EM Advances

Derivation of a clinical decision rule for chest radiography in emergency department patients with chest pain and possible acute coronary syndrome

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ABSTRACT

Objective: We derived a clinical decision rule to determine which emergency department (ED) patients with chest pain and possible acute coronary syndrome (ACS) require chest radiography.

Methods: We prospectively enrolled patients over 24 years of age with a primary complaint of chest pain and possible ACS over a 6-month period. Emergency physicians completed standardized clinical assessments and ordered chest radiographs as appropriate. Two blinded investigators independently classified chest radiographs as "normal," "abnormal not requiring intervention" and "abnormal requiring intervention," based on review of the radiology report and the medical record. The primary outcome was abnormality of chest radiographs requiring acute intervention. Analyses included interrater reliability assessment (with κ statistics), univariate analyses and recursive partitioning.

Results: We enrolled 529 patients during the study period between Jul. 1, 2007, and Dec. 31, 2007. Patients had a mean age of 59.9 years, 60.3% were male, 4.0% had a history of congestive heart failure and 21.9% had a history of acute myocardial infarction. Only 2.1% (95% confidence interval [CI] 1.1%–3.8%) of patients had radiographic abnormality of the chest requiring acute intervention. The κ statistic for chest radiograph classification was 0.81 (95% CI 0.66–0.95). We derived the following rule: patients can forgo chest radiography if they have no history of congestive heart failure, no history of smoking and no abnormalities on lung auscultation. The rule was 100% sensitive (95% CI 32.0%–40.4%) and 36.1% specific (95% CI 32.0%–40.4%).

Conclusion: This rule has potential to reduce health care costs and enhance ED patient flow. It requires validation in an independent patient population before introduction into clinical practice.

Keywords: diagnosis, radiography, emergency medical services, acute coronary syndrome, myocardial infarction, unstable angina

RÉSUMÉ

Objectif : Nous avons établi une règle de décision clinique pour déterminer qui, parmi les patients qui se présentent à l'urgence avec des douleurs thoraciques et un possible syndrome coronarien aigu (SCA), doit subir une radiographie pulmonaire.

Méthodes : Nous avons inscrit de manière prospective, pour une période de 6 mois, les patients de plus de 24 ans dont la principale raison de consultation était des douleurs thoraciques et un possible SCA. Les médecins d'urgence ont réalisé des évaluations cliniques normalisées et prescrit des radiographies pulmonaires au besoin. Deux chercheurs ont classé à l'insu les radiographies pulmonaires comme étant « normale », « anormale ne nécessitant aucune intervention » et « anormale nécessitant une intervention », d'après le rapport de radiologie et le dossier médical. Le principal critère d'évaluation était les anomalies des radiographies pulmonaires nécessitant une intervention en phase aiguë. On a calculé la fiabilité inter-évaluateurs (avec statistiques κ) et fait des analyses univariées et par partitionnement récursif.

Résultats : Nous avons retenu la participation de 529 patients pendant la période de l'essai, soit du 1er juillet au 31 décembre 2007. L'âge moyen des patients était de 59,9 ans; 60,3 % étaient des hommes, 4,0 % avaient des antécédents d'insuffisance cardiaque globale et 21,9 % avaient des antécédents d'infarctus aigu du myocarde. Seulement 2,1 % des patients (intervalle de confiance [IC] à 95 %, de 1,1 à 3,8 %) présentaient une anomalie sur la radiographie thoracique nécessitant une intervention en phase aiguë. Les statistiques κ pour la classification des radiographies pulmonaires étaient de 0,81 (IC à 95 %, de 0,66 à 0,95). Nous avons établi la règle suivante : le patient n'a pas besoin de radiographie pulmonaire s'il n'a pas d'antécédents d'insuffisance cardiaque globale ou de tabagisme et que l'auscultation pulmonaire ne révèle aucune anomalie. La règle était sensible à 100 % (IC à 95 %, de 32,0 à 40,4 %), avec une spécificité de 36,1 % (IC à 95 %, de 32,0 à 40,4 %).

Conclusion : Cette règle pourrait réduire les coûts de santé et améliorer le déplacement des patients à l'urgence. Elle doit être validée auprès d'une population de patients indépendante avant d'être appliquée dans la pratique clinique.

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INTRODUCTION

Chest pain is a common chief complaint in Canadian emergency departments (EDs). Although we've been unable to find published country-specific data on the frequency of visits to Canadian EDs for chest pain, data from the United States indicate that chest pain accounts for more than 6 million ED patient visits annually.[1] When a patient presents to the ED with chest pain, clinicians use information from the history, the physical examination, electrocardiography (ECG), basic laboratory tests and chest radiography to identify potential life threats and determine pain etiology. After the initial history and physical examination, if acute coronary syndrome (ACS) is high enough on the differential diagnosis to warrant further cardiac evaluation, then several routine tests are commonly ordered. Among these are ECG, cardiac troponin testing and chest radiography. Substantial evidence supports the use of ECG and cardiac troponin testing in the diagnosis and risk stratification of ACS.[2,3] However, unlike ECG and cardiac troponin, comparatively little evidence supports the routine use of chest radiography in patients with chest pain and possible ACS. In fact, we are not aware of any studies that address the utility of routine chest radiography in this patient population.

Clinical prediction rules attempt to reduce the uncertainty of medical decision-making by standardizing the collection and interpretation of clinical data.[4,5] They are derived from original research and incorporate 3 or more variables from the history, physical examination or basic laboratory tests.[6,7] Given that chest pain is a high-volume condition and that chest radiographs are routinely ordered in the evaluation of possible ACS, a clinical decision rule that identifies high-risk patients for whom chest radiography is indicated, and very low-risk patients for whom it is unnecessary, has the potential to enhance cost efficiency and patient flow in our busy and overcrowded EDs. We sought to determine the prevalence of chest radiographic abnormalities requiring acute intervention in patients with chest pain and possible ACS, and to derive a clinical decision rule for chest radiography in this patient population.

METHODS

Study design

Our study was part of an ongoing prospective cohort study to derive a clinical decision rule for triage of ED patients with chest pain. We enrolled patients presenting to the ED with a primary complaint of chest pain and possible ACS. Our hospital research ethics board approved the protocol without the need for written informed consent. Patients with whom we followed up had the opportunity to give verbal consent during a telephone interview conducted by a study nurse.

Study setting and participants

Our study was conducted at a Canadian university-affiliated ED with an annual census of 60 000 patient visits. We prospectively enrolled a cohort of ED patients over 24 years of age who presented with a primary complaint of chest pain and possible ACS that was high enough on the attending physician's differential diagnosis to order cardiac troponin T testing for the purpose of detecting acute cardiac ischemia. We excluded patients with acute ST-segment elevation in at least 2 contiguous leads, hemodynamic instability or tachycardia (i.e., systolic blood pressure < 90 mm Hg, or heart rate < 50 or > 100 beats/min), a suspected history of cocaine use based on the treating physician's clinical judgment or a positive test for cocaine, a clear traumatic etiology of pain, a terminal noncardiac illness, no available phone contact, pregnancy or previous enrolment within 30 days. On-duty attending emergency physicians and supervised emergency medicine residents assessed patient eligibility and completed data assessment forms.

Data collection

Before beginning data collection, we designed standardized data collection forms. We selected potentially important clinical variables based on a rigorous review of the literature and feedback from the designator emergency physicians.[8] The primary investigator explained the data collection form and individually trained each emergency physician to ensure standardized collection of data. We conducted a 2-month run-in phase during which the data collection forms and variable definitions were further refined as necessary.

On patient arrival, a registration clerk or triage nurse attached the physician data collection form to the ED record of treatment. On-duty attending emergency physicians who were certified in emergency medicine or who supervised emergency medicine residents assessed patient eligibility, completed data collection forms and ordered diagnostic investigations as appropriate. Physician assessors completed data collection forms before ordering chest radiographs and were thus blinded to chest radiographic findings at the time of data collection. A second emergency physician, blinded to the initial assessment, evaluated a subset of patients to determine the interobserver agreement of the predictor variables.

A study nurse identified missed eligible patients by reviewing the daily patient log for all patient visits to the ED with a primary complaint of chest pain. Demographic data were extracted to compare with the overall cohort to ensure that the enrolled patient sample was not biased. A study nurse conducted telephone follow-up 1 month from the ED visit for all enrolled patients. We also reviewed the entire medical record starting at 30 days after ED presentation to determine the occurrence of any adverse outcomes within 30 days of the ED visit.

Outcome measures

The primary outcome was abnormality of a chest radiograph requiring acute intervention. We classified radiographic findings of the chest into 3 categories: "normal," "abnormal not requiring acute intervention" or "abnormal requiring acute intervention." Findings, such as atelectasis, chronic fibrosis, a benign pulmonary nodule or hyperinflation, that were consistent with chronic obstructive pulmonary disease were classified as not requiring acute intervention. We considered pulmonary nodules that were identified on radiographs or computed tomography scans of the chest to be benign if the nodule had a benign appearance. Close follow-up was not recommended if the nodule was present on previous chest radiographs, or if the current investigation did not show any interval changes. We classified abnormalities such as pulmonary edema, consolidation consistent with pneumonia, symptomatic pleural effusion, pneumothorax or any other abnormality requiring treatment by the emergency physician as requiring acute intervention. Two investigators, who were blinded to the data collection forms, independently reviewed all chest radiographic interpretations and the entire medical record to ascertain the clinical significance of radiographic findings. A third investigator, also blinded to the data collection forms, resolved discordances.

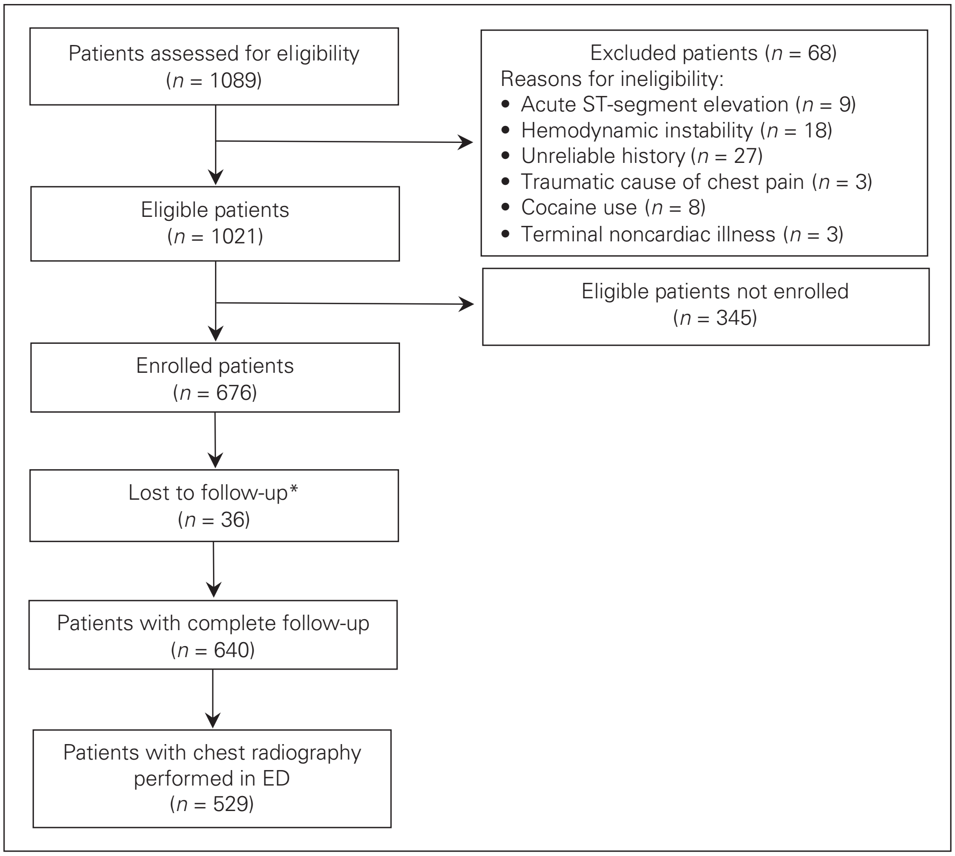

Fig. 1. Flow diagram of prospective cohort study of emergency department (ED) patients with chest pain and possible acute coronary syndrome. *Thirty-six patients could not be reached by telephone for 30-day outcome assessment.

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Data analysis

We calculated descriptive statistics using proportions or means with standard deviations (SDs), as appropriate for the data. The interobserver agreement for each predictor variable was assessed by calculating the κ coefficient, the proportion of potential agreement beyond chance, along with 95% confidence intervals (CIs). Kappa values were not calculated for variables collected from the medical record (e.g., age and oxygen saturation). We also calculated κ values with 95% CI to determine the interobserver agreement between co-investigators for classification of the chest radiographs. Variables with κ values indicating at least substantial agreement (i.e., > 0.6) were considered for inclusion in the prediction rule.

We used univariate analyses to determine the strength of association between each predictor variable and the primary outcome and recursive partitioning to derive the clinical prediction rule. We used SAS software (SAS Institute, Inc.) version 9.1 TS Level 1M3 for data entry and univariate analyses and KnowledgeSEEKER software Version 6.0 (Angoss Software International) for recursive partitioning analysis.[9–11]

RESULTS

From Jul. 1, 2007, to Dec. 31, 2007, we assessed 1089 ED patients for eligibility (Fig. 1), of which 1021 (93.8%) were eligible for enrolment. Of those patients, 345 were seen but not enrolled by treating physicians. Demographics were similar among eligible enrolled and eligible nonenrolled patients, particularly with regard to age (mean 59.9 [SD 14.1] yr v. 62.2 [SD 12.7] yr) and sex (60.3% male v. 58.0% male). Of the 676 enrolled patients, 36 (5.3%) could not be contacted by telephone after 30 days, and thus were considered lost to follow-up. Of the 640 enrolled patients with complete follow-up, chest radiographs were obtained in 529 (82.7%). We included 529 patients in the final analysis.

Table 1 summarizes patient characteristics, management and outcomes of the 529 study patients. Mean patient age was 59.9 (SD 14.1) years, and 60.3% were men. Of the patients, 21.9% had a history of acute myocardial infarction, 21.4% had a history of angina and 27.6% had known coronary artery disease. Thirty-two percent underwent cardiac stress testing and 18.2% coronary angiography. Twenty-one percent were admitted to

Table 1. Patient characteristics, management and outcomes of 529 emergency department patients with nontraumatic chest pain

Characteristic	No. (%) of patients,* n = 529
Mean (SD) [range] age, yr	59.9 (14.1) [26–99]
Male sex	319 (60.3)
Arrival by ambulance	111 (21.0)
Mean (SD) length of stay in ED, h	6.0 (2.9)
Smoking history	
Current	94 (17.8)
Former (< 1 yr)	30 (5.7)
Former (≥ 1 yr)	133 (25.1)
Cardiovascular history	
Acute myocardial infarction	116 (21.9)
Angina (chest pain on exertion)	113 (21.4)
Known coronary artery disease	146 (27.6)
Congestive heart failure	21 (4.0)
Atrial fibrillation	27 (5.1)
Stroke or transient ischemic attack	14 (2.6)
Management and outcomes	
Cardiac stress testing	172 (32.5)
Computed tomographic coronary angiography	19 (3.6)
Coronary angiography	96 (18.1)
Admitted to hospital	112 (21.2)
Acute myocardial infarction†	116 (21.9)
Revascularization	60 (11.3)
Percutaneous coronary intervention‡	47 (8.9)
Coronary artery bypass grafting	13 (2.5)
Death	1 (0.2)
Acute myocardial infarction, revascularization or death within 30 d	77 (14.6)

ED = emergency department; SD= standard deviation.
*Unless otherwise indicated.
†30 of 48 patients with acute myocardial infarction underwent revascularization.
‡Angioplasty and/or stent placement.

Table 2. Chest radiographic findings in 529 emergency department patients with nontraumatic chest pain

Chest radiographic findings	No. (%) of chest radiographs, n = 529
Normal	482 (91.1)
Abnormal requiring acute intervention	11 (2.1)
Pulmonary edema	7 (1.3)
Consolidation	3 (0.6)
Large pleural effusion	1 (0.2)
Abnormal not requiring acute intervention	36 (6.8)
Atelectasis	12 (2.3)
Cardiomegaly	8 (1.5)
Benign pulmonary nodule	8 (1.5)
Hyperinflation	3 (0.6)
Chronic fibrosis	2 (0.4)
Small pleural effusion	2 (0.4)
Postoperative changes	1 (0.2)

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hospital and 14.6% experienced acute myocardial infarction, revascularization or death within 30 days of the ED visit.

Table 2 describes the radiographic chest findings in further detail. Of the chest radiographs, 91.1% were classified as normal and 2.1% (95% CI 1.1%–3.8%) were classified as having an abnormality requiring intervention. The κ value for classification of the chest radiograph was 0.81 (95% CI 0.66–0.95). Of the 11 abnormal chest radiographs requiring intervention, 7 demonstrated pulmonary edema and 3 consolidation consistent with pneumonia. One chest radiograph identified a new pleural effusion that opacified approximately 50% of the patient's hemithorax and required therapeutic drainage. Of the 36 abnormal chest radiographs not requiring intervention, 12 demonstrated atelectasis, 8 showed cardiomegaly and 8 showed a pulmonary nodule.

Table 3 shows the association between the predictor variables and chest radiographic abnormalities requiring acute intervention as determined by univariate analyses. Of the 37 predictor variables assessed, 6 were significantly associated with the primary outcome ($p < 0.05$). Two variables were marginally associated with the primary outcome: shortness of breath ($p = 0.06$) and being a smoker ($p = 0.07$). All the variables displayed in Table 3 had κ values greater than 0.6.

Using recursive partitioning analysis, we derived a clinical decision rule to determine which patients require chest radiography (Box 1). In deriving the rule, we maintained 100% sensitivity while optimizing specificity. The rule determines that patients with chest pain and possible ACS can forgo chest radiography if they meet 3 criteria: 1) there is no history of congestive heart failure, 2) there is no history of smoking and 3) the lung examination is normal.

The accuracy of the decision rule to predict clinically important abnormalities of chest radiographs is shown in Table 4. The decision instrument had 100% sensitivity

Table 3. Univariate correlation and κ values of select variables from the history and physical examination for abnormality on chest radiography requiring intervention

	No. (%) of chest radiographs			
Patient characteristic/clinical finding	No abnormality requiring acute intervention, $n = 518$	Abnormality requiring acute intervention, $n = 11$	p value	κ value, $n = 49$
Age ≥ 65 yr	178 (34.4)	9 (81.8)	< 0.01	—
Smoker (current or former)	250 (48.3)	7 (63.6)	0.07	0.88
History of congestive heart failure	17 (3.3)	4 (36.4)	< 0.01	1.00
History of myocardial infarction	111 (21.4)	5 (45.5)	0.17	0.95
History of atrial fibrillation	23 (4.4)	4 (36.4)	0.01	0.88
No cardiovascular history	288 (55.6)	2 (18.2)	0.02	1.00
Hypoxia (oxygen saturation < 93%)	54 (10.4)	1 (9.1)	1.00	—
Shortness of breath	219 (42.3)	8 (72.7)	0.06	0.70
No abnormalities on lung auscultation	471 (90.9)	5 (45.5)	< 0.01	0.65
Pitting edema	34 (6.6)	4 (36.4)	0.01	0.77

Box 1. Clinical decision rule to determine which patients require chest radiography

A patient with chest pain and possible acute coronary syndrome who meets no exclusion criteria* can forgo chest radiography on initial assessment if ALL of the following criteria are met:

- there is no history of congestive heart failure
- the patient is not a smoker
- the lung examination is normal

*We excluded patients with acute ST-segment elevation, hemodynamic instability or cocaine use.

Table 4. Diagnostic accuracy of a clinical decision rule for chest radiography in patients with chest pain and possible acute coronary syndrome

Decision rule	Abnormality requiring intervention	No abnormality requiring intervention
Yes	11	331
No	0	187
Classification performance	%	(95% CI)
Sensitivity	100.0	(71.5%–100.0%)
Specificity	36.1	(32.0%–40.4%)
Proportion of chest radiographs	64.5	(60.2%–68.5%)

CI = confidence interval.

(95% CI 71.5%–100.0%) and 36.1% specificity (95% CI 32.0%–40.4%) for predicting chest radiographic abnormalities requiring acute intervention. The ordering rate for potential chest radiography was 64.5% (95% CI 60.2%–68.5%). Based on these data, usage of chest radiography could drop from 82.7% to 64.5% (18.2% absolute reduction) if the rule were applied in our practice setting.

DISCUSSION

To our knowledge, this is the first study to determine the prevalence of abnormalities of chest radiographs requiring intervention and to derive a clinical decision rule for chest radiography in patients with chest pain and possible ACS. Given that we order chest radiographs every day when evaluating patients with chest pain, it is surprising that routine chest radiography has received such little scrutiny in the medical literature. These data suggest that current ordering practices for chest radiographs are inefficient, with over 90% having no abnormal findings. Using simple clinical features, we successfully derived a highly sensitive clinical prediction rule for chest radiographs (sensitivity 100%, 95% CI 71.5%–100.0%). Applying this rule in our practice setting would result in an 18.2% absolute reduction in the proportion of chest radiographs ordered. The potential cost efficiency is even greater in practice settings with higher baseline ordering rates of chest radiographs, with a potential relative reduction of 36%. Validation in an independent patient population is necessary before applying the prediction rule in clinical practice.

We are aware of no other studies that evaluate the efficiency of chest radiography in patients with chest pain. However, other ED-based studies have evaluated use of chest radiography in the elderly and in patients with altered mental status. Hubbell and colleagues[12] conducted a prospective controlled before and after study to determine the impact of baseline chest radiography in the care of 48 ED patients over the age of 65. Housestaff completed questionnaires addressing their treatment plans before and after reviewing reports of chest radiography. Chest radiography reports caused a change in treatment in only 2 (4%) of the 48 ED visits. Birkemeier and coworkers[13] conducted a retrospective review of 100 consecutive ED patients who underwent head CT for evaluation of altered mental status and had chest radiography performed during the same visit. Of the 17 patients with chest radiographic findings requiring intervention, 15 had signs or symptoms suggesting a chest radiograph was needed and the other 2 had leukocytosis. Similar to our findings, these 2 studies highlight the inefficiency of current chest radiography ordering practices.

We believe that an important strength of our study is adherence to the methodological standards for clinical decision rules.[6,14] Study participants were selected without bias and not based on the subjective decision of individual physicians to order a chest radiograph. Physician assessors were blinded to chest radiographic findings at the time of initial assessment, and the outcome was evaluated without knowledge of the predictor variables. The mathematical techniques for deriving the rule were explicit and appropriate. The simple format of the rule is clinically sensible and user friendly for busy emergency physicians. It is highly sensitive for clinically significant chest radiographic findings and therefore safe for use in patient care.

Limitations

There were several limitations in our study. Some may question our method for classifying chest radiography. Classifying some chest radiographic abnormalities as requiring acute intervention and others as not requiring acute intervention involves clinical judgment. However, 2 practising emergency physicians independently classified all chest radiographs after review of the complete medical record, and the high κ value indicates near perfect agreement between investigators. Also, we classified pulmonary nodules without radiologic features that were worrisome for malignancy as benign. It is possible that some of these benign-appearing pulmonary nodules may develop features of malignancy at a future time. Although it is important to follow-up incidental findings identified during a patient's ED visit, we feel it is not the role of the emergency physician to order diagnostic tests for the purpose of identifying incidental findings. The study was conducted at 1 hospital only. We did, however, collect a representative sample of cases and believe our results are applicable to most EDs.

Not all eligible patients were enrolled. This is likely because registration clerks and triage nurses did not attach data collection forms to the ED record of treatment during periods of high ED volume, particularly at night when the ED was very busy. However, we collected demographic cardiac risk factor and cardiovascular history characteristics and outcome data for all eligible patients either missed or enrolled. Moreover, there is no reason to suspect that fluctuating ED volume would make any particular patient group more or less likely to be enrolled. In addition, not all of the 640 patients in our cohort had chest radiography performed. Rather than assuming normality in cases without chest radiographs, we limited our analysis to cases in which chest radiography was performed. This approach reduces the risk of work-up bias, thus ensuring more accurate estimates of diagnostic accuracy.

Perhaps the greatest limitation of our study is the relatively small number of chest radiographs with abnormalities requiring acute intervention. This resulted in a 95% CI with upper and lower confidence limits of 100% and 71.5%, respectively. To overcome this limitation, we plan to prospectively validate the rule in an independent patient population before recommending its use in clinical practice.

CONCLUSION

The prevalence of chest radiographic abnormalities requiring acute intervention in patients with chest pain and possible ACS is low. Application of this rule in our setting would have resulted in an 18.2% absolute reduction in use of chest radiography. The rule has potential to enhance ED patient flow and decrease health care costs. It requires validation in an independent patient population before introduction into clinical practice.

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