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ORIGINAL RESEARCH

Assessment of Chest X-Ray Utilization for the Evaluation of Non-Traumatic Chest Pain in an Academic Emergency Department

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Abstract

Background: Overutilization of chest X-rays (CXR) is costly, inefficient and results in increased radiation exposure. Several studies have proposed clinical decision rules (CDR) for chest X-ray utilization in non-traumatic chest pain patients presenting to the Emergency Department (ED). However, CDRs are often not one size fits all and may differ based on population variability. The purpose of this study is to 1) Evaluate CXR utilization among ED patients suspected of acute coronary syndrome (ACS) presenting with non-traumatic chest pain and 2) Assess for factors associated with an abnormal CXR in our patient population using criteria from previously developed CDRs.

Methods: We identified 14 clinical criteria from previously derived CDRs that may be predictive of an abnormal CXR. We retrospectively identified 500 patients over age 18 who presented with non-traumatic chest pain between January 2016 and December 2017. Charts were screened for 1) Whether a CXR was performed, 2) CXR results, and 3) The presence of any of the 14 clinical criteria.

Results: 487 (97%) non-traumatic chest pain patients had a CXR performed. 266 (54.6%) patients with zero of the 14 risk factors had a CXR performed. Of those patients, 11 (4.1%) had an abnormality on CXR, 3 (1.1%) of which led to a change in clinical management. Absence of all 14 clinical criteria resulted in a negative predictive value (NPV) of 99%. Further analysis revealed that 9 of the 14 risk factors could be removed in our population with no change in the NPV.

Conclusion: The use of the 6 risk factors from the previously developed CDRs would have reduced CXR utilization by 55% with a NPV of 99%. No single CDR perfectly fit our ED population thus demonstrating variability and need to tailor criteria to each patient population.

Keywords

Chest X-ray, Chest radiograph, Chest pain

Introduction

Chest X-ray (CXR) is commonly used in the ED setting for the evaluation of patients presenting with a complaint of chest pain. However, recent literature suggests that routine CXR in patients presenting with non-traumatic chest pain is over-utilized [1], particularly in patients without any signs or symptoms of other cardiac or pulmonary pathology [2]. In patients that present with non-traumatic chest pain, CXR findings are abnormal in only a small percentage of patients (2.1-19%) [3-6]. Some downstream effects of X-ray overutilization include inefficient allocation of resources across the health system as well as the financial burden to the patient and health system. The average cost of a CXR is about $420, with a range from $120 to $2100 depending on the location [7]. Several studies have proposed clinical decision rules (CDRs) for CXR utilization in non-traumatic chest pain patients presenting to the ED [8,9]. There is some evidence that CDRs have the ability to reduce the number of CXRs performed by up to 47% [4,5]. Developing a CDR with high sensitivity that does not significantly lower specificity can be difficult [6]. This is further complicated by the existence of unique ED patient populations which may each have distinct risk factors for abnormal CXR findings in their non-traumatic chest pain patients. Therefore, CDRs may

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Table 1: Prior studies' CDR criteria and statistical findings for CXR utilization among non-traumatic chest pain patients.

	Rothrock (2002)	Hess (2010)	Poku (2012)	Goldschlager (2013)	Newsom (2018)
Criteria	1. Age ≥ 60 2. Hemoptysis 3. Hx of alcohol abuse 4. Hx of tuberculosis 5. Hx of thromboembolic disease 6. O_2 sat < 90% 7. RR > 24 8. Temp ≥ 38 °C 9. Rales 10. Diminished breath sounds	1. Hx of CHF 2. Hx of smoking 3. Abnormality on lung auscultation	1. Age ≥ 55 2. Hx of smoking 3. SOB 4. Abnormality on lung auscultation	1. Hx of CHF 2. Hx of smoking 3. Abnormality on lung auscultation	1. Age ≥ 60 2. Hx of alcohol abuse 3. Hx of tuberculosis 4. Hx of thromboembolic disease 5. Hx of CHF 6. Hx of smoking 7. O_2 sat < 90% 8. RR > 24 9. Temp ≥ 38 °C 10. Rales 11. Diminished breath sounds
Sensitivity	95%	100%	100%	80%	92.9%
Specificity	40%	36.1%	11.5%	50%	30.4%
PPV	25%	-	6.7%	18%	-
NPV	98%	-	100%	95%	98.4%

NPV: Negative Predictive Value; PPV: Positive Predictive Value; Hx: History; O_2 Sat: Oxygen Saturation; RR: Respiratory Rate; Temp: Temperature; CHF: Congestive Heart Failure; SOB: Shortness of Breath

not be one size fits all and may need to be tailored to a specific patient population. The purpose of our study is to 1) Evaluate CXR utilization among an academic ED patient population presenting with non-traumatic chest pain, and 2) Assess for factors associated with an abnormal CXR in our patient population using criteria from previously developed CDRs.

Methods

Through review of prior literature, we identified 14 clinical criteria from previously derived CDRs that may be predictive of a significant CXR abnormality (Table 1) [8,9]. Using ICD10 codes for non-traumatic diagnoses that might be associated with chest pain, we retrospectively identified 500 patients over the age of 18 who presented to the emergency department with chest pain and who underwent electrocardiogram (ECG) and testing with troponins between January 2016 and December 2017 at Penn State Health Milton S Hershey Medical Center. We assumed that the physician ordering of ECG and troponins signified clinical suspicion of acute coronary syndrome. A single reviewer performed a retrospective review of all 500 medical records. For a single ED visit, each chart was screened for 1) Whether a CXR was performed, 2) The results of the CXR and 3) The presence of any of the 14 clinical criteria from previously developed CDRs.

The CDR clinical criteria were derived from the five prior studies seen in Table 1. The CDRs often shared some of the same criteria, but a few had unique criteria. After taking into account duplicates, there were a total of 14 unique criteria identified including age 60 years or older at time of the ED visit, hemoptysis, or a history of any of the following diseases: Thromboembolic disease, alcohol abuse, tuberculosis, asthma, or congestive heart failure; or if any of the following were evident on physical exam: Rales, rhonchi, wheezes, decreased breath sounds, fever ≥ 100.4 °F, oxygen saturation < 90%, or respiratory rate > 24. All the clinical criteria from the CDRs we identified were examined as potential risk factors in our study in order to minimize the possibility of missing important risk factors for our ED population. We utilized the radiologist's interpretation: normal, no significant change from prior study, or abnormal. Normal and no significant new findings were considered the same for the purposes of this study. All other radiographs were defined as abnormal. Any discrepancies in CXR interpretation were evaluated by an independent physician reviewer. An independent reviewer was required for 23 (4.7%) chest X-rays. As shown in Figure 1, we determined the total number of patients who had CXRs performed and how many of those CXRs had abnormal findings. We then calculated the proportion of abnormal CXRs that were obtained on patients with no risk factors present. For patients with no risk factors and an abnormal CXR, we then identified the patients whose CXR findings led to a change in clinical management. Our research was approved by the institutional review board (IRB) at Penn State College of Medicine. All methods were performed in accordance with the relevant guidelines and regulations. Consent requirement was waived by the IRB as this is a

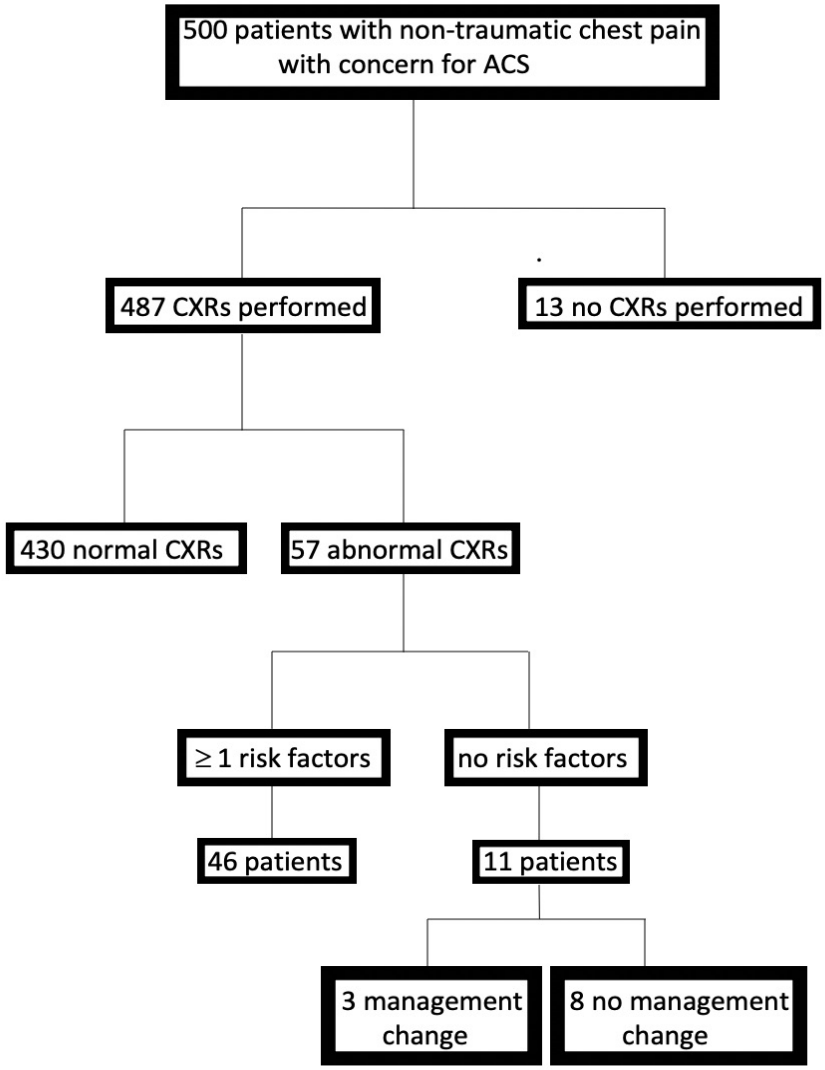

Figure 1: Flow diagram of data analysis and findings. From the entire cohort, we identified the number of patients suspected of Acute Coronary Syndrome (ACS) who had a CXR ordered in the ED. We then determined if the CXR findings were normal or abnormal. For patients with abnormal CXRs, we then assessed if they had any of the risk factors for an abnormal CXR. If patients had no risk factors, we further assessed whether the abnormal CXR findings led to a change in management.

Table 2: Patient characteristics.

Age:	
Mean age	53.8 years of age
Median age	53 years of age
Age range	18 to 99 years of age
18-39	109 (21.8%)
40-59	214 (42.8%)
60-79	138 (27.6%)
80-99	39 (7.8%)
Gender:	
Male	234 (46.8%)
Female	266 (53.2%)
Criteria:	
History of thromboembolic disease	32 (6.4%)
History of alcohol abuse	10 (2.0%)
History of tuberculosis	1 (0.2%)
History of asthma	63 (12.6%)
History of congestive heart failure	35 (7.0%)
Hemoptysis	4 (0.8%)
Rales	13 (2.6%)
Rhonchi	2 (0.4%)
Decreased breath sounds	13 (2.6%)
Wheezes	17 (3.4%)
Temperature ≥ 38 °C	2 (0.4%)
Oxygen saturation < 90%	2 (0.4%)
Respiratory rate > 24	25 (5.0%)

retrospective study with no patient identifiers.

Results

The average age of our patient population was 54 (Table 2). Forty-seven percent of patients were male (Table 2). As seen in Table 3, 487 (97%) patients received a CXR in the ED. Of those 487 patients, 266 (54.6%) had zero of the 14 previously identified risk factors for an abnormal CXR. Eleven (4.1%) of the 266

Table 3: Summary of the results.

Total number of patients	500
Patients that received a chest X-ray	487 (97.4%)
Patients that received chest X-ray and had no risk factors	266 (54.6%)
Patients that received a chest X-ray and had at least 1 risk factor	221 (45.4%)
Patients with an abnormal CXR and at least 1 risk factor	46 (20.8%)
Patients with an abnormal CXR and zero risk factors	11 (4.1%)
Patients with an abnormal CXR which led to a change in management and had zero risk factors	3 (1.1%)

patients with zero risk factors were found to have an abnormal CXR, 3 (1.1%) of which may have led to a change in management. These patients were a stem-cell transplant patient treated for a left lower lobe sub-segmental opacity, a patient with a cough and respiratory rate of 24 with new opacities suggesting pneumonia and treated with antibiotics, and a patient without fever or cough but with "atelectasis versus early pneumonia" who was sent home with antibiotics to use if he became ill.

Eight patients had zero risk factors but abnormal CXR findings which did not result in management changes. Their CXR findings are listed below:

1. Persistent right pleural collection with elevation of right hemidiaphragm. Persistent metallic densities over right flank and left axilla.
2. Streaky opacity in left base, likely atelectasis - cannot exclude early pneumonia.
3. Cardiac silhouette mildly enlarged, prominent interstitial markings.
4. Mild interstitial prominence may reflect pulmonary vascular congestion.
5. Deformities of the right seventh and eighth ribs of indeterminate chronicity. Clinical correlation is recommended.
6. Mild enlargement of the cardiopericardial silhouette which may be due to cardiomegaly, prominent peri-cardial fat, or pericardial effusion. Hypoventilatory changes.
7. Subtle streaky opacity in the left lower lung likely representing atelectasis.
8. Hypoinflated chest with streaky bibasilar opacities likely representing atelectasis.

The absence of all 14 risk factors resulted in a negative predictive value (NPV) of 99%. The presence of at least 1 risk factor had a sensitivity of 94%, specificity of 49%, and a positive predictive value of 15% for an abnormal CXR. Further analysis suggested that we could consolidate to 6 risk factors with no change in NPV or sensitivity. Those 6 risk factors included: Age ≥ 60, history of thromboembolic disease, history of alcohol abuse, history of tuberculosis, history of asthma, and history of congestive heart failure.

Discussion

Several prior studies have demonstrated that clinical decision tools can effectively decrease the number of CXRs obtained in the ED for patients with non-traumatic chest pain [4,5,8,9]. For instance, Goldschlager, et al. demonstrated that their CDR which incorporated Canadian Acute Coronary Syndrome guidelines had a NPV of 95% [4]. The Canadian guidelines are relatively simple consisting of "no history of congestive cardiac failure, no history of smoking, and no abnormalities in lung auscultation." Newsom, et al. performed a prospective validation of a CDR with 12 criteria that had a NPV of 98.4% and would have reduced CXR utilization by 28.9% [5]. However, despite their substantial negative predictive value, CDRs have not been widely implemented for this purpose.

The previously identified CDR criteria, outlined in Table 1, were combined to establish the set of risk factors for our study. Given that the risk factors included nearly all the CDR criteria from these studies, we expected that our sensitivity and NPV would be the highest among the studies. Our sensitivity was 94% which was lower than Hess and Poku, and not much higher than Rockroth. A likely explanation is that Poku, Hess, and Rothrock refined or created criteria retroactively to strengthen the CDR within each study's ED population. In our study, we did not retrospectively add new risk factors to increase our sensitivity. Yet, this provides even stronger evidence that each ED patient population is unique and may each require a modified CDR.

Newsom performed a prospective validation, which used Rothrock's CDR along with 2 new criteria (history of smoking, history of congestive heart failure). Despite adding new criteria that should increase the strength of the CDR, the Newsom study had a lower sensitivity and similar NPV than in Rothrock's study. Patient population differences likely played a role in reducing strength of the CDR in the Newsom study.

In addition to population differences, the research method may also impact CDR accuracy. Goldschlager performed a retrospective study of the Hess criteria. Goldschlager had a lower sensitivity than Hess (80% vs. 100%) and the lowest NPV of all the studies suggesting retrospective analysis could be flawed due to missing data from patient charts. Our study had a lower sensitivity than studies that included fewer criteria,

which could be due to several reasons including lack of retroactive CDR changes, population differences compared to other EDs, and the retrospective nature of our research.

Our study shows the continuing nearly ubiquitous practice of ordering CXRs in our ED on non-traumatic chest pain patients suspected of ACS with 97% of patients receiving CXRs. Overall, for our entire group, 11.7%, had abnormal findings. In the group with zero risk factors, 4.1% had an abnormal CXR. However, these findings changed management in only 1% of patients. Using risk factors to guide decision making in our patient population would have reduced the amount of CXRs ordered by 55%. With an average CXR cost of $420, the cost associated with CXR use would have been decreased by as much as $112,000. The risk factors we identified would miss very few patients with clinically significant CXR findings, as demonstrated by a NPV of 99% and sensitivity of 94%.

Of the 3 patients in whom management was changed, only 1 was likely clinically significant due to immunocompromised status (stem-cell transplant). Another patient had a cough and respiratory rate of 24, which is concerning for a respiratory illness but does not meet any of the criteria. The final patient had possible pneumonia on CXR and was empirically treated with antibiotics despite being asymptomatic on chart review. We question whether treatment was warranted in the last case. The addition of respiratory rate ≥ 24 and immunocompromised status to the CDR would have increased the NPV to nearly 100%. Further analysis showed that we could have consolidated to 6 risk factors, rather than 14, with no change in the NPV or sensitivity. The 6 risk factors are age ≥ 60, history of thromboembolic disease, history of alcohol abuse, history of tuberculosis, history of asthma, and history of congestive heart failure.

Despite the multitude of CDRs in existence and evidence that various CDRs can effectively reduce CXR use with a very high NPV, we identified no CDR that perfectly fit our patient population. The 6 risk factors that proved to be independent positive predictors of an abnormal CXR were a combination of criteria from multiple CDRs rather than just one. Our research indicates that to strengthen the predictive value of a CDR for ordering CXRs in non-traumatic chest pain patients, each ED should evaluate which risk factors apply to their patient populations and consider prospective studies.

Our study had several limitations outlined below:

Our research was a single center study with one reviewer. The retrospective nature of the study requires the use of clinical data that was collected and documented by physicians in the medical record. The physician may not obtain or document all criteria pertinent to our study, and therefore the medical records might not include pertinent positives that would increase the number of patients meeting at least 1 criterion. If any of the criteria were not documented in the chart, the criteria were assumed to be negative.

Conclusion

CXRs are expensive, delay decision-making, and expose patients to radiation. Applying the 14 risk factors from previously developed CDRs to our population resulted in a negative predictive value of 99%. Further analysis revealed that we could have consolidated to 6 risk factors with no change in the NPV or sensitivity. These 6 risk factors were different than any of the previously developed CDRs, suggesting that CDRs are not one size fits all and may vary by patient population. In the future, a prospective study could be performed to determine if the 6 risk factors identified may work as a CDR in our ED.

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None.

Authors Contribution

All authors contributed equally to this work.

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