received a lung biopsy). Only 2 of the 69 patients with incidental nodule findings

**Table 5.** Comparison of Variables Between Patients with and Without Incidental Nodule Finding on CT.<sup>4</sup>

Variable	No Nodule on CT (n = 233)	Nodule on CT (n = 69)	Absolute Difference	P-value
Female	46.4%	63.8%	17.4%	<b>.011</b>
Asthma	6.9%	18.8%	12.0%	<b>.003</b>
COPD	4.7%	13.0%	8.3%	<b>.015</b>
ASA 1	4.7%	8.7%	4.0%	.210
ASA 2	60.1%	52.2%	7.9%	.243
ASA 3	33.9%	33.3%	0.6%	.930
Surgical Indication:	59.7%	46.4%	13.3%	.051
aTSA				
Cancer History	36.5%	37.9%	1.4%	.841
Smoking History	40.3%	48.5%	8.1%	.238
AVN	1.3%	0.0%	1.3%	.345
Cuff Tear	16.7%	21.7%	5.0%	.343
Arthropathy				
Fracture	6.0%	5.8%	0.2%	.948
Malunion	1.3%	0.0%	1.3%	.345
Osteoarthritis	70.8%	63.8%	7.0%	.267
Rotator Cuff Tear (RCT)	3.9%	8.7%	4.8%	.118

Bold =  $P < .05$ .

(2.9%) were later diagnosed to be malignant (Table 4). None of the patients had their orthopedic surgery delayed, canceled or postponed as a result of the incidental nodule findings on CT of the shoulder.

Unpaired student's t-test showed that compared to patients with negative CT findings, there were significantly more females (63.8% vs. 46.4%;  $P = .011$ ), COPD patients (13.0% vs. 4.7%;  $P = .015$ ), and asthma patients (18.8% vs. 6.9%;  $P = .003$ ) among those with incidental nodules on CT (Table 5). There were no significant differences in the mean values of the other variables between patients without nodule findings and patients with nodule findings on CT. Multivariate binary logistic regression analysis confirmed that female sex (OR = 2.00; 95% CI = 1.04 to 3.88;  $P = .037$ ), COPD history (OR = 3.02; 95% CI = 1.05 to 8.65;  $P = .040$ ), and asthma history (OR = 3.17; 95% CI = 1.30 to 7.77;  $P = .011$ ) were significantly associated with incidental pulmonary nodule finding on shoulder CT scans (Table 6). There were no significant associations between incidental nodule finding and any of the other predictor variables, including age, surgical indication (TSA or RSA), ASA class, personal or family cancer history, smoking history, or preoperative diagnosis.

## Discussion

This study elucidated data on the prevalence and characteristics of pulmonary nodules on shoulder CT scans done for preoperative planning of total shoulder arthroplasty, with over 20% of the scans revealing incidental pulmonary nodules.

**Table 6.** Factors Associated with Incidence of Pulmonary Nodule on CT (Odds-Ratio), on Logistic Regression Analysis.<sup>5</sup>

Variable	Odds Ratio	P value	[95% Conf. Interval]	
Age	1.012	.449	0.982	1.043
Female Sex	2.009	<b>.037</b>	1.041	3.876
Asthma	3.175	<b>.011</b>	1.297	7.773
COPD	3.019	<b>.040</b>	1.053	8.652
Surgical Indication: aTSA	0.866	.718	0.397	1.889
ASA 1	5.069	.346	0.173	148.566
ASA 2	1.128	.941	0.047	27.117
ASA 3	0.921	.960	0.038	22.445
Cancer History	0.931	.826	0.494	1.755
Smoking History	1.645	.119	0.880	3.076
Cuff Tear Arthropathy	0.778	.811	0.099	6.102
Fracture	0.438	.484	0.043	4.413
Osteoarthritis	0.565	.577	0.076	4.191
Rotator Cuff Tear	1.408	.780	0.128	15.461

Bold =  $P < .05$ .

Most nodules were smaller than 5 mm and did not require further workup, and none of the patients had their arthroplasty surgery delayed, postponed or cancelled because of the nodule workup. Female sex, COPD, and asthma were shown to have a significant association with incidental pulmonary nodule findings on shoulder CT scans. To our knowledge, this is the first study to report data on the prevalence and management of incidentally detected pulmonary nodules on shoulder preoperative CT scans for arthroplasty planning, and it may provide guidance to orthopedic surgeons regarding how to counsel and manage patients with incidental pulmonary nodules.

Given that lung cancer is a leading cause of mortality in the United States, and early detection of a tumor increases the chances of a favorable prognosis,<sup>14</sup> incidental pulmonary nodules on preoperative shoulder CT scans can become a source of anxiety for patients and families, and uncertainty for the surgeons as to whether the orthopedic procedure should be cancelled, delayed or postponed in order to focus on the pulmonary nodule workup. Other questions often arise as to whether a nodule found on an incomplete thoracic scan is relevant or how the thickness of CT sections intervene on nodule characterization. Additionally, there remains uncertainty about malignancy risk of nodules and corresponding need for referral to a lung specialist or complete high-resolution lung CT scan.

While the reported average prevalence of pulmonary nodules detected on chest CT scans done for reasons other than cancer screening is around 10%,<sup>2,15-17</sup> it may vary with certain patient risk factors, including smoking history and age.<sup>17,18</sup> Our study demonstrates incidental pulmonary nodules to be twice as prevalent in shoulder arthroplasty preoperative CT scans. This difference may be explained in part by the older population that undergo shoulder arthroplasty.

Literature has shown that over 95% of detected nodules are benign and may have various etiologies, including infection, granulomatous disease, hamartomas, atelectasis, and reactive lymph nodes,<sup>6,19</sup> and nearly all small (<10 mm) nodules are found to be benign during follow-up evaluation, with the exception of small calcified nodules such as chondrosarcomas.<sup>17,18</sup> Additionally, calcified nodules are also considered to be benign and do not require further evaluation.<sup>17</sup> In a recent study of almost 5 million patients who received a CT scan, over 1.5 million patients had nodules identified, and a new lung cancer diagnosis was made in roughly 63 000 patients within 2 years of initial imaging.<sup>20</sup> Although the standard slice thickness for CT scans of the chest is 5 mm, with the current emphasis on preoperative templating of total or reverse shoulder arthroplasty (TSA or RSA), patients often receive thin slice (1.2 mm) CT scans of the operative shoulder, which includes some portion of the ipsilateral lung. Despite this rise in preoperative CT imaging, there are no studies in the literature regarding the frequency of incidental pulmonary nodules for shoulder arthroplasty. In our study, 84% of nodules were smaller than 5 mm and did not require further workup, and only two nodules were found to be malignant. Thus, the small size and low risk of malignancy of incidental nodules found on shoulder CT scans support the decision to proceed with shoulder arthroplasty.

The Fleischner Society provides guidelines for the management of incidental pulmonary nodules detected on CT scans in adults 35 years or older.<sup>7</sup> Decision-making is based on individual patient risk factors, the number of nodules (single or multiple), and specific high-risk nodule features. High-risk patient factors include older age and heavy smoking, and high-risk nodule characteristics include larger size, irregular or spiculated margins, and upper lobe location. These guidelines offer precise recommendations based on patient risk factors and nodule features, but also some flexibility regarding follow-up imaging, which has been shown to reduce unnecessary utilization and costs associated with over-management.<sup>13</sup> In our study, only 30% of the radiology reports mentioned the Fleischner guidelines, and about 10% of the reports suggested inconsistent follow-up decisions. Compliance to Fleischner guideline has been reported to be as low as 34% among radiologists.<sup>8,9</sup> Factors such as nodule size, subspecialty of the radiologist interpreting the imaging results, and incomplete lung imaging CT scans have been identified to influence radiologists' adherence to guidelines.<sup>8,9</sup>

For patients receiving incomplete thoracic CT scans, including CT of the upper extremity, the Fleischner guidelines do not recommend any additional workup for most small nodules (under 6 mm in size), based on slow growth rates and a very low estimated risk of malignancy.<sup>14,21</sup> However, for intermediate-sized nodules measuring between 6 and 8 mm, a follow-up complete CT scan of the chest is recommended within 6 to 12 months, depending on clinical risk,

to confirm nodule stability and to evaluate the other areas of the lung that were not shown on the shoulder CT scan. Only 5 patients in our study had intermediate-sized nodules, of which 3 patients received follow-up with CT scans within 3 or 6 months. Patients with large (> 8 mm) or suspicious nodules (ground-glass, spiculation and upper lobe location) are recommended for further evaluation with chest CT scan within 3 months.<sup>7</sup> Our study had 6 patients with nodules larger than 8 mm of which all except one were recommended to a follow-up chest CT. Not all patients followed recommendations for further imaging of incidental nodules in this study, and the reasons for lack of follow-up or surveillance are not known, but we suspect that COVID-19 pandemic-related disruptions may have prevented some patients in early 2020 to receive workup in adequately time manner. Tanner et al reported that Fleischner guidelines are followed by a minority of providers, or approximately 40%.<sup>22</sup>

Despite providing recommendation for follow-up of suspicious nodules, the Fleischner guidelines do not address specific guidance regarding delaying, postponing or canceling surgical procedures for patients with incidental nodule findings. Within the orthopedic literature, there is a paucity of studies that evaluate the rate of incidental pulmonary nodule findings on preoperative CT or their management. In our study, no patients delayed, postponed or canceled their arthroplasty surgery due to a nodule. Outside of the orthopedic literature, management of pulmonary nodules is discussed in studies of preoperative thoracic CT scans for transcatheter aortic valve implantations (TAVI), with varied treatment decisions. Hussien et al reported that the procedure was canceled in patients whose incidental findings were diagnosed as lung cancer.<sup>23</sup>

In contrast, Schmidt et al found that further tests for incidental solitary pulmonary nodules could be safely performed after the TAVI, such as a follow-up CT scan 6 months after the initial scan, rather than delaying the procedure.<sup>24</sup> Markowiak et al followed patients with incidental solitary pulmonary nodules found on CT evaluation for TAVI and found that only 17% of patients received further work-ups, suggesting that the patients either had lost of follow-up or the cardiac comorbidities had received more clinical attention.<sup>25</sup> Thus, as long as the incidental pulmonary nodule receives adequate management according to the Fleischner Society guidelines, even on the worst risk scenario for malignancy (nodule > 8 mm, located on the upper lobe and high-risk characteristics), it is safe and acceptable to delay the nodule workup up to 3 months in order to the shoulder arthroplasty be done.

It is strongly recommended that the complete chest CT use contiguous thin sections (typically 1.0 mm) with tridimensional reconstruction and archiving to determine the baseline size and characteristics of pulmonary nodules.<sup>6,7</sup> CT scans with thicker sections are less accurate due to greater volume averaging, making it more difficult to characterize and manage small nodules.<sup>7</sup> Current preoperative templating

of aTSA and rTSA require thin slice (<1.0 mm) CT scans of the operative shoulder, which includes about two-thirds of the ipsilateral lung. Thus, nodules found on these shoulder CT scans are of relevance to establish a baseline size and features, and they should be monitored when larger than 5 mm. Once an incidental nodule is found, the risk of cancer depends on a combination of nodule characteristics and patient risk factors. Solid nodules less than 6 mm may have a risk of cancer less than 1%, but other suspicious nodule characteristics may increase this risk up to 5%.<sup>7</sup> Henschke et al found that the risk varied by type of nodule, noting that 63% of partly solid nodules were malignant, while 18% of pure ground-glass nodules and 7% of solid nodules were malignant.<sup>26</sup> In previous studies, patients were referred to pulmonary specialists when follow-up CT scans showed fast-growing pulmonary nodules, defined as nodules with volume-doubling times of less than 400 days. This threshold was sensitive for lung cancer diagnoses.<sup>27,28</sup> In a study by Rosenkrantz et al, all patients with malignant incidental nodules were successfully identified and treated, and these patients did not have disease progression or metastasis. Their findings suggest that the Fleischner Society guidelines are sufficient for follow up.<sup>13</sup>

Nodule multiplicity may also pose a higher risk of cancer. The Netherlands–Leuven Longkanker Screenings Onderzoek trial analyzed patients with multiple nodules and showed that cancer risk is increased as the total nodule count increased from 1 to 4 but decreased with 5 or more nodules.<sup>29</sup> Additionally, the PanCan trial showed that nodule multiplicity was associated with a reduced cancer risk compared to the risk associated with one nodule.<sup>14</sup> Fleischner guidelines recommend that multiple sub-solid nodules smaller than 6 mm should receive chest CT within 3 to 6 months of discovery with additional surveillance CTs every 2 years for up to 5 years of total follow-up.<sup>6</sup> Although 53.4% of incidental nodules found on our study had multiplicity, only two patients had multiple sub-solid nodules that required follow-up CT within 3 to 6 months, as per Fleischner recommendations.

While asthma, COPD, and emphysema seen on chest CT are each independent risk factors for increased lung cancer risk,<sup>30–32</sup> the Fleischner guidelines do not consider asthma or COPD history to be high-risk patient factors for malignancy of incidentally detected pulmonary nodules. Although the current literature does not support an association between the rate of incidental pulmonary nodule detection and patient factors such as asthma or COPD history,<sup>33</sup> our study of shoulder arthroplasty patients found that asthma and COPD are each associated with significantly greater odds of an incidental nodule finding on preoperative CT. Other factors such as smoking history and personal or family history of cancer have been found to be strongly associated with lung cancer, regardless of smoking history.<sup>7,14</sup> Smoking is a well-established major risk factor for lung cancer, especially small cell and squamous cell carcinomas, posing a 10- to 35-fold

increased risk compared to non-smokers.<sup>34–36</sup> Out of the 69 patients with incidental nodule findings on CT, almost half (48.5%) had a current or past history of smoking. Our analysis did not, however, find smoking history to be significantly associated with the odds of an incidental nodule finding, and neither of the two patients with a confirmed cancer diagnosis had any smoking history. Female sex has also been found to be a significant risk factor for cancer in several studies, including the PanCan trial,<sup>7,14,37</sup> and our study found female sex to be significantly associated with a two-times higher odds ratio of an incidental nodule finding. Over 63% of the patients with nodule findings on CT in our study were female, a proportion which was significantly greater than the percent of females in group of patients without nodule findings on CT.

Our study presents with certain limitations. It is a retrospective single-center level III study with a relatively low sample size for an epidemiological study. We did not account for risk factors such as race or occupation history in our analysis, and the study population comprised primarily of older patients, with an average age of over 70 years and various medical co-morbidities. As such, the findings from this study cannot be generalized to patients from other age groups who receive shoulder imaging, including young and healthy patients. Nodules found on patients with a past medical history of malignancy were considered incidental, which may have affected the prevalence of incidental pulmonary nodules in this study. Because they have a much higher risk of pulmonary nodules since lungs are primary site for metastatic disease, the Fleischner guidelines recommend this population subgroup not to be considered as incidental and follow-up recommendations should be individualized. Another limitation stems from the disruption caused by the COVID-19 pandemic as some patients who were recommended to receive follow-up CT scans were unable to obtain them. This study shows that there was not a standard protocol for how pulmonary nodules were managed, and the purpose of this study was not a prescriptive one with regards to management, but rather to report data on management practices. *While our study is not meant to provide prescriptive guidelines or information, we believe that our article offers useful findings that inform readers about the different approaches being used for management of pulmonary nodules. Our study was well powered, confirmed by a priori power analysis.* Additional studies will need to be conducted, across a broader population and including patients undergoing other surgical procedures, to evaluate if radiologist recommendations for follow-up of incidental nodule findings are followed and if they affect surgical plans.

## Conclusion

Incidental pulmonary nodules found on shoulder arthroplasty preoperative CT scans are twice as prevalent as nodules detected on chest CT scans done for reasons other than cancer screening. These nodules are often low risk in size, with low risk of malignancy and do not require further

workup. No patients cancelled, delayed or postponed their arthroplasty surgery because of their findings. Those with comorbidities such as COPD and asthma, as well as females, were found to comprise a significantly greater proportion of the patients with incidental nodule findings on shoulder CT scans.

IRB approval received for protocol # AAAS8117 (M00Y01)

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

### Ethical Approval

Not applicable, because this article does not contain any studies with human or animal subjects.

### Informed Consent

Not applicable, because this article does not contain any studies with human or animal subjects.

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### Trial Registration

Not applicable, because this article does not contain any clinical trials.

### Notes

1. aTSA, anatomic Total Shoulder Arthroplasty; rTSA, reverse Total Shoulder Arthroplasty
2. OA, osteoarthritis; AVN, avascular necrosis
3. COPD, chronic obstructive pulmonary disease; ASA, American Association of Anesthesiologists (classification)
4. aTSA, anatomic Total Shoulder Arthroplasty; COPD, chronic obstructive pulmonary disease; ASA, American Association of Anesthesiologists (classification); AVN, avascular necrosis
5. aTSA, anatomic Total Shoulder Arthroplasty; COPD, chronic obstructive pulmonary disease; ASA, American Association of Anesthesiologists (classification)

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