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Incidental findings in thoracic CTs performed in trauma patients: an underestimated problem

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Abstract

Objectives Whole-body CT scans are commonly performed to assess trauma patients, and often reveal incidental findings (IFs) the patient may be unaware of. We assessed the prevalence, associations, and adequacy of follow-up of IFs.

Methods We retrospectively identified 1113 patients who had a chest CT to assess for traumatic injuries (6-year interval). We coded the radiology reports for IFs and queried our EMR regarding clinical history and adherence to follow-up recommendations for IFs mentioned in the reports.

Results IFs are much more likely (62.2%) to be found in a chest CT scan than acute traumatic injuries (ATI, 32.4%), in patients being evaluated for potential traumatic injuries. A total of 86.4% of patients who had IFs also had another relevant ICD-10 diagnosis (RD). Lung nodules were the most common IF (45.7%). A multivariate logistic regression model (MLR) demonstrated an accuracy of 89% to predict IFs; the 3 statistically significant predictors ($p < 0.05$) were any RD (FDR logworth 68.6), followed by smoking history (29.8) and age (4.1). Radiologists recommended follow-up for IF 53.5% of the time, but only 13.9% of patients ever received a follow-up imaging exam or invasive procedure.

Conclusions IFs are much more common than ATI and can be accurately predicted based on MLR utilizing only 3 clinical variables. While radiologists often recommend follow-up for IFs in trauma patients, most are never effectively followed up or addressed, leading to increased risk of poor outcomes. Clinicians should be aware of the high prevalence of IFs and develop systems for appropriate, evidence-based recommendations, and effective management.

Key Points

- *Incidental findings (IFs) are much more common (2×) than acute traumatic injuries (ATI) in chest CTs performed in trauma patients.*
- *IFs can be accurately predicted via logistic regression modeling with only 3 variables (any relevant ICD-10 diagnosis; positive smoking history; age), which may help radiologist to focus their attention on higher risk patients.*
- *Radiologists recommend follow-up for IFs more than half of the time; however, IFs are seldom followed up appropriately (less than 14%), leading to missed opportunities and potentially poor patient outcomes.*

Keywords Incidental findings · Tomography · Trauma center · Patient compliance

Abbreviations

ATI	Acute traumatic injuries
EMR	Electronic medical record
F/Up	Follow-up
HIPAA	Health Insurance Portability a nd Accountability Act
ICD-10	International Classification of Diseases, 10th edition
IFs	Incidental findings
IRB	Institutional Review Board
MLR	Multivariate logistic regression
NIH	National Institutes of Health
NPV	Negative predictive value
PPV	Positive predictive value
RD	Relevant diagnosis
WBCT	Whole-body CT

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Introduction

Trauma is the greatest cause of loss of years of life in the USA. The total cost associated with trauma-related patient care and decreased productivity associated with disability and loss of life exceeds U$ 670 billion per year (2013) [1], which is greater than the combined societal burden of cancer and cardiovascular disease. Every year, more than 27 million people are treated in emergency departments, 3 million are hospitalized, and nearly 200 thousand patients die as a consequence of violence and unintentional traumatic injuries [1]. A systematic review of nine studies suggested that the use of whole-body CT scans (WBCT), including head, cervical spine, chest, abdomen, and pelvis CTs, is associated with reduced overall mortality in blunt trauma patients, compared with conventional radiographic evaluation [2]. Following ATLS (advanced trauma life support) guidelines, WBCT is widely utilized in trauma patients in the USA, to accurately detect and characterize internal injuries and inform management decisions.

While the increased usage of WBCT has improved the detection of internal injuries in trauma patients, it can also reveal abnormal findings that the patient may not be aware of, which we refer to as incidental findings (IFs), defined as abnormal imaging findings that are not a result of a traumatic event, and which comprise a large variety of etiologies, including neoplastic, infectious, auto-immune, and degenerative diseases. Some of these findings may be clinically significant, such as a lung nodule or a mediastinal mass. Several studies have assessed the prevalence and significance of IFs in trauma patients [3–13], including patterns of utilization of CT in the trauma setting [3]. Many studies concluded that most IFs are found in the abdomen [4, 5, 8–11] and are more common in elderly patients [5, 8, 10]. Nonetheless, IFs requiring diagnostic workup were found to be proportionally more common in the chest than in the abdomen [7]. IFs are detected at a greater rate in WBCT performed routinely in trauma patients (1.5 times more common) when compared with selective, non-routine CTs [12, 13]. A few studies have evaluated the prevalence of IF and the likelihood these are properly communicated to the patient and adequately followed up. One study discovered that 12.5% of IFs required immediate attention before discharge and 37.4% required follow-up within 1 to 2 weeks [5]. Most studies indicate that the rates of disclosure and adequate follow-up of IFs are very low [5, 6, 9, 10]. Another study [9] demonstrated that the most common IF was a lung nodule; however, the disclosure rate of potentially significant IF was low (32.6%). Healthcare providers often do not follow-up adequately with trauma patients who were found to have significant IF. Even worse, many IFs are never disclosed to the patient [9], in spite of potential future harm if clinically significant IFs are ignored. The disclosure rate of incidental findings to trauma patients as documented in the discharge paperwork is generally low and less than 10% in this study [11].

Our aim was to assess a large retrospective cohort of patients who underwent chest CTs as part of evaluation post trauma in a large tertiary healthcare system in the USA, to address the prevalence of IFs in trauma chest CTs, associations, and adequacy of disclosure and follow-up. We also addressed the relevant question of what clinical variables can predict the likelihood that a trauma patient will have a clinically significant IF.

Materials and methods

Patient selection We conducted this IRB (Institutional Review Board)-approved (with HIPAA waiver of informed consent) 6-year retrospective study (2011–2017) of chest CTs of trauma patients admitted through a level I trauma center of a large hospital in the Northeastern USA, via a radiology-centric search engine (Montage, Nuance Corporation), including only patients who experienced a recent traumatic event (< a week before the date of the chest CT) and for which the reason for the chest CT was to assess for acute traumatic injuries (ATI). We assessed patient demographical and clinical information, including age, gender, ethnicity, smoking history, and relevant ICD-10 diagnoses mentioned in the EMR. We defined an ICD-10 diagnosis as relevant if it was a disease diagnosis, not a symptom or a hypothesis. We categorized ICD-10 diagnoses into etiologic groups: cardiovascular, immunologic, oncologic, respiratory, environmental/exposures, and others (which included musculoskeletal, gastrointestinal, genitourinary, and psychiatric).

Imaging protocols We did not directly review the patients' images and instead relied on a review of radiology reports and medical records. Given the wide date range (6 years) of included CT scans, there was variability in scanning protocols; however, all scans included soft tissue and lung reconstruction algorithms, as well as axial, sagittal, and coronal reformations, with axial volumetric, contiguous slices with thickness of 1–2 mm, and were performed on multidetector row CTs (MDCT) scanners from Siemens Healthcare and General Electric Healthcare.

Data collection, coding, and analysis We queried each patient's unique chest CT radiology report and ascertained whether each patient had IF, ATI, both, or neither and subsequently assessed relevant patient outcomes via querying our institution EMR (electronic medical record, Epic Corporation). The conclusion (impression) of chest CT radiology reports was analyzed for any ATI (e.g., fractured ribs or vertebrae, lung contusion, pneumothorax, mediastinal hematoma) and also for any IF not related to the traumatic event. We reviewed each report to determine if IFs were described, as well as whether specific recommendations were made in the conclusion of the report, which we considered to indicate a potentially clinically significant IF. We coded ATI (pulmonary, pleural, cardiovascular, skeletal/chest wall) and IF (lungs, pleural, mediastinum, chest wall, thyroid, skeletal, esophageal, upper abdominal) according to anatomical location. For lung nodules, we categorized radiologists' recommendations into 3 groups: clinically significant with invasive follow-up (biopsy, resection) recommended, clinically significant with non-invasive follow-up recommended, and clinically insignificant—no recommendations made. For IFs that were not lung nodules, we coded the radiologist's recommendations as follows: follow-up chest CT, follow-up with a different imaging study, follow-up with an invasive procedure (such as a biopsy or bronchoscopy), or asking for correlation with clinical and/or laboratorial findings. We also documented the time period (e.g., how many months from the date of the scan) radiologists recommended that follow-up should be completed by. Given that the data analysis happened throughout 2018, every patient had between 1 and 7 years of time elapsed since their trauma chest CT. We cross-referenced the information obtained from chest CT reports with EMR data, to evaluate if at any subsequent visits within our health system any actions were taken regarding IF and also whether the radiologist's recommendations were followed in a timely manner. Patients were considered lost to follow-up if they had no follow-up visits or appointments within our health system after the initial Trauma Department visit. If patients continued to see providers within our health system but did not receive any of the recommended follow-ups for their IF, their discharge papers were analyzed for documentation of the IF. Finally, if the IFs were disclosed to the patient and actions were taken by the patient's healthcare providers; the patients' adherence to the prescribed course of action was assessed.

Data organization and statistical analysis Data was recorded and organized utilizing REDCap [14], a web-based, open access, secure database, and statistical analyses were performed with JMP Pro v14 (SAS). Statistical analyses included a summary and descriptive statistics, univariate analysis, and multivariate analysis to measure the strength of association between key variables, as well as predictive power for IF. Statistical significance was established if p values were < 0.05.

Results

Patient characteristics and demographics We identified a cohort of 1113 patients who underwent chest CT due to a traumatic event in a period of 6 years. Table 1 details the distribution of age, gender, ethnicity, smoking history, and relevant ICD-10 diagnoses mentioned in the EMR.

Prevalence and distribution of ATI and IF Figure 1 and Table 2 detail the distribution of patients who had positive ATI only, positive IF only, both, neither (Fig. 1), and the total prevalence of ATI (31.3%, 349/1113) and IF (62.3%, 694/1113) in our cohort. IFs were nearly twice as prevalent at ATI. Of all patients with positive IF, 86.4% had 1 or more ICD-10 diagnoses. Lung nodules were the most common IF (45.7%). Table 3 details the categories of ATI and IF. The most common ATI category was skeletal/pleural (309/1113), followed by pulmonary (170/1113). The most common IF anatomical location was the lungs (509/1113), followed by mediastinum (237/

Table 1 Demographics, clinical history, and known diagnoses

Variable	Summary and descriptive statistics ($N = 1113$ patients)
Age	Median = 49, range = 17–99, standard deviation = 21
Gender	407 female (36.6%); 706 male (63.4%)
Ethnicity	Asian, 22 (2.0%)
	African American, 360 (32.3%)
	Caucasian, 282 (25.3%)
	Unknown/not reported, 449 (40.3%)
Smoking history	Never or unknown, 870 (78.2%)
	Current smoker, 127 (11.4%)
	Past smoker, 116 (10.4%)
If positive smoking history (past or current), pack-years	Median = 15, range = 0.5–171, standard deviation = 26
ICD-10 diagnosis	Cardiovascular, 276/1113
	Immune-mediated, 44/1113
	Oncologic, 20/1113
	Environmental/exposures, 147/1113
	Respiratory, 103/1113
	Other (MSK, GI, GU, Psych), 316/1113
	Any, 441/1113 (39.6%)
	None, 672/1113 (60.4%)

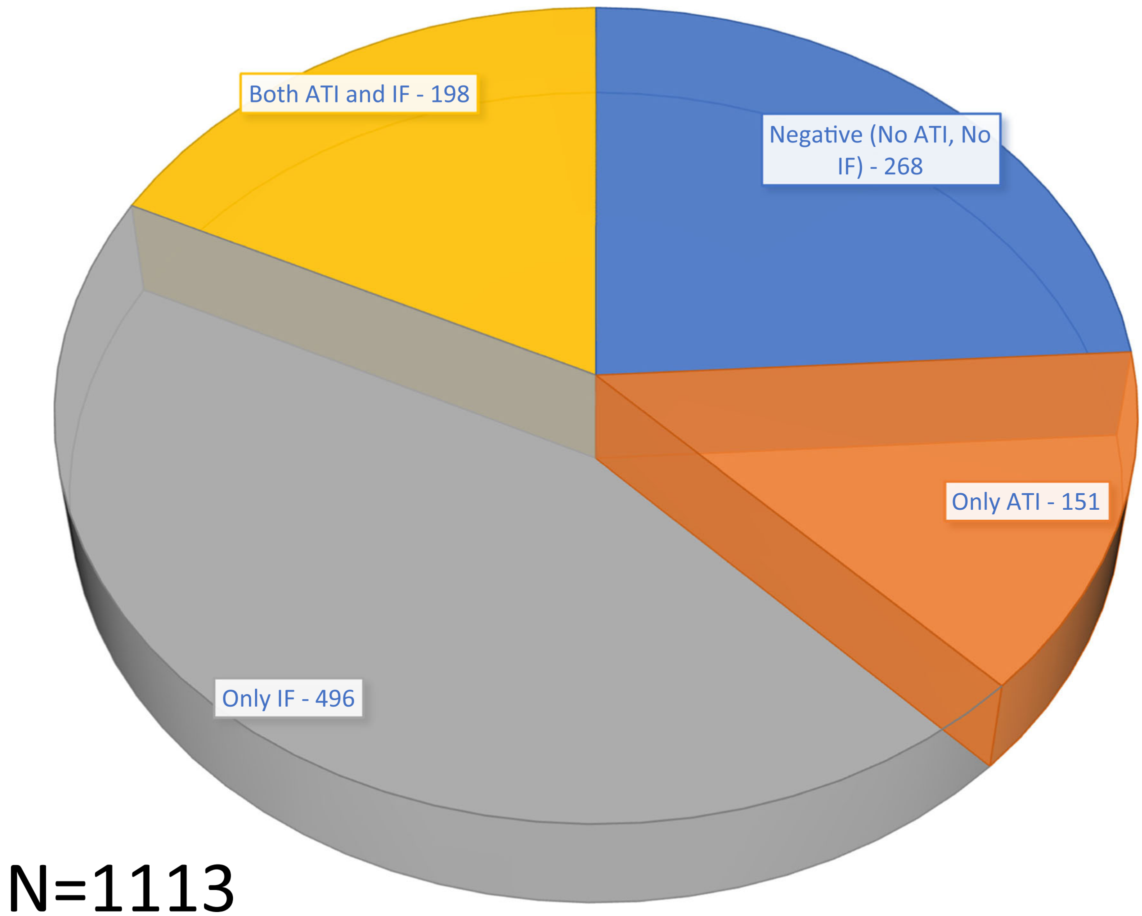

Fig. 1 How many patients had negative chest CTs, only ATI, only IF, or both? (N = 1113 trauma patients)

1113). Of all IFs, lung nodules were the most common (275/694, 39.6%). The median size was 4 mm, mean was 5.3 mm (SD 3.9), and range 1–28.5 mm. Of 275 patients with lung nodules, most had solid (253) attenuation, whereas 17 were ground-glass, and 2 were part-solid. When multiple nodules were present, the nodule deemed most concerning by the interpreting radiologist was recorded.

There were a total of 567 positive ATI (in 349 patients who had any ATI), resulting in an average rate of 1.62 ATI per patient who had a positive chest CT for ATI (764 had no ATI). There were a total of 1056 positive IF (in 694 patients who had any IF), resulting in an average rate of 1.52 IF per patient who had a positive chest CT for IF (419 had no IF).

Table 2 Distribution of ATI and IF

N = 1113 patients	Percentage/number
Prevalence of acute traumatic injuries (ATI)	31.3% (349/1113)
Prevalence of incidental findings (IFs)	62.3% (694/1113)
ATI only	13.6% (151/1113)
IF only	44.6% (496/1113)
ATI and IF	17.8% (198/1113)
ATI or IF	75.9% (845/1113)
Negative scans	24.1% (268/1113)

Table 3 Type of ATI and IF

Type of ATI	Percentage and number
Skeletal/chest wall	27.7% (309/1113)
Pulmonary	15.2% (170/1113)
Pleural	7.4% (83/1113)
Cardiovascular	0.44% (5/1113)
Type of IF	Percentage and number
Lungs	45.7% (509/1113)
Mediastinum	21.3% (237/1113)
Chest wall	1.6% (18/1113)
Thyroid	4.1% (46/1113)
Skeletal	9.3% (103/1113)
Esophageal	4.9% (55/1113)
Upper abdomen	4.9% (54/1113)
Pleural	3.1% (34/1113)

Univariate associations with IF and ATI

Older age is associated with a higher likelihood of positive IF, with AUC (area under the ROC curve) of 0.77. Patients without IF have a mean age of 40.2 (SD 16.8), whereas patients with positive IF have a mean age of 56.2 (SD 21.0), $p < 0.0001$. On the other hand, age is not a predictor of positive ATI, noting that the AUC is 0.51, and there is no statistical difference in age of patients with or without ATI ($p > 0.25$).

Having any relevant ICD-10 diagnosis listed in the EMR is strongly associated with positive IF, with a gamma coefficient of 0.99 and a relative risk of 2.6 (95% CI 2.38–2.89). Positive smoking history is also associated with positive IF, with a relative risk of 1.9 (95% CI 1.80–2.04).

Multivariate models predicting IF

In a multivariate logistic regression model to predict the status of IF (positive or negative), depicted in Table 4, three variables achieved statistical significance and contributed to the model (any ICD-10-relevant diagnosis, positive smoking history, age), with overall model accuracy of 89.0%. Any ICD-10 diagnosis dominated the model, followed by positive smoking history and age.

We also applied a Bayesian classifier using all clinical variables (age, gender, race, ICD-10 diagnoses, smoking history), which achieved a classification performance of 83.9% (16.1% misclassification rate), for the status of IF (positive or negative). The PPV was 98.3% and NPV was 70.7%, similar to the multivariate logistic regression model.

How often radiologists recommend follow-up for IF and how often patients receive appropriate follow-up per radiologist recommendations?

Of all patients with positive IF (694/1113), the interpreting radiologist noted them in the impression of the report 365/694 (52.6%)—these were defined as potentially clinically significant. The other 329/694 (47.4%) were mentioned only in the body of the report and no specific recommendation was made—these were defined as likely not clinically significant. Figure 2 displays the distribution of radiologist recommendations. A clear recommendation was made on 313/365 (85.8%) of potentially clinically significant IF, whereas in 14.2% (52/365) the recommendation was vague or unclear. For the 313/365 potentially clinically significant IF, the most common recommendation was non-invasive imaging follow-up, either with chest CT (mostly for lung nodules) in 49.9% (182/365), followed by other imaging exams (which could be an MRI, CT, US, or nuclear medicine exam) in 27.1% (99/365).

Figure 3 displays the outcomes of the 365 patients who had potentially clinically significant IF. Only 13.7% (50/365) received a follow-up exam as recommended (45/365 timely, meaning within ± 1 month of the radiologist recommended time frame, and 5/365 delayed). A plurality of this cohort did not receive any follow-up that was documented in the EMR, either because the patient was no longer seen in our health system (lost to follow-up, 120/365, 32.9%) or no action was taken by physicians who saw the patient subsequently regarding the IF and the radiologist recommendation (140/365, 38.4%—this group includes the patients for which the radiologist recommendation was unclear or vague). In 54/365 (14.8%) of this cohort, a decision was made and documented not to pursue the radiologist recommendation—in other words, the IF was not considered clinically significant or the clinical context precluded further evaluation.

We assessed, for the 140/365 patients in which no action was taken but who were still seen in our health system following their traumatic event, whether the IF and the radiologist recommendation were explicitly mentioned in the discharge instructions given to the patient. Fifty-seven out of 140 (40.7%) patients received that information, 61/140 (43.6%) did not, and the remainder were either unclear (10/140, 7.1%) or included only in the discharge summary (11/140, 7.9%), which is not necessarily discussed with the patient.

Table 4 Multivariate nominal logistic regression to predict likelihood of IF

Clinical variable	Predictive power (FDR logworth), $^*p < 0.05$
Any ICD-10 diagnosis (on EMR)	68.7*
Smoking history (current, former)	28.3*
Age	4.0*
Model performance	Value
Accuracy	89.0%
Sensitivity	75.0%
Specificity	97.4%
Positive predictive value	97.9%
Negative predictive value	70.3%

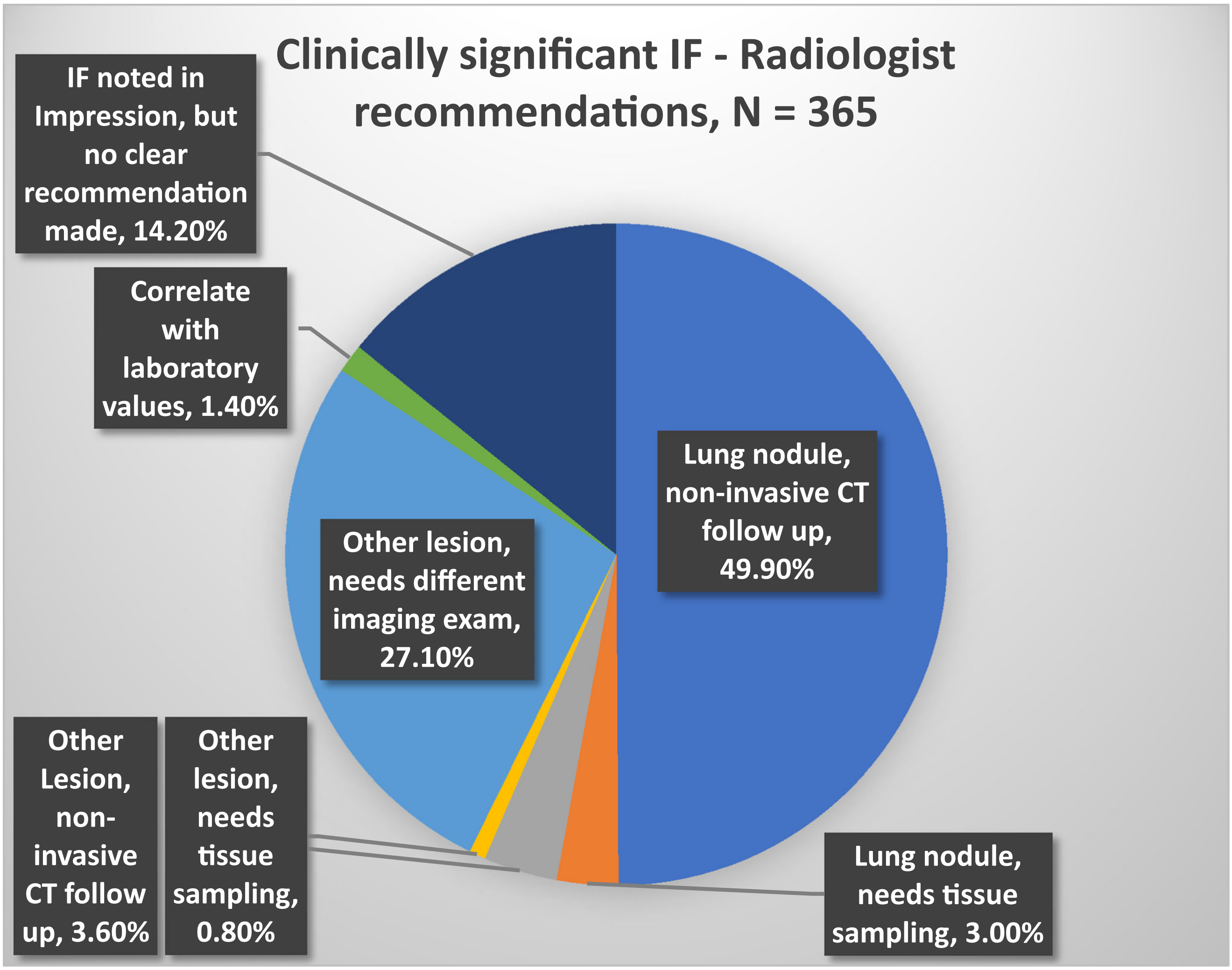

Fig. 2 Radiologist recommendations for clinically significant IF, $N = 365$ trauma patients

Discussion

Our findings demonstrate that IFs are highly prevalent among trauma patients evaluated for ATI with WBCT, and most importantly IFs are nearly twice more likely to be present than ATI (the reason for the exam). Our rate of IF is 1.52 per patient who had any IF (positive IF comprised 62.3% of our cohort). Our rate of ATI is 1.62 per patient who had any ATI (positive ATI comprised 31.3% of our cohort). Published studies have found IFs between 30.4 and 43% of trauma patients undergoing WBCT [15, 16].

Our patient cohort is diverse, substantiating that trauma affects patients of all ages, genders, and ethnic background. We noted that ICD-10 diagnoses, reflecting co-morbidities, were common and 39.6% of all patients had at least one. While prior studies have shown an association of older age and greater prevalence of IF, our study has shown that co-morbidities, as denoted by ICD-10 diagnoses in the EMR, are the strongest predictive factor of positive IF. To our knowledge, our study is the first to elucidate via a quantitative multivariate logistic regression model the 3 most important predictors for a positive IF in chest CTs performed for workup of trauma—co-morbidities (denoted by ICD-10 diagnoses), positive smoking history, and older age, as well as to measure the model predictive accuracy.

While it is a difficult problem to establish in general whether any IF is clinically relevant or not to a particular patient, because of uncertainty regarding the actual diagnosis and variability in the clinical context (e.g., a particular lung nodule has very different clinical significance in a young patient versus an older patient with substantial co-morbidities and limited life expectancy), we relied on our radiologists' expertise and judgment as a surrogate. We made the reasonable assumption that an IF that is only mentioned in the body of the report is unlikely to be clinically relevant, whereas an IF that is mentioned in the conclusion of the report probably is. Using that metric, we found that 52.6% of all patients who had positive IF were deemed to have clinically significant IF.

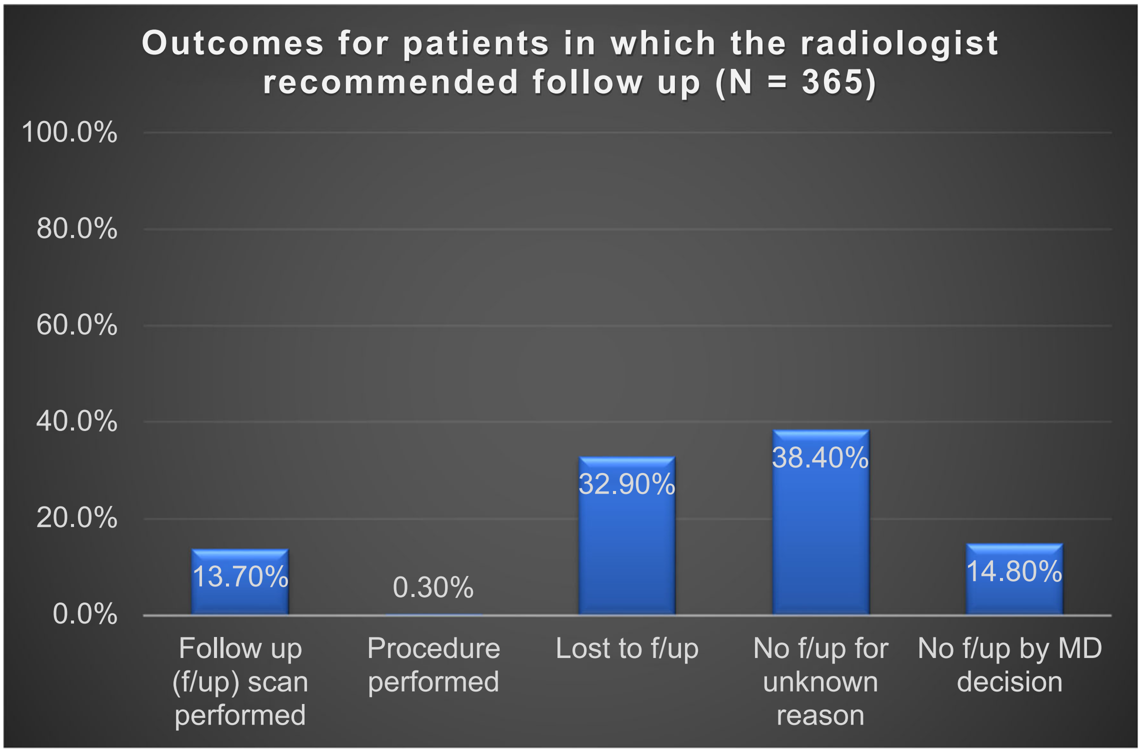

Fig. 3 Outcomes for patients with clinically significant IF in which radiologist recommended follow-up, $N = 365$ trauma patients

Notwithstanding, we showed that most patients never receive adequate follow-up. This is a consistent observation across multiple published studies [5, 9, 15, 16].

However, our study has several limitations. Given its retrospective design and long time period of observation (6 years), there is heterogeneity of reporting attitudes, and documentation of IF is likely to have relatively increased towards the end of the interval. Due to resource constraints, we relied on the radiology reports rather than on direct review of the CT images, meaning that we would not be able to detect errors of perception or interpretation by the radiologists and had to assume that the reports were the "ground-truth." For the patients who were lost to follow-up, we did not have the resources to attempt direct contact, and it is conceivable that some of these patients received follow-up at a different health system. It is also conceivable that some of the positive IFs were already known to the patient, even if not adequately documented in the EMR, which could explain the lack of action/follow-up. Finally, we could not assess an objective severity score for the patients who had positive ATI (not used in our health system) and the management of significant ATI could supersede any action related to positive IF. In spite of these limitations, our large sample size and long observation period likely allow representative conclusions generalizable to the population of patients who underwent WBCT in the setting of trauma.

In conclusion, IFs are very common in the trauma setting (occurring in nearly 2/3 of all trauma patients) and actually 2–3 times more common than ATIs, which are the primary reasons the patients underwent WBCT. While unexpected in the sense that these are not related to the clinical presentation, IFs can be predicted, effectively, via multivariate regression model utilizing only 3 variables (any ICD-10 diagnosis, smoking history, age). The majority of IFs are deemed clinically significant by the interpreting radiologists. While radiologists often document IFs in the conclusion of their reports (and recommend follow-up more than half of the times), only a small minority of patients (less than 14%) received appropriate follow-up, and most patients are never effectively followed up, leading to increased risk of poor outcomes. The lack of documentation of IF on discharge instructions creates an additional potential liability for health systems and providers and may hinder optimal patient care in the setting of clinically significant IF. Radiologists, referring clinicians and health system administrators, need to be aware of the high prevalence of IF and develop better strategies to ensure appropriate, evidence-based recommendations as well as effective management with higher patient adherence [17, 18]. For example, a letter written in lay terminology could be provided to the patient by a physician or advanced non-physician at the time of hospital discharge, with a concise and clear set of recommendations for future action regarding incidental findings detected on trauma-related WBCTs, with the option to discuss directly with a radiologist, should the patient wish. Radiology departments, working together with the patient's primary care provider and family care practices, could establish closed-loop automated confirmation systems to notify the primary care provider whether a patient has missed the time frame for a recommended follow-up examination, or even directly notify the patient via a variety of means, including letters, emails, or other forms of non-intrusive electronic messaging. Taken together, our findings demonstrate the need for substantial improvements in the documentation, disclosure, and follow-up of IF. Opportunistic screening in the setting of trauma offers a unique opportunity to positively impact many lives.

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Compliance with ethical standards

Guarantor The scientific guarantor of this publication is Eduardo J. Mortani Barbosa Jr., MD.

Conflict of interest The authors of this manuscript declare no relationships with any companies, whose products or services may be related to the subject matter of the article.

Statistics and biometry One of the authors (EB) has significant statistical expertise.

Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional Review Board approval was obtained.

Methodology
- retrospective
- observational
- performed at one institution

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