The Ordering and Impact of Chest Radiography in the Management of Adult Patients with Acute Asthma in Canadian Emergency Departments.

by

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Abstract

Objectives: Asthma is a reversible chronic disease of the airway characterized by symptoms of persistent dyspnea, wheezing, chest tightness, cough, and occasional sputum production. Acute asthma is a severe form of asthma, which may result in emergency department (ED) visits, hospitalization or, very rarely, death. Clinicians frequently order chest X-rays (CXR) to rule out comorbid infections (e.g., pneumonia) or pneumothorax/mediastinum complications, however, guidelines are inconsistent with respect to recommendations for ordering CXR for adult patients with acute asthma in emergency departments (ED). This thesis focused on adult patients with acute asthma with the objectives of examining: 1) the literature for CXR ordering in the ED setting; 2) factors associated with CXR ordering; and 3) the impact of CXR ordering on patient outcomes.

Methods: Two studies were completed to investigate the ordering of CXR for adult patients with acute asthma in the ED. First, a systematic review was conducted to examine the ordering and outcome of CXR in the ED for adult patients with acute asthma. Second, a Canadian ED dataset was examined for factors associated with CXR ordering and the impact of CXR ordering on the patient's disposition after ED visits.

Results: The systematic review identified 15 published studies and 1 unpublished dataset, conducted in nine countries, including a Canadian study. The mean weighted proportion of CXR ordered upon ED presentation was 60.0% (95% CI: 47.0, 72.2) and was 87.6% (95% CI: 81.0, 93.1) for only admitted patients. The weighted proportion of positive outcomes for CXRs ordered in the ED was 9.5% (95% CI: 7.1, 12.4) and 26.0% (95% CI: 6.1, 53.0) for hospitalized adult patients with acute asthma. Positive CXR outcomes were variably

defined among studies and complications were infrequent (e.g., pneumothorax/mediastinum (0.1%) and pneumonia (7.1%)) for adult patients with acute asthma seen in the ED. Factors associated with CXR ordering and the impact of CXR ordering on patients' disposition were not reported, and this leaves a significant knowledge gap.

In a secondary analysis of existing clinical databases of patients discharged with acute asthma involving multiple Canadian EDs, nearly 50% (95% CI: 44.7, 51.3) of adult patients with acute asthma received a CXR. CXR ordering was not associated with most clinical and demographic factors; however, sputum production, fever and ECG ordering were associated with an increased CXR ordering, and early PEF assessment was associated with reduced CXR ordering. While CXR ordering is also associated with an increased length of stay in the ED, it had no impact on relapse after discharge.

Conclusions: The existing literature suggests that a high proportion of adult patients with asthma exacerbations seen in the acute care setting receive a CXR and this is especially so in patients who are admitted. In Canadian EDs, a similarly high proportion of adult patients with acute asthma who are well enough to be discharged home following treatment received a CXR. Radiographic ordering is independent of most clinical/demographic factors, and does not influence future relapse; however, it is associated with a longer length of stay in the ED. Overall, CXR appears over-used in the management of adult patients with acute asthma in the ED, and it seems, physicians' concern for pneumonia and rare thoracic complications were the main drivers of CXR ordering. Emergency physicians should engage patients in a discussion about the need for a CXR. CXR should be considered in acute

asthma only if there are clear signs and symptoms of pneumonia and pneumothorax/mediastinum. Most patients do not require a CXR and given the frequency of presentation, its contribution to ED flow delays, safety (radiation exposure) and cost concerns, reducing CXR ordering in acute asthma is a possible Choosing Wisely® target for emergency practitioners.

Keywords: Chest X-ray, Emergency Department, Ordering, Canada, Asthma, Pneumonia, Choosing Wisely®

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Dedication

To my siblings; Junior, Fred, and Henrietta and my best friend, Gbenga, for supporting me during difficult times.

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List of Abbreviations

AAP = Asthma Management Plan.

ABG = Arterial blood gases

CAD = Canadian Dollar

CAEP = Canadian Association of Emergency Physicians

CHF = Congestive Heart Failure

CI = Confidence interval

CIHR-EPHPP = Canadian Institute of Health Research - Effective Public Health Practice Project quality assessment tool.

COPD = Chronic Obstructive Pulmonary Disease

CTAS = Canadian Triage and Acuity Score

CWC = Choosing Wisely® Canada

CXR = Chest radiography ("X-ray")

ECG = Electrocardiogram

ED = Emergency Department

EDACP = Emergency Department Asthma Care Pathway (EDACP)

FEV_1 = Forced expiratory volume in one second.

GERD = Gastric esophageal reflux diseases.

GINA = Global Initiative for Asthma

ICS = Inhaled corticosteroids.

ICU = Intensive care unit

IgE = Immunoglobulin E

IM = Intramuscular

IOM = Institute of Medicine

LABA = Long acting ß$_2$-agonists.

LOC = Level of consciousness

LOS = Length of stay

MBS = Modified Borg Scale

MD = Doctor of Medicine

NAEPP=National Asthma Education and Prevention Program

NIV = Non-invasive ventilation (NIV)

NSAIDS = Non-steroidal anti-inflammatory drugs

OR = Odds Ratio

PEF = Peak expiratory flow.

PHAC = Public Health Agency of Canada

SAAC = short-acting anticholinergic

SABA = Short-acting ß$_2$-agonists

SaO_2 = Oxygen Saturation.

SIGN/BTS = Scottish Intercollegiate Guidelines Network/ British Thoracic Society

VBG = Venous blood gases

WHO = World Health Organization.

1 Chapter 1: Introduction

1.1 Asthma Definition

Asthma is a reversible chronic disease of the airway characterized by symptoms of persistent dyspnea ("shortness of breath"), wheezing, chest tightness, cough, and occasional sputum production.[1-2] Asthma is caused by a combination of genetic and environmental factors leading to reversible and variable obstruction of the airway.[3] The primary pathophysiology of asthma is airway inflammation; however, secondary bronchoconstriction causes many of the patient's symptoms.[2] Historically, asthma attacks were described as being either extrinsic or intrinsic, depending on the trigger. Extrinsic asthma was thought to be caused by exogenous (environmental) allergens such as air pollution, pollen, animal dander, dust and were often associated with other atopic diseases (e.g., allergic rhinitis, eczema, etc) and elevated serum immunoglobulin E (IgE) levels.[1,4] Intrinsic asthma was thought to be caused by endogenous stimuli including infection, drugs such as aspirin and non-steroidal anti-inflammatory drugs(NSAIDS) and diseases such as gastric esophageal reflux diseases(GERD) and emotional stress etc.[1, 5] Given the difficulty determining the cause of asthma exacerbations and the similarity in presentations between the extrinsic and intrinsic models, this traditional classification has been dropped in favor of more descriptive terms such as acute asthma or asthma exacerbation.

1.2 Pathophysiology of Asthma

Asthma attack occurs when external or internal triggers lead to IgE mediated degranulation of serum and organ-specific mast cells when they come in contact with airway mucosa, this triggers the release of inflammatory mediators such as histamines and leukotrienes, as well as recruitment of other cellular agents (i.e., eosinophils, macrophages and T-helper cells) to the airway.[4] The ensuing symptoms and cascade of events after this interaction leads to the early acute phase of the disease which occur within thirty minutes to one hour and is characterized by airway endothelial permeability, fluid exudates, cellular recruitment, and bronchospasm. If left untreated or with continued trigger exposure, consequent bronchoconstriction, airway mucosa edema and mucus hyper-secretion ensues (***Table 1-1***). An occult airway inflammation cascade forms the basis for the late phase of asthma episodes which occurs five to six hours later and duration could be up to forty eight hours.[6] The late phase (***Table 1-1***) of an asthma presentation is mediated by the infiltration of the airways by inflammatory cells (e.g., eosinophils, neutrophils, monocytes and lymphocytes) and the release of inflammatory mediators (e.g., histamines, leukotrienes, interleukins (ILs), prostaglandins, etc) thereby resulting in bronchial hyper-responsiveness and airways obstruction.[6] The cascade of inflammatory processes which occur in the late phase of the disease leads to a tightening of the band of muscles surrounding the large and small airways, mucosal edema, and increased symptoms. Remodeling of the airway (due to the release of endothelium remodeling factor by the eosinophils) and mucus plugging of the airways (due to mucus hyper-secretion) follow.[7] The outcome of these events is the reversible obstruction of the large and small airways of the lungs resulting in severe respiratory distress, hypoxemia and respiratory acidosis if not treated.[7-8] As shown in

Table 1-1 in the appendix, every episode of asthma attack is a sequence of acute and late phase of asthma which results in reversible airway obstruction and remodeling.

1.2.1 Acute asthma pathophysiology

Acute asthma or exacerbations of asthma, represent potentially life-threatening asthma attacks which requires changes in medical management, often result in health services use, and when severe may result in emergency department (ED) visits, hospitalization, and death (rarely). Severe acute asthma involves the use of accessory muscles of respiration when breathing, tachycardia, tachypnea, severe airway obstruction, and documented reduction in forced expiratory volume in one second (FEV_1) or peak expiratory flow (PEF).

Asthma exacerbation presents variably, with a varying clinical symptoms and prior history of the disease.[9-10] Some of the triggers of acute asthma are allergens, smoking, viral and bacterial (e.g., chlamydia and mycoplasma) infections, aspirin use and occupational and environmental allergens.[11-12] Genetic polymorphism also plays a role in acute asthma severity and response to controller medication such as short-acting ß$_2$-agonists (SABA).[13-15] Other factors which influence acute asthma severity are chemokine receptors and IL mediators, these cells and mediators attract leucocytes to the site of inflammation. The duration of asthma exacerbation as well as its severity is influenced by many factors, such as the pre-existing asthma control and the inflammatory mechanisms triggered by these cells.[9] Asthma exacerbations have heterogeneous etiologies, and is a complex interaction, many factors have varying extent of involvement in each patient and in each episode of asthma exacerbations.[16] Severe acute asthma has different phenotypes, which may be type 1 or type 2. Type one phenotype which comprises of 80 - 85% of asthma exacerbations is

progressive, slow in onset, presents with excess mucus plugging, eosinophils mediated, characterized by late perception of symptoms and responds slowly to treatment. Type two phenotype accounts for 15 - 20% of asthma exacerbation and is characterized by rapid onset of symptoms, neutrophils mediated, responds quickly to treatment and its symptoms are perceived early.[17] Excessive mucus production and obstruction of the airway lumen have been implicated in life threatening and fatal asthma.[18]

1.3 Prevalence of Asthma

Asthma is a significant public health challenge worldwide, it is presently the most common non-infectious disease, most common disease among children, and most deaths from asthma occur in developing countries.[19] The World Health Organization (WHO) estimates 235 million people reported suffering from asthma in 2013.[19] An independent 2012 study on the "Global Asthma Prevalence" differs from this figure and estimated the global prevalence of doctors' diagnosed asthma at 4.3% with an estimated 315 million people worldwide with clinically diagnosed asthma. This figure may be as high as 623 million people when it is based on self-report, there is also a significant geographical variation in the prevalence of asthma.[20] According to the United States Centre for Disease Control and Prevention, in 2012, the prevalence of asthma in the United States' population was 8% and 9.3% for adults and children, respectively.[21] In Canada, it is estimated 3 million people had asthma in 2012 and this number is expected to increase to 3.9 million by 2030. Statistics Canada estimated 7.9% of Canadian, an estimated 2.4 million people over the age of twelve

years, had asthma in 2013, the prevalence was higher in females (8.9%) than in males (6.9%).[22]

There is a significant variation in the prevalence of asthma among different age groups in Canada, according to the Public Health Agency of Canada (PHAC) which uses administrative data to conduct chronic disease surveillance. For example, the prevalence of asthma in children and youths (1 to 19 years) in 2014 was 15.7%. Asthma prevalence is highest amongst adolescent of age 10 - 14 years (19.5%), followed by 15 - 19 years of age and 5 to 9 years of age (18.9% and 14.9%, respectively). The prevalence is lowest in children of ages 1 - 4 years (6.8%).[20] The PHAC surveillance program also reported an asthma prevalence of 9.0% in adult twenty years and above, with adults of age group 20 – 24 years reporting the highest prevalence of 13.9%, while the prevalence among seniors above 70 years remained above the national average (above 9.0%).[23] There was also downward trend in new cases of asthma between 2000 and 2011. ***Table 1-2*** shows the asthma prevalence across the different age groups in Canada

The prevalence of asthma among young people also significantly differs between rural and urban areas.[24] There are variations in the prevalence of asthma among Canadian provinces, according to statistics Canada, asthma prevalence in Alberta for people of age twelve years and above is 8.8% (9.7% for females and 7.9% for males).

Approximately 240 Canadians are estimated to have died from asthma in 2010, this number is projected to grow at an annual rate of 1.0% and expected to increase to 400 by 2030. The impact of asthma on missed school days is well documented, children from low-income homes are more likely to be absent from school due to asthma.[25-27] Asthma remains

a major cause of hospitalization in Canada among children and adolescents,[28] with a projected hospitalization growth rate of 3.0% from 2010 to 2030.[29]

1.4 Cost of Asthma Management

According to a 2012 report by the Conference Board of Canada (***Table 1-3***), the direct (drugs, hospitals and physicians) and indirect (long term disability and mortality) costs of asthma are expected to increase by 90% from $2.2 billion in 2010 to $4.2 billion by 2030.[29] The Conference Board of Canada also estimated the direct cost of asthma to be $1 billion in 2010 and projected this cost to reach $1.34 billion and $1.8 billion by 2020 and 2030, respectively at an average annualize growth rate of 3.3%.[29] A study estimated asthma related loss in productivity (***Table 1-4***) and put the loss to Alberta economy at $70-84 million.[30] In British Columbia, medication cost accounts for the major cost of asthma and the majority of the cost is attributable to poorly controlled asthma. There was also no difference in asthma related cost and readmission between patients managed by primary and secondary practitioner, although the secondary care patients were deemed to be more appropriately managed.[31-32]

1.5 Diagnosis of Asthma

1.5.1 Clinical history and symptoms

Asthma is diagnosed using clinical history and physical examination. In the absence of alternative explanation for wheezing, cough, chest tightness, breathlessness, variable

airflow obstruction (e.g., abnormality in spirometry), as well as symptoms consistent with airway inflammation and hyper-responsiveness, asthma is diagnosed. For asthma to be diagnosed, each of these symptoms must be frequent, recurrent, nocturnal, occur in response to stimuli and in the presence of cold air. Other features associated with asthma include history of atopic disorders, family history of atopic disorder and/or asthma and reversibility of symptoms with the initiation of therapy with a bronchodilator.[33-35]

1.5.2 Spirometry

Diagnosis of asthma is based on demonstrable airflow obstruction using spirometry (measures FEV_1) or peak flow meter (measures PEF).[2, 5] Normal or near normal spirometry does not exclude the diagnosis of asthma, hence the need for alternative forms of testing or treatment trials with reversibility testing (measuring the FEV_1 and PEF pre and post administration of trial bronchodilators or ICS) to confirm the diagnosis of asthma. [36-37] Challenge testing with exercise or methacholine (using the FEV_1 variation pre and post challenge testing) can also assist in the diagnosis of asthma (especially mild asthma).[38-39]

1.5.3 Differentiating asthma from other conditions

Differential diagnosis is also necessary to rule out other conditions such as upper airway obstruction, foreign-body aspiration, vocal cord dysfunction syndrome, pulmonary edema, acute exacerbation of chronic obstructive pulmonary disease.[40-43]

Asthma has some similarities with chronic obstructive lung disease (COPD) and may even been mistaken for the latter. Asthma and COPD have similar symptoms such as wheezing, dyspnea, and cough (occasional in asthma but chronic, and can be productive, in COPD), and airway hyper-responsiveness. COPD may also be comorbid with asthma, especially in

elderly people.[44] Asthma is often diagnosed in childhood while COPD occurs in people over the age 40 years and is mostly caused by exposure to cigarette smoke (primary or secondary).[44] Conversely, smoking does not cause asthma but aggravates the disease. Asthma diagnosis may be missed in the elderly with COPD due to the similarities in symptoms.[44] Asthma attacks are often triggered by allergens, cold air and drugs like aspirin, while COPD is often caused by infections such as bronchitis, lower-respiratory tract infections, and environment pollutants. Airway obstruction is reversible in asthma but the damage to the airway is irreversible and progressive in COPD (***Table 1-5***).

Overall, FEV_1 does not return to normal in stable patients with COPD post bronchodilator use due to incomplete restoration of airway patency; in asthma, spirometry values may return to normal in stable patients.

Both asthma and COPD are monitored using symptoms (i.e., night-time awakenings, exercise tolerance, cough, activities, etc. measured by self-report or diary cards), pulmonary functions (e.g., FEV_1, PEF), medication use (e.g., bronchodilator use, asthma attacks, medication changes, and oral corticosteroids) and health services utilization (e.g., physician/ED visits, and hospital admission).

1.6 Assessment of Acute Asthma in Emergency Department

The definitions of acute asthma and severity of acute asthma are variable amongst the various asthma guidelines, especially on the benchmark PEF for the various asthma severity definitions. Various guidelines, such as the National Asthma Education and

Prevention Program (NAEPP) and the Canadian Thoracic Society (CTS) guidelines require early recognition of the severe asthma exacerbations, signs and symptoms of acute asthma and risk factors for near fatal asthma to be assessed in the ED. Patients should also be triaged promptly, treatment must commence immediately and the intensity of the treatment should be based on the severity of asthma presentation, which may be mild, moderate, severe or life threatening.

Assessment and monitoring of acute asthma include the use of patient's history, physical examination, such as; use of accessory muscles for respiration, vital signs (e.g., heart rate, respiratory rate, and oxygen saturation) as well as a measure of airway obstruction (e.g., FEV_1 or, more commonly, PEF). While recommendations for prompt objective measurement of airway obstruction using FEV_1 or PEF exist in patients presenting with acute asthma, in most Canadian EDs, this does not occur on a regular basis. Triage levels are assigned using the Canadian Triage and Acuity Score (CTAS) in Canada and using valid triage tools in other countries; however, airway obstruction is not often followed or monitored closely.[45]

The measurement of arterial blood gases (ABG) in severe airflow obstruction, CXR, ECG and sputum cell count are not routinely required, although they can aid in the assessment and monitoring of acute asthma in patients who fail to respond to evidence-based treatment.[1-2, 5, 46-47]

1.6.1 Canadian Triage and Acuity Score (CTAS)

Triage scores can be used to preliminary assess asthma severity in ED. Triage nurses use the patients' history, physical examination, vital signs, airflow measurement (e.g., FEV_1,

PEF) and continuous oxygen saturation in the ED to assign scores, which ranges from 1 (immediate resuscitation) to 5 (non-urgent) to the patients.[48] The CTAS score is used to determine the severity of asthma presentation and the predicted outcome of the asthma exacerbation. The CTAS score also helps determine the time frame the patients should be seen by the physicians, which aids in the efficient and effective resource utilization in the ED. For instance, patients with near a fatal asthma exacerbation are assigned a CTAS score of 1. The oxygen saturation of these patients tends to be below 90% and they are unable to use spirometer or peak flow meters. The clinical presentation is severe enough to necessitate immediate nurse and physician assessment and intervention (e.g., bronchodilator administration). Patients with severe asthma are assigned CTAS score 2 with oxygen saturation values of 90-95% and FEV_1 of less than 40% predicted. Patients with mild/moderate asthma exacerbation are assigned a CTAS score of 3. These patients have normal oxygen saturations and FEV_1 values of 40-60% predicted. These patients require a nurse assessment within thirty minutes, bronchodilator administration within thirty minutes and physician assessment within another thirty minute after triage nurse assessment (***see Table 1-6***).

1.6.2 Modified Borg Scale, MBS

This is a triage tool used in the ED to assess the level of dyspnea, a subjective component of asthma severity. The MBS has a score which ranges from 0 (no breathlessness at all) to 10 (maximum breathlessness); mild, moderate, and severe breathlessness are reported. Patients' subjective assessment of dyspnea determined with MBS has been found to negatively correlate with clinical parameters, such as peak flow and oxygen saturation

reading, therefore, as the PEF and the oxygen saturation improves, the patient's subjective assessment of dyspnea on the MBS scale decreases (less dyspnea).[49]

1.6.3 Spirometry (FEV_1) and peak expiratory flow (PEF)

Spirometry and peak flow meters provide objective measurement of lung function. The FEV_1 and PEF provide clinicians with measures of the degree of lung obstruction which are standardized based on age, height and sex. Based on these assessments, a patient's asthma severity is stratified as either mild to moderate, moderate to severe asthma or those with impending respiratory failure/arrest. After the severity determination, treatment is initiated without waiting for more laboratory results. According to the NAEPP Expert Panel Report 3, assessment of symptoms using physical examination, objective lung function measurements (e.g., FEV_1 and/or PEF) and oxygen saturation is performed and initial therapy is instituted. Treatment is either sustained or intensified based on the response of the patient (i.e., symptoms, physical examination and FEV_1 and PEF values).[50]

In the assessment and stratification of acute asthma severity in the ED, early recognition and prompt management of near fatal asthma is also emphasized. Identifying near fatal acute asthma is relatively difficult due to similarities in symptoms with other forms of acute asthma.[51] An indicator for severe asthma is the failure to respond to standard treatments of acute asthma in the ED. In severe asthma exacerbations, oxygen saturations must be monitored using pulse oximetry or arterial blood gases, when the former is inadequate, in order to guard against hypercapnia indicated by PEF and FEV_1 of less than 25% and 30% respectively.

1.6.4 Chest x-ray (CXR)

Ordering a CXR is not routinely recommended in the management of asthma. Chest radiography may be required if a pneumothorax, pneumomediastinum and/or pneumonia are suspected or in the setting of severe and/or refractory asthma. Guideline recommendations for CXR are variable and there is a paucity of evidence to support the routine use of CXR in the ED assessment of acute asthma (***See Table 1-7***). [2,5,47] See Chapter two for more details on the evidence, utilization and benefit of CXR utilization in the ED management of acute asthma.

1.6.5 Blood gases

Arterial (ABG) or venous (VBG) blood gas measurement are objective measures of acid-base balance, hypoxemia, and hypercapnia in acute situations. ABG measurement is indicated in cases of life threatening asthma, very low FEV_1/PEF, and/or low oxygen saturation.[2, 47, 50] ABG is used to identify hypercapnia, hypoxemia and respiratory acidosis and to predict respiratory failure. ABG measurement may be repeated after treatment initiation and in the presence of depressed oxygen saturation. There are variations in guideline recommendation for the use of ABGs in asthma. Due to the invasive nature of ABG measurements, VBGs may be used instead. While less invasive, they do have limitations. While both ABG and VBG may help identify impending respiratory failure, VBG oxygen saturation values are not equivalent to arterial blood gases values, despite efforts at correction.[52-53] Pulse oximetry and capnography also provide a non-invasive and evidence supported means of measuring arterial oxygen saturation and carbon dioxide levels for patients in the ED.[54]

1.6.6 Electrocardiography

Since asthma is usually a disease of younger patients, an ECG is generally not required in the absence of suspected cardiac chest pain or acute coronary syndrome.[55]

1.7 Management of Asthma

The main objective of asthma management is to reduce future risk of disease exacerbation, morbidity and mortality, by preventing the risk of long and short-term complications, and to minimize the impact of the disease on the patient's quality of life. This is represented by the concept of *asthma control* - a standard for accessing the adequacy of asthma management. Symptoms control is assessed in every interaction the asthma patient has with the physician. Since symptoms do not always correlate with lung function, the goal of therapy is to achieve a normal or near normal lung function, not necessarily symptoms control.[2, 5]

1.7.1 Chronic management of asthma

It is important to understand the management of asthma prior to the ED presentation. According to the CTS asthma guidelines, the management of asthma involves the use of reliever medications, (e.g., SABAs) and the use of controller medication (e.g., ICS) to reduce the frequency of exacerbations. Once an asthma diagnosis is established, the severity and prior treatment are assessed. The use of an ICS is the first line therapy for asthma control. When control is not achieved with low dose ICS, long-acting beta-2-agonists in adult patients (LABA) can be added, usually as combination (ICS/LABA) agents. Leukotriene receptor antagonists (LTRA) are an alternate for second line mono-therapy in children and

could also be an add-on therapy for adult patients .[5, 56] Adding LABA as an adjunct to ICS is more effective than adding LTRA in adults.[57]

1.7.2 Acute asthma management in the ED

The management of acute asthma in the ED involves taking a focused clinical history (e.g., exposure to known triggers, adherence to chronic management medications and previous history of ED visits for asthma exacerbations, etc.) and performing a targeted physical examination, using vital signs, PEF and/or FEV_1 measurements. For example, using the severity stratification determined by PEF/FEV_1 and oxygen saturation in combination with triage scores such as the CTAS and MBS, patients can be assigned to either mild, moderate, severe or life-threatening asthma and treatment can be appropriately initiated based on these parameters. The following options are available for the management of acute asthma in the ED (***see Table 1-8***).

1.7.3 ß$_2$-agonists bronchodilators

Pharmacological treatment is usually initiated with short and rapid acting bronchodilators. Evidence supports the effectiveness of inhaled SABA agents in the management of acute asthma over the intravenous ß$_2$-agonists in people who can still use inhaled bronchodilators. Intravenous ß$_2$-agonists should only be used in patients who cannot use inhaled ß$_2$-agonists due to the severity of asthma. In a systematic review, ß$_2$-agonists which were administered using either a nebulizer or a spacer device were found to be equally effective. There was no significant difference in the duration of stay in the ED and admission rates for adults. The PEF and FEV_1 were similar for both nebulized and spacer administration of SABA.[58-59]

1.7.4 Corticosteroids (glucocorticoids)

Early initiation of systemic corticosteroids improves patient outcomes; [60] the administration of systemic corticosteroids within an hour of ED presentation has been shown to reduce admissions and improve lung function. Administration of multiple doses of ICS within two hours of ED presentation improves clinical outcome, FEV_1/PEF values and reduces the admission rate compare to IV corticosteroids. However, the difference between a single dose of ICS and IV corticosteroids was less significant.[60-61]

Systemic corticosteroids are one of the cornerstones of acute asthma management in the ED. As stated above, the use of ICS is associated with earlier clinical improvement compared to the standard of care in the ED, which is intravenous conticosteroids.[62] The use of ICS reduces admission in patients when administered alone and may also reduce admission when administered in combination with systemic corticosteroids.[63-65] Systematic reviews evidence has failed to identify differences between intravenous and oral corticosteroids in preventing admissions in acute asthma. For patients whose asthma presentation is too severe to permit the use of oral corticosteroids (e.g., too dyspneic, impending intubation, severe nausea and/or vomiting, etc.), the intravenous route of administration is preferred.

1.7.5 Short acting anticholinergics bronchodilator

Evidence supports the use of ipratropium bromide in exacerbations of asthma. Studies have shown that a combination of ipratropium bromide and SABA produces a significant improvement in PEF and FEV_1 as well as a significant reduction in the admission rates for patients with acute asthma.[65-66]

1.7.6 Intravenous magnesium sulphate

Adjunctive treatments with intravenous magnesium sulfate may be required in adult with refractory and severe asthma characterized by significant airway onstruction.[67] The use of intravenous magnesium sulfate is uncommon in the ED. The use of nebulized magnesium sulfate as an adjunct to inhaled SABA has been shown to improve pulmonary function in severe asthma in the ED.[68]

1.7.7 Epinephrine

Epinephrine has been used as a treatment in acute asthma. It can be delivered through three main routes: intravenously, as a nebulized solution and intramuscularly. Intramuscular injection of epinephrine has been used most effectively in asthma associated with anaphylaxis and allergic reactions. Intravenous epinephrine may be used in the management of patients with life threatening asthma exacerbations and in patients not responding to standard care. While both the IV and nebulized delivery methods have been shown to be effective in children, the benefit in adults is questionable. A meta-analysis has shown no statistically significant benefit of nebulized epinephrine over SABA in the treatment of moderate to severe asthma in adults and children.[69] Epinephrine may significantly improve the flow rate in people with acute asthma.[70] There are safety concerns for epinephrine use for acute asthma; however, infrequent major and minor adverse effect have been reported in some studies. There is a need for more concrete studies on the safety of epinephrine, especially for adult patients.[71]

1.7.8 Non-invasive ventilation

In more severe cases where patients still experience persistent respiratory distress and based on clinical judgment in unstable patients, non-invasive ventilation (NIV) may be required in selected patients in a bid to prevent the need for intubation or invasive ventilation.[55] Non-invasive mechanical ventilation appears beneficial and reduces the need for mechanical ventilation,[72] although evidence to support this strategy is relatively scarce.[73]

1.7.9 Emergency intubation and mechanical ventilation

Refractory acute asthma characterized by oxygen saturation < 90%, cyanosis, cardiac complications, progressive loss of consciousness, silent chest, progressive acidaemia (pH < 7.10) and worsening hypercarbia may warrant emergent intubation when aggressive treatment fails.[74-75]

1.7.10 Care Map

The implementation of guideline based care protocols such as an asthma care map have also be found to improve adherence to treatment recommendations, help prevent suboptimal assessment and management of asthma in the ED[76] and improve ED resource utilization.[77] For instance; studies have found suboptimal use of PEF/ FEV_1 measurements, intensive bronchodilator therapy and systemic and ICS therapy in the ED and when discharged.[78] Evidence shows ICS and systemic corticosteroids use significantly improve post-implementation of asthma care map.[79]

1.8 Risk Factors for Acute Asthma Fatalities

Acute asthma can be fatal if not properly managed. Risk factors for acute asthma fatalities are multifactorial and include: poor control of asthma, prior hospitalization and admission to the intensive care unit (ICU), history of multiple reporting to and late presentation to the ED.[80-84] Medication related factors are poor adherence to medication, excessive use of reliever medication, prior use of oral corticosteroids and use of inadequate inhaled corticosteroids (ICS).[82, 84-90] The psychosocial factors associated with poor outcomes include age, poor perception of symptoms and asthma severity, psychological disorders and socioeconomic factors, including smoking and alcohol/substance abuse.[80, 91-100] Finally, physicians related factors such as slow initiation of aggressive and effective therapy and mechanical ventilation also have been implicated.[99, 101-102]

Variable evidence exists for these risk factors but history of admission for asthma, ICU utilization, mechanical ventilation, old age, excessive use of reliever medication, poor adherence to medication, socio-economic status and psychological dysfunction are the strongest indicators for potentially fatal asthma.[55]

Signs of potentially life threatening acute asthma include: use of accessory respiratory muscles, heart rate greater than 120/min, respiratory rate above 25–30/min, difficulty in speaking due to dyspnea or fatigue, altered level of consciousness, quiet chest in a patient who has dyspnea, PEF below 30% of predicted or FEV_1 < 25% of predicted 1–2 hours after initial therapy, oxygen saturation below 90% and cyanosis.[105-108] The symptoms include: breathlessness, feeling of fear or impending doom, progressive agitation or anxiety.[2, 55, 96]

1.9 Post ED Disposition and Management of Acute Asthma Patients

The decision to admit or discharge a patient with acute asthma is determined by the severity of asthma presentation (using triage score, vital signs, oxygen saturation and lung function values, if assessed), degree of lung function improvements after initial therapy (patient's response one hour or more after initial ED therapy), patient symptoms and clinician's judgment.[109] Following the decision to discharge a patient, an arrangement should be made for adequate follow up in the first few weeks of discharge from the ED. These patients may be referred to a family physician or a general practitioner to ensure continuity of care.[110] There is also a need to optimize outpatient asthma management such as controller medication use, inhaler technique and self-management. Some patients with prior history of asthma exacerbations and hospitalization may be referred to an asthma specialist for follow up in order to assist their primary care provider in providing the best outpatient management.[111] Patients referred to a specialist have been shown to have less rates of relapse and improved asthma control compared to patients referred to only their primary care providers.[109]

Patients with moderate to severe asthma who achieve slow or minimal symptom resolution and/or airflow improvement, require supplemental oxygen therapy or develop an asthma related complication (e.g., pneumomediastinum, pneumothorax, or pneumonia) often require hospitalization after ED management (***see Table 1-9***).

Airflow measures have been used in some guidelines to determine discharge readiness. For example, initial PEF above 40% predicted is associated with a good outcome and may not require admission.[112] Patients who presents with a pre-treatment FEV_1 or PEF below 40%

predicted may need to be admitted.[113] Clinical judgments, signs and symptoms determine if patients with an intermediate FEV_1 or PEF values (i.e., 40-60% predicted) may be admitted or discharged depending on the response to therapy. Patients for whom there are concerns about medication compliance, an unstable housing situation (e.g., living alone or socially isolated) or the presence of a serious psychological problem may also need to be admitted. Other admission criteria suggested are a prior history of life threatening asthma exacerbation despite intensive therapy with corticosteroids before presentation in the ED, severe nocturnal symptoms, pregnancy or other markers of fatal asthma.[55, 47, 113] Patients with pre-treatment FEV_1 or PEF above 60% of the expected values may be discharged provided there is an adequate post discharge plan for adherence and supervision.[110] The main reasons for these considerations is the prevention of relapse and the impact of repeated ED utilization on ED resources.

In Canada, 6 to 13% of patients with asthma exacerbation will be hospitalized, and this is responsible for 25% of the costs of asthma care.[114-115] A multicenter study showed admissions for acute asthma in United States is significantly higher than in Canada(21% versus 11%).[116] In Alberta, an estimated 93,146 asthma patients made 199,991 visits to the EDs in the six years' period (1999 to 2005) and ED presentation was higher in non-urban areas.[117] Over the same period, ED visits by adult (18 years and above) patients with acute asthma in Alberta declined from 9.7/1,000 populations in 1999/2000 to 6.8/1,000 in 2004/2005 and 9.8% of ED visits resulted in admission.[117] Factors associated with admission included: increasing age, admission in the previous two years, more than eight β_2-agonists puffs in the 24 hours prior to the ED visit and low oxygen saturations.[118] Patients admitted to the ED for acute asthma and frequent ED users for acute asthma also

have poor self-management, poor adherence to controller medication and poor inhaler technique.[113]

In both the United States and Canada, relapse rate within the first two weeks of acute asthma have been reported to be 12- 16% and relapses after 4 weeks approach 18%. [119] Multiple factors are associated with relapse in patients with asthma discharged from the ED. These factors include female sex, any ED visit in the prior two years for asthma exacerbation, prior oral corticosteroids use, increasing age, previous asthma hospital admission and maximal anti-inflammatory treatment with ICS/LABA agents.[28, 119-120] To date, authors have not been able to make a clear association between the risk of relapse post ED discharge and symptoms or PEF.[121-122]

1.9.1 Non pharmacologic management of asthma after ED visit

Non-pharmacologic management of patients with acute asthma after discharge is also important. Patient education and the use of a personalized and written asthma action plan (AAP) are essential to preventing future exacerbations leading to ED visits. Since asthma is a chronic disease with frequent exacerbations, self-management is an essential part of the post discharge care for asthma patients. Provision of and easy access to information is a requirement for the long-term outpatient care of asthmatics. A written AAP in combination with adequate patient education significantly improves asthma outcome, especially in preventing relapse in patients with poor adherence to medical advice, controller medication and inhaler device utilization instruction.[123] For a written AAP to be effective, it has to have some level of patient input and be adapted to each patient's disease status.[124] It also has to have details about medication dose adjustment during an asthma exacerbation,

as well as instructions on when to seek medical attention based on the patient's PEF or symptoms.[125] Asthma action plan are also associated with a reduced number of unscheduled visits in the ED,[126] a reduction in the number of re-admission after discharge from the ED[127] and a reduced risk of death.[48] Despite the evidence, studies have also shown that asthma action plan possession is low among patients with asthma who present to an ED. Only one in ten asthma patients had a written action plan and those who had an AAP infrequently utilized it.[128]

1.9.2 Pharmacologic management of asthma after ED visit

Patients with moderate to severe asthma exacerbation who received a short course of oral corticosteroids for a period of less than two weeks have a reduce risk of relapse.[122,129] The addition of ICS to a short course of oral corticosteroids (***see Table 1-9***) has also been associated with a decrease risk of relapse after discharge from the ED.[130] Evidence also support the use of a single dose of intramuscular corticosteroids in reducing relapse after discharged from the ED.[131-132] The use of high dose ICS post-discharge have also been associated with a lower rate of relapse and may be as effective as oral corticosteroids in preventing relapse in people with non-life threatening asthma exacerbation after ED visit.[63]

1.10 The Thesis Topic

The assessment and management of acute asthma patients is not always straight forward. As stated previously, signs and symptoms do not always demonstrate the extent of airway obstruction. Efforts to safely manage patients with acute asthma rely on accurate assessment and management using objective factors (e.g., signs and symptoms, FEV_1, PEF, triage score), judicious use of investigations (e.g., blood gases, laboratory tests, ECG, CXR)

and subjective factors (e.g., patient perception asthma severity, ED physician's clinical judgment, etc). The interplay of these factors and the varying severity of asthma presentation in the ED affect resource utilization, cost of care and ED efficiency.

ED physicians may order CXR in order to rule out comorbidity and complications. It is important to understand the utility for CXR as well as the frequency of ordering. How does this test alter the effectiveness and efficiency of therapy, the disposition of patients during the ED visit, the timeliness of care, the ED flow and finally the patient's perception of this test in terms of safety and convenience?

1.10.1 Objective of this investigation

The objective of this study is first to determine the evidence related to CXR ordering in acute asthma and if minimal evidence to support it use exists, this research will seek to identify ways to influence the ED management using the Choosing Wisely® approaches targeting ED physicians**.** In order to accomplish this, a systematic review will be conducted of studies on the ED ordering of CXR in adult patients with acute asthma in order to estimate the proportion of these patients who receive a CXR, the proportion of CXRs with a positive finding, as well as identify the most common CXR outcome of clinical significance. Secondly, efforts will be made to identify factors associated with CXR ordering in adult patients with acute asthma in the ED and the impact of CXR ordering on patients' outcome, in a bid to create a framework for reduction in CXR ordering as a possible Choosing Wisely® target for ED physicians. Finally, the thesis will conclude with a proposed intervention to be applied widely to reduce CXR ordering in adult patients with acute asthma seen in the ED setting.

Table 1-1 Asthma Phase Categorization

	Early phase	Late Phase
Onset	30min – 60min	5-6 hours
Duration	Less than 12 hours	Up to 48 hours
Main Pathophysiology	Bronchospasm	Airway inflammation
Presentation	bronchoconstriction, airway mucosa edema, mucus secretion	Bronchial hyper-responsiveness, airway obstruction and remodeling
Mediators	histamines and leukotrienes, eosinophils, macrophages and T helper cells	eosinophils, neutrophils, monocytes and lymphocytes

Table 1-2 Asthma Prevalence Vs Age Distribution - Canada

Age category (years)	Prevalence (%)
1-4	6.8
5-9	14.9
10-14	19.5
15-19	18.9
20-24	13.9
25-29	9.8
Above 70	9.0

Adapted from Public Health Agency of Canada Infobase.[55]

Table 1-3 Burden of Asthma in Canada

BURDEN OF ASTHMA (Canada)	
Estimate of Burden	Numbers/Percentages/Costs
Estimated numbers of people with asthma †	3 million.
Prevalence among age 12 years and above(2013)	7.9%.
Direct cost of care (2010) †	$1 billion.
Direct and indirect cost (2010) †	$2.2 billion.
Average annual cost growth rate†	3.3%
Number of deaths (2010) †	240.

Adapted from Statistics Canada;[54] Conference Board of Canada;[61] †: For all age groups

Table 1-4 Burden of Asthma in Alberta

BURDEN OF ASTHMA (Alberta)	
Estimate of Burden	Numbers/Percentages/Costs
Prevalence (12 years and above)	8.8%.
Male vs female prevalence (12 years and above)	7.9% vs 9.7%.
Estimated loss in productivity	$70-84 million.
ED visits (2004/2005)	6.8/1000.
ED admission proportion	9.8%.

Adapted from Statistics Canada;[54] Asthma-related productivity losses in Alberta, Canada;[62] Asthma presentations by adults to emergency departments in Alberta, Canada;[113]

Table 1-5 The Difference Between Asthma and Chronic Obstructive Pulmonary Disease (COPD)

Characteristics	Asthma	COPD
Age at onset	< 40 years	> 40 years
Smoking history	Not causal, aggravates it	> Causal, usually 10 pack-years
Sputum Production	Uncommon	Common
Allergies	Common	Uncommon
Clinical symptoms	Intermittent and variable	Persistent and progressive
Course of Disease	Stable with exacerbations	Progressive with exacerbations
Airway Inflammation	Eosinophilic	Neutrophilic
Spirometry result	Often normalizes	May improve, but does not normalize
Non respiratory (systematic) comorbidity	Not common	Common

Adapted from the Canadian Pharmacists Journal: 140[Suppl 3], 2007; COPD = Chronic Obstructive Pulmonary Disease.

Table 1-6 Asthma Severity Based On History, Examination Findings, Vital Signs and Canadian Triage and Acuity Score.

	Mild	**Moderate**	**Severe**	**Near-fatal**
CTAS	4,5	3	2	1
SaO_2	Normal	Normal	90-95%	<90%
SABA Use prior to ED	Increased	Increased	Increased	Constant
Response to SABA	Complete	Partial	Blunted	None
FEV_1/PEF (% predicted)	>60%	40-60%	Unable to perform or < 40%	Unable to perform
Level of consciousness	Alert and oriented	Alert and oriented	Conscious, difficulty speaking	Decreased level of consciousness
Time frame for physicians consultation	> 60 minutes	30 minutes	15 minutes	immediately

Adapted from Reference from Canadian Association of Emergency Physicians; [130] Adult Emergency Department Asthma Care Pathway (EDACP); [129] CTAS = Canadian Triage and Acuity Score; SABA = short-acting ß$_2$-agonists; SaO_2 = Oxygen Saturation; PEF = Peak expiratory flow; FEV=Forced expiratory volume in one second.

Table 1-7 Guidelines Recommendation for CXR in Acute Asthma Management

Guideline	Guideline Quote	Admission	Incomplete response	Suspected infection	Chest pain	Other
GINA	CXR should only be considered in adult asthmatic patients if a complication or alternative cardiopulmonary process is suspected, especially in older adults or for patients who are not responding to treatment where a pneumothorax may be difficult to diagnose clinically	ND	√	ND	+/-	PT
NAEPP	Needed to exclude other diagnosis	No clear statement on specific indications				
CTS/CAEP	Chest radiography should be performed if there is no response to therapy or if there is suspicion of an infectious cause, to identify or exclude unrecognized pneumothorax, pneumomediastinum or pneumonia.	ND	√	√	ND	PT/PM
SIGN/BTS	Chest X-ray is not routinely recommended in patients in the absence of suspected pneumomediastinum or pneumothorax, consolidation, life-threatening asthma, failure to respond to treatment satisfactorily requirement for ventilation.	ND	√	√	ND	PT/PM
Total		-	4 (100%)	2 (50%)	1 (25%)	3 (75%)

Note: √ = mentioned in the guideline; GINA = Global Initiative for Asthma; NAEPP=National Asthma Education and Prevention Program; CTS/CAEP = Canadian Thoracic Society/Canadian Association of Emergency Physicians; SIGN/BTS =

Scottish Intercollegiate Guidelines Network/ British Thoracic Society; ND = not documented; PT = pneumothorax; PM = pneumomediastinum; CXR= Chest X-ray.

Table 1-8 Management of Acute Asthma in the Emergency department and After Discharge.

Management of acute asthma in the ED		**Post emergency department management of acute asthma**	
Pharmacologic	Non-pharmacologic	Pharmacologic	Non-pharmacologic
Inhaled ß2-agonists bronchodilators (MDI + spacer> nebulization)	Oxygen	Systemic corticosteroids: (IM or shot-course oral)	Patient education
Systemic corticosteroids (IV, oral)	Non-invasive ventilation	ICS (Mono-therapy or combined with LABA)	AAP
ICS	Elective intubation and mechanical ventilation		Smoking Cessation
Inhaled short acting anticholinergics bronchodilators (ipratropium bromide)			Immunization for influenza
Intravenous magnesium sulfate (in severe cases)			Follow-up with primary care provider and re-assessment
Epinephrine (IM)			Trigger avoidance
			MDI + spacer technique review

AAP = Asthma Management Plan; ICS = Inhaled Corticosteroids; ED = Emergency Department; IM = Intramuscular corticosteroids; LABA = Long acting ß2-agonists

Table 1-9 Post emergency department disposition and management of acute asthma

Criteria	Definite admission	Observation/prolonged ED stay	Discharged
Patient LOC/fatigue	Abnormal	Normal	Normal
History	Previous intubation Recent ED visits or hospital Non-adherence, prior admission.	Previous ED visit, history of poor adherence to controller medication. Socially isolated, psychological problems	No recent or prior ED visit or admission, no history of poor adherence to controller medication
Response to therapy	Blunted	Moderate	Near-complete
PEF/FEV1 (%predicted)	No change	40-60%	>60%
Medical management	Repetitive PEF, FEV1, pulse oximetry and ABG, consider Non-invasive ventilation, Elective intubation and mechanical ventilation	Continue ICS, oral corticosteroids and repeated monitoring of oxygen saturation, PEF and FEV_1	Oral corticosteroids short cause, then ICS/LABA for chronic management, asthma education and individualized asthma action plan to prevent relapse and follow up.

LOC = Level of consciousness; ED = Emergency department; ICS = Inhaled corticosteroids; PEF = Peak expiratory flow rate; FEV = Forced expiratory volume in one second; ABG = Arterial blood gases; LABA = Long acting beta-agonist.

Adapted from Acute asthma in adults: a review; 107 Asthma exacerbations. 5: assessment and management of severe asthma in adults in hospital; [108] Assessing severity of adult asthma and need for hospitalization; [109] and British Thoracic Society/Scottish Intercollegiate Guidelines Network guideline.[80]

2 Chapter 2: The Role of Chest Radiography in Acute Asthma-A Systematic Review

2.1 Abstract

2.1.1 Objectives

Acute asthma is a common presentation to the emergency department (ED) and most patients do not require a chest radiograph (CXR). Given the frequency of ED asthma presentations and the contribution that ordering a CXR adds to ED flow delays, safety issues (e.g., radiation exposure) and cost concerns, reducing CXR ordering in acute asthma is a possible Choosing Wisely® target for emergency practitioners. The objective of this study is to synthesize the evidence and generate clinical recommendations about CXR ordering for adult patients with acute asthma in the ED.

2.1.2 Methods

A comprehensive search of the literature was conducted including nine different databases (e.g., MEDLINE, EMBASE and CINAHL). All study designs examining the utility of CXRs conducted in the ED for patients with acute asthma were eligible. Two independent reviewers using standardized inclusion and exclusion criteria assessed the articles for inclusion and conducted a quality assessment using the Canadian Institute of Health Research-Effective Public Health Practice Project (CIHR-EPHPP) quality assessment tool. Results are reported as weighted proportions and pooled data represents the mean for the outcome.

2.1.3 Results

From 455 citations, 15 published studies and one unpublished dataset from the Anti-inflammatories in Relapses of Asthma (AIR) met the inclusion criteria, these studies involved5093 patients. There was considerable diversity in terms of design, follow-up, and outcomes in the included studies. Across all selected studies, the quality was low to moderate. The proportion of CXR ordered varied from 22-95.7% for all included studies. The weighted proportion of CXR ordered was 60.0% (95% CI: 47.0, 72.2) for patients seen in the ED and 87.6% (95% CI: 81.0, 93.1) for admitted patients, whose asthma presentation was severe enough to warrant hospitalization. The weighted proportion of positive CXR was 9.5% (95% CI: 7.1, 12.4) for patients seen in the ED and 26.0% (95% CI: 6.1, 53.0) for hospitalized adult patients with acute asthma. Positive CXR outcomes were variably defined among studies and complications were infrequent, the most commonly reported abnormality was pneumonia (7.1% and 7.0% for ED and hospitalized patients respectively).

2.1.4 Conclusions

Although variability was demonstrated, the existing literature suggests CXR use is high and positive findings are infrequent, even in hospitalized patients. Clearly, chest radiography could be reduced in patients presenting to the ED with acute asthma. Recommendations for when a CXR is indicated (e.g., features of pneumonia, chest pain suggesting a pneumothorax/mediastinum, first-time asthma exacerbation and part of the admission process) could assist clinicians with decision-making. EDs should explore ways to implement intervention and measure/report this outcome.

2.2 Introduction

Asthma is a chronic disease of the airways characterized by dyspnea and associated with wheezing, non-productive cough and chest tightness. The underlying cause is recurrent and reversible airway obstruction secondary to airway hyper-responsiveness and mucus hyper-secretion in people with a genetic predisposition to the disease.[133] It is estimated that approximately 3 million Canadians are diagnosed with asthma and more may be suffering without a diagnosis.[22]

Acute asthma attacks occur when patients with asthma suffer an increase in their airway inflammation, experience worsening/sustained symptoms and require medication changes or access to additional health service. Acute asthma attacks are potentially life-threatening events if patients do not respond to therapy.[134-135] At times, these events are serious enough to result in emergency department (ED) presentation, hospital admission, and/or mechanical ventilation in an intensive care unit.

When patients have moderate to severe exacerbations of asthma, presentation to the ED often occurs. Use of investigations in this setting is uncommon; however, arterial blood gases (ABG) and chest x-rays (CXRs) may be obtained. Chest radiographs have been used to rule out a variety of asthma-related complications (e.g., pneumothorax/mediastinum) or comorbidities (e.g., pulmonary oedema, heart failure and pneumonia/consolidation). ***Table 2-1*** summarizes the recommendations for ordering a CXR from current international guidelines on acute asthma management. Overall, there was variability in the text statements from all guidelines; however, some consistency emerged. For example, all guidelines suggested failure to respond/incomplete response represented a rationale for

ordering a CXR.[2, 5, 47, 50] Few guidelines, however, identified chest pain as a symptom to trigger the need for a CXR (e.g., concern regarding pneumothorax/mediastinum).

Despite these guidelines, CXRs are still ordered in the absence of suggested indications in asthma patients who present to EDs.[136-140] This disconnect between guidelines and practice in the ED has significant ramifications for existing and stretched health care resources. The over-use of CXRs for patients with asthma who present to the ED is similar to challenges elsewhere in the healthcare system to improve efficiency, provide high quality care and "do less". Several factors such as cost, cumulative radiation exposure, finite healthcare resources and patient factors need to be considered when ordering CXRs for patients with acute asthma in the ED. While guidelines aid physician decisions, one cannot rule out exceptions due to the diversity of presentations of acute asthma and the physician's acumen when it comes to managing their patients. In order to determine the value of a CXR in patients with asthma and to guide physicians in practice decisions, it will be useful to know if CXR ordering influences the outcome of patients (e.g., the proportion of positive CXRs that influence management of patient) and how patients perceive their care. Finally, such information is needed in order to determine if reducing CXR ordering is a potential Choosing Wisely® target for emergency medicine practice.

Given the variations[141-142] among studies on proportion of positive CXRs and the lack of systematic reviews on the use and influence of CXRs on the care of adult patients with acute asthma, this chapter describes a systematic review to assess CXR use and results for adult patients with moderate-severe acute asthma. The objectives of this systematic review were to assess the ordering of CXRs for adult patients with acute asthma in the ED, to

determine the percentage of positive CXR findings and to assess the impact of the CXRs for patients who present to the ED. Moreover, the research was also designed to identify the factors associated with CXR ordering in adult patients with acute asthma presenting to EDs.

2.3 Methods

2.3.1 Protocol

A study protocol was developed *a priori* to define the objectives, outline the search strategy, establish explicit selection criteria, determine the primary outcome, guide the data collection process, and define the analysis.

2.3.2 Research Question

The research question addressed in this review was: In adult patients presenting to the ED with acute asthma (Population), what is the proportion of chest radiographs ordered, the definition and proportion with positive results (Outcomes), and the factors associated with those positive results?

2.3.3 Search Strategy

Based on a pre-specified search protocol, we conducted a comprehensive search of Medline, EMBASE, Scopus, CINAHL, Proquest, LILAC as well as Web of Science-Biosis and web of science core with the help of a librarian. No language or date restrictions were applied; however, the search was restricted to adults (16 years and above). The search included search terms in medical subject headings (MeSH) as follows: asthma, thoracic, radiography, bronchography, and emergency services hospital, adult or middle age. The

search strategy is detailed in the appendix, studies published between 1946 to 7 May 2016 were included. In January 2016, grey literature searches of the *Canadian Journal of Emergency Medicine* (2009 - 2015), *Academic Emergency Medicine* (2005 - 2014), and *Annals of Emergency Medicine* (2004 - 2014) were completed. Searches of Controltrial registry, Clinicaltrials.gov, Cochrane registry of control trials as well as Google Scholar were also completed on 7 May 2016.

2.3.4 Study Selection and Eligibility Criteria

Studies which assessed the ordering of CXRs in the ED for adult patients with acute asthma, and studies involving ED management of acute asthma were included (***see Table 2-2***). Based on screening of the study titles, studies were excluded if they were unrelated to asthma, ED management of asthma, studies on the use of CXRs for children with asthma who presented to the ED, studies on the use of CXRs for chronic obstructive pulmonary disease (COPD). Two independent reviewers (FO and TY) conducted a full text review based on inclusion and exclusion criteria.

2.3.5 Data Extraction

Two independent reviewers (FO and TY) extracted data from the included papers using a predesigned data extraction form. The items on the data extraction form were: study design, study setting, study outcome, study country, number of participants, gender, study date, asthma severity of the study participants, treatment changes due to CXR outcome and other factors worthy of notes in the included studies.

2.3.6 Study Quality Assessment

In order to assess the quality of included studies, the Canadian Institute of Health Research - Effective Public Health Practice Project quality assessment tool (CIHR-EPHPP) was employed. The CIHR-EPHPP assigns a score to a study using the following criteria; selection bias, study design, confounders, blinding, data collection methods and withdrawal and drop-outs. In each of these categories, studies are rated and assigned points: 1 for strong, 2 for moderate and 3 for weak ***(see Table 2-3)***, allowing for a best score of 6 (strong in all categories), and a maximum score of 18, indicating weakness in all categories.

2.3.7 Summary of Evidence/Data Analysis

This systematic review summarised the evidence for CXR ordering and abnormalities in adult patients with acute asthma in the ED. In order to take the effect of varying samples sizes of the included studies into consideration when estimating the overall mean (Simpsons' paradox),[143-144] this study estimated: a weighted proportion (in percentage) of CXR ordering among all adult patients with acute asthma seen in the ED, and in admitted patients. It estimated the weighted proportion (in percentage) of CXR abnormalities among patients in the ED and in admitted patients. This study also combined the data of CXR ordering and data of all positive CXRs for pneumonia (defined variably as: radiographic evidence of infiltrate, opacification and/or consolidation), heart failure, pneumothorax/mediastinum (comorbidity and complications) from all included studies and estimated an overall proportion in percentage (not weighted) for each of these outcomes. These pooled estimates were carried out using Microsoft Excel (Microsoft Corporation, Washington, USA) and Review Manager (Version 5.3; Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014).

2.4 Results:

2.4.1 Search Results

From 455 citations and subsequent full text review of 29 potentially relevant studies, fifteen studies met our pre-specified inclusion criteria (they were all selected with the help of an adjudicator; BHR). One unpublished data on CXR ordering was also retrieved from the Anti-inflammatories in Relapses of Asthma (AIR).[145] The grey literature searches only yielded one additional citation; but this paper was subsequently excluded for failing to meet our inclusion criteria after a thorough review. The 15 papers for quality assessment were all identified with the comprehensive search strategy outlined in the protocol.

2.4.2 Included Studies

The studies were carried out in nine countries; Turkey, USA, Pakistan, United Kingdom, Singapore, Canada, Malta, Australia, and Spain. Twelve of the 16 (including one unpublished dataset) studies were retrospective chart reviews, while four were prospective studies; there was heterogeneity across study design, research question and analysis of the studies.

2.4.3 Radiology Ordering

Eleven studies involving adult patients seen in the ED included 3546 patients, while four studies involving hospitalized patients included 1547 patients. There was variability in the proportion of people who received CXR across studies in both subgroups of patients, which ranged from 22-95.7% (***see Table 2-3***). The median proportion of CXR ordering for patients in the ED was 58.6%, while the weighted proportion of CXR ordered was 60.0%

(95% CI: 47.0, 72.2). The median proportion of CXR ordered for the more severe and hospitalized adult patients with acute asthma was 84.5%, while the weighted proportion of CXR ordering for this subgroup of patients was 87.6% (95% CI: 81.0, 93.1). In order to accurately estimate these values; we excluded two studies which focussed solely on abnormalities for CXR in asthma patients which excluded patients for whom CXR were not ordered (***See Table 2-3***). There was also a variation in how the CXRs were ordered, and how the results of the CXRs were interpreted. Seven of these studies were primarily designed to investigate the use of CXRs in acute asthma; [137-140,146] while eight studies investigated the management of acute asthma generally (CXRs ordering in the ED was part of a broader investigation of the appropriate management of acute asthma in ED).[136, 145, 147-152] The sixteen (including one unpublished study) studies included adult patients with acute asthma; two of these studies were Canadian studies, although one of these Canadian studies may have included some children (mean age was 23.7),[146] the additional information received from the authors when contacted were insufficient to determine the proportion of children in this data.

2.4.4 Study Quality

Using the CIHR-EPHPP quality assessment tool, the 15 (excluding the unpublished data from AIR study) included studies were generally weak studies due to the nature of the study design (retrospective and prospective chart reviews). The 15 included studies (published) were of poor quality in terms of global quality assessment rating, their global scores were from 16 to 18 (***see Table 2-3****).*

2.4.5 Radiographic Criteria

Positive outcomes from CXRs were variably defined among studies. The median proportion of positive CXRs was 8.4%, while the weighted proportion of abnormalities reported was 9.5% (95% CI: 7.1, 12.4) for patients seen in the ED. The weighted proportion of positive CXRs was 26.0% (95% CI: 6.1, 53.0) for studies which involved more severe and hospitalized adult patients with acute asthma. Three of the studies were excluded from this weighted proportion estimation for not reporting the outcome of CXR ordered for patients seen in the ED, while two were excluded for not reporting the outcomes of CXR ordered for hospitalized patients *(**see Table 2-3**).*

From the perspective of positive CXR results (***See Table 2-3 and 2-4***), the following abnormalities were reported: pneumonia (7.1% of ED patients, and 7.0% of admitted patients), heart failure (None for ED patients and 5.3% of admitted patients), pneumothorax/mediastinum (0.1% of ED patients, and 0.2% of admitted). Other abnormalities reported included atelectasis (None for ED patients and 1.2% of admitted patients), and interstitial markings (0.9% of ED patients and 0.6% of admitted patients). The impact of these positive outcomes on the management of individual were not clearly stated.

2.4.6 Associations

Factors associated with positive CXR were not clearly evaluated in most of the included studies. Overall, CXR ordering and abnormalities were higher among admitted patients than in patients seen in the ED (***see Table 2-3***)

2.5 Discussion

Using a comprehensive search strategy and methods to limit publication and selection bias, this systematic review searched for evidence of CXRs ordering for adult patients with an exacerbation of asthma who presented to the ED. Out of the 455 citations, only 16 studies (including the unpublished data from AIR study) met our pre-specified inclusion criteria (***see Figure 2-1***). Overall, these studies involved mostly patients with known history of asthma. There was a significant variation in the percentage of CXR ordering among patients seen in the ED and those patients who were admitted (60.0% vs. 87.6%, respectively), suggesting patients with more severe asthma, requiring hospitalization are more likely to receive CXR. The mean weighted proportion of positive CXR results for patients seen in the ED was also considerably less than that of hospitalized patients (9.5% vs. 26.0%, respectively).

The positive outcomes mainly represented infection/consolidation, other findings were: perihilar markings, atelectasis, interstitial markings, hyperinflation, heart failure and pneumomediastinum (***see Table 2-3***). CXRs are ordered for asthma patients to rule out complications of asthma (e.g., pneumothorax/mediastinum) and important comorbidities (e.g., pneumonia, heart failure and lung cancer). The percentage of CXRs resulting in a diagnosis of heart failure (0%), pneumothorax/mediastinum (0.1 %), atelectasis (0%), and interstitial markings (0.9%) was exceedingly low for ED patients (*See Table 2-4*).

Two of three (66.7%) pneumothorax/mediastinum, 57 (100%) heart failure and 13 of 13 (100%) of atelectasis reported were from a study whose participants were 16 to 94 years old and were all admitted patients.[150] Which means, age may have contributed to the

numbers of these complications and comorbidity detected by CXR in this study. When this is taken into consideration, this review found rare positive findings for these radiographic entities, suggesting clinical reality does not reflect the concerns of most physicians. While CXRs ordering slightly increased from 1987 to 2015, it appears abnormalities detected from these CXRs have been stable in the same period. There was also no statistically significant correlation between CXR ordering and positive outcomes for CXR in the included studies {Pairwise correlation coefficient, R= -0.3 (p-value: 0.53)}.

Patients and physicians worry about infection, the percentage of pneumonia/consolidation was 7.1% and 7.0% for patients seen in the ED and hospitalized patients, respectively. This finding was the most common positive outcome of clinical significance. Many patients with asthma would exhibit hyperinflation and mucous plugging and result in atelectasis and over-committing to the diagnosis of pneumonia by radiologists,[153] consequently, the proportion of positive pneumonia cases may represent an over-estimation. Nonetheless, community acquired pneumonia is a genuine concern and guidelines should provide recommendations regarding signs (e.g., fever, auscultatory adventitial sounds, etc.) and symptoms (e.g., sputum purulence, chest pain, cough, etc.) of suspected lung infections.

The high occurrence of pneumonia in the positive CXRs for asthma makes it a potential target for selective CXR ordering for asthma patients in the presence of risk factors. Since CXR ordering was mostly based on the physician's decision, it is suspected that more severe asthma presentations were more likely to have received CXR (confounded by severity). This higher proportion of admitted patients, compared to patients seen and discharged from the ED, who received a CXR further highlights the role of severity of

asthma presentation in CXR ordering; however, the proportion of pneumonia and pneumothorax/mediastinum (the most important comorbidity and complications) reported, however, were similar for both subgroups of patients. Most CXRs are interpreted by staff radiologists with knowledge of the clinical presentation, which can bias the interpretation. The preferred methods would involve an experienced radiologist who was blinded to the clinical features and the study question; however, this was not completely reported in any study. It was not also clearly stated if the findings from the CXR influenced the management of patients.

Considering the cost implications for diagnostic testing, the impact on ED resources and radiation exposure, these results suggest that chest imaging could be restricted to adult patients with acute asthma who show signs and symptoms consistent with pneumonia, older asthma patients (with a risk of COPD and/or heart failure) and patients with moderate-severe chest pain (e.g., suspected pneumothorax/mediastinum). Reducing CXR ordering is a potential Choosing Wisely® target for practitioners in emergency medicine. Choosing Wisely®, an initiative of the American Board of Internal Medicine Foundation and Consumer Reports, widely supported by many medical specialty societies and recently initiated in Canada, encourages the use of tests and procedures that are supported by evidence and are truly necessary, safe and cost effective. Choosing Wisely Canada (CWC) aims to achieve the above objective by encouraging dialogue and collaboration between physicians and patients. The CWC approach has been adopted by a number of provincial health care groups, medical associations and health quality councils in Canada as well as internationally in nations such as Japan, Germany and Switzerland.[154-156]

The failure of studies to provide multi-variable models or other methods to identify factors associated with positive CXR findings is disappointing. There is an urgent need for further studies in this regard to determine the factors associated with positive CXRs in the ED, as this will enable practitioners to better target CXR ordering for asthma patients that presents to the ED with these predictive factors. Understanding the needs, preferences and opinions of patients and ED physicians regarding CXR use in patients with asthma will inform the Choosing Wisely® program on ways to structure their knowledge translation activities.

2.5.1 Limitations

There are several limitations of this systematic review that need to be discussed. First, the quality of the studies was generally low to moderate using the CIHR-EPHPP scale. The studies were mostly chart reviews and CXR ordering and outcomes for asthma patients were mostly carried out retrospectively (**12** out of the **16** studies); however, this may reduce the impact of the Hawthorne effect on studies' result. Secondly, the blinding of radiologists was unclear. The CXR reporting was mostly carried out by physicians who were blinded to the study hypothesis and CXR ordering, this is a general weakness of most diagnostic studies. Third, positive CXRs for infection were not compared to earlier CXRs in all cases. This may have increased the percentage of "positives" observed for this comorbidity, since it is not clear if these were new infiltrates related to true infections or reflecting chronic changes. Lastly, not all patients received a CXR and follow-up of those who did not receive imaging was not always available. The decision to order a CXR was at the discretion of treating physician which makes the most severe cases/patients, in whom

complications are suspected, more likely to receive a CXR *(**see Table 2-3**).* The follow-up of patients not receiving a CXR was incomplete and precludes confirmation they remained well or uninfected. The high CXR ordering also means there are higher chances of false positives in the included studies than otherwise.

2.5.2 Conclusions

There is a significant variation in CXR ordering for adult patients with acute asthma in ED settings, the proportion of positive CXRs results for the most important complications (pneumothorax/mediastinum) and co-morbidities (pneumonia) that need to be diagnosed in the ED management of asthma patients are relatively low.

Guidelines provide variable recommendations for the ordering of CXR for patients with asthma in the ED setting. Given the rare findings of clinically important co-morbidities and/or complications identified in this systematic review, interventions and strategies to reduce CXR ordering are urgently needed. Successful implementation could reduce patient exposure to unnecessary ionizing radiation, improve patient flow through the ED and reduce health care costs in this setting.

Table 2-1 Guidelines Recommendation for CXR in Acute Asthma Management

Guideline	Guideline Quote	Admission	Incomplete response	Suspected infection	Chest pain	Other
GINA	CXR should only be considered in adult asthmatic patients if a complication or alternative cardiopulmonary process is suspected, especially in older adults or for patients who are not responding to treatment where a pneumothorax may be difficult to diagnose clinically	ND	√	ND	+/-	PT
NAEPP	Needed to exclude other diagnosis	No clear statement on specific indications				
CTS/CAEP	Chest radiography should be performed if there is no response to therapy or if there is suspicion of an infectious cause, to identify or exclude unrecognized pneumothorax, pneumomediastinum or pneumonia.	ND	√	√	ND	PT/PM
SIGN/BTS	Chest X-ray is not routinely recommended in patients in the absence of suspected pneumomediastinum or pneumothorax, consolidation, life-threatening asthma, failure to respond to treatment satisfactorily requirement for ventilation.	ND	√	√	ND	PT/PM
Total		-	4 (100%)	2 (50%)	1 (25%)	3 (75%)

Note: √ = mentioned in the guideline; GINA = Global Initiative for Asthma; NAEPP=National Asthma Education and Prevention Program; CTS/CAEP = Canadian Thoracic Society/Canadian Association of Emergency Physicians; SIGN/BTS = Scottish Intercollegiate Guidelines Network/ British Thoracic Society; ND = not documented; PT = pneumothorax; PM = pneumomediastinum; CXR= Chest X-ray.

Table 2-2 Descriptions of Included Studies

Study, Year	Location	Sample Size	Timing of Data Collection	Design/Populations	Ordering/Skills	Asthma severity
All cases						
Dalton AM, 1987.	United Kingdom	349	1987	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physician's skill level: ED MDs	None described
Eddy E, 2004.	Australia	140 (158 episodes)	2001	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	According to National Australian Guidelines; validity done by independent researcher Mild: 36% Moderate:32% Severe 32%
Leong LB, 2012.	Singapore	201	2010	A prospective observational study of all patients presenting to ED with acute asthma.	CXR ordering: Physician's decision Physician's skill level: ED MDs	Global Initiative for Asthma (GINA) Mild: 67.1% (135/201) Moderate: 28.4% (57/201) Severe: 3% (6/201) IRA: 1.5% (3/201)
Rowe B, 2014 (unpublished data)	Canada	382/805	2007	A prospective observational study of all patients presenting to ED with acute asthma.	CXR ordering: Physician's decision Physician's skill level: ED MDs	Mild-moderate (all patients discharged)
Vermeulen, 2015a	Canada	1371	2008	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: No detail provided	Not provided

Gouder C, 2013.	Malta	244	2010	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	Non described
Linares T, 2006.	Spain	46	2003	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Gentile NT, 2003.	USA	213	1999	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Findley LJ, 1981.	USA	60 patients (90 episodes, I used 90 patients instead)	1981	A prospective study of all patients admitted for asthma for acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	Non described
Akoglu S, 2004.	Turkey	72	2002	A prospective study of all patients admitted for asthma for acute asthma	CXR ordering: Physician's decision. Physician's skill level: Residents.	Global Initiative for Asthma (GINA) Mild/moderate = 46 Severe = 12
Stell IM, 1994	UK	87	1994	A retrospective chart review of all patients admitted for asthma for acute asthma	CXR ordering: Senior house officers' decision.	None described

					Physicians skill level not stated	
Admitted cases						
White CS, 1991	USA	54	1887	A retrospective chart review of asthma patients admitted for acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Daley J, 1986.	USA	127	1984	A retrospective chart review of asthma patients admitted for acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Hussain SF, 1995.	Pakistan	102	1993	A retrospective chart review of asthma patients admitted for acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Hussain SF, 2004.	Pakistan	100	2004	A retrospective chart review of asthma patients admitted for acute asthma	CXR ordering: Physician's decision. Physicians skill level not stated	None described
Pickup CM, 1994.	United Kingdom	1016	1993	A retrospective chart review of all asthma patients presenting to ED with acute asthma	CXR ordering: Physician's decision. Physician's skill level: (junior doctors) house	None described

					officer/resident only?	
Total	9	5093		12 retrospective study (75%), 4 prospective study (25%)	2 ED MDs (16%)	

Note: ED = Emergency Department; CXR = Chest X-ray; COPD = Chronic Obstructive Pulmonary Disease; GINA = Global Initiative For Asthma; MD = Doctor Of Medicine; IRA = Imminent Respiratory Arrest.

Table 2-3 Quality Assessment, Chest Radiographic Ordering and Results from Included Studies.

Study, Year	Global score	Global rating	Overall CXR ordering	Abnormal outcome	Outcome/Results
All cases					
Dalton AM, 1987.	16	Poor	76/349 (22.0%)	11/76 (14.5%)	Edema (3), Infection (8), Hyperinflation
Eddy E, 2004.	18	Poor	107/158 (68.0%)	9/107 (8.4%)	Consolidation (5), Pneumo-mediastinum(1), Moderate pleural effusion (1), oval density (1), abscess (1)
Leong LB, 2012.	16	Poor	170/201 (84.6%)	19/170 (11.2%)	Opacifications: 19 (12 patchy, 6 diffuse, 1 lobar) Mild: 9/135 Moderate 9/57 Severe: 1/6 IRA 0/3
Rowe B, 2014 (unpublished data)	-	-	382/805	Not provided	Not described
Vermeulen, 2015	17	Poor	590/1371(43.0%)	Not provided	None described.
Gouder C, 2013	17	Poor	206/244(84.4%)	12/206(5.8%)	Pneumonia (12).
Linares T, 2006.	18	Poor	44/46(95.7%)	Not provided	None described.
Gentile NT, 2003.	16	Poor	85/213(40.0%)	6/85(7.1%)	Pneumonia (6).
Findley LJ, 1981.	17	Poor	None provided	7/90 (7.8%)	Pneumonia (1), interstitial marking (7).

Akoglu S. 2004	18	Poor	34/72 (47.2%)	6/33 (18.2%)	infiltration (3); hilar enlargement (3); hyperinflation
Stell IM, 1994	17	Poor	51/87 (58.6)	Not provided	Not provided
Pooled weighted proportion for ED patients (95% CI)		Poor	60.0% (95% CI: 47.0, 72.2)	9.5% (7.1- 12.4%)	None provided
Admitted cases					
Daley J, 1986	17	Poor	122/127 (96.1%)	Not Provided	Not provided
White CS, 1991	15	Poor	None provided	23/58 (40.0%)	Focal parenchyma opacity (7), New pulmonary nodule (1), pulmonary vascular congestion (3), interstitial markings (6), enlarged cardiac silhouette (5). Pneumothorax (1)
Hussain SF, 1995	16	Poor	87/102(85.0%)	Not provided	Not provided
Hussain SF, 2004	16	Poor	84/100 (84.0%)	Not provided	Not provided

Pickup CM, 1994.	17	Poor	1016/1218 (83.4%)	151/1016 (15.0%)	Pulmonary infection(68), segmental atelectasis(13), pneumothorax(1), pneumomediastinum (1), cardiac failure (57), pulmonary tuberculosis(10), carcinoma (1)
Pooled weighted proportion for admitted patients (95% CI)		Poor	87.6% (81.0-93.1%)	26.0% (6.1-53.0%)	-

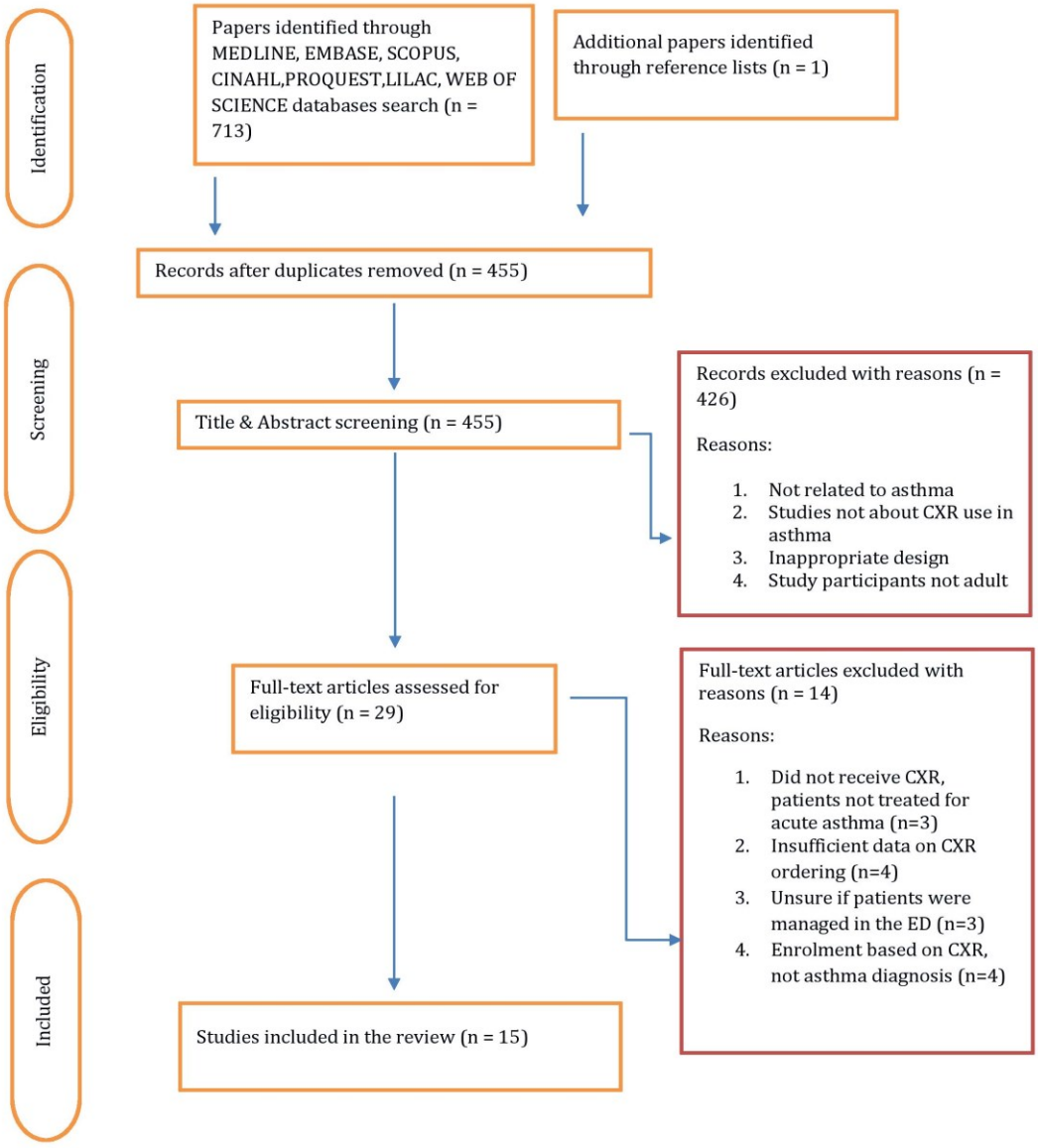
CXR = Chest X-Ray; CHF = Congestive Heart Failure; IRA = Imminent Respiratory Arrest.

#: Excluded (every patient received CXR); CI=Confidence Interval

Table 2-4 Major abnormalities reported

Comorbidity and complications	ED cases (n=767)	Admitted cases (n=1074)
Pneumonia	54 (7.1%)	75 (7.0%)
Pneumothorax/mediastinum	1 (0.1%)	3 (0.3%)
Heart Failure	0 (0%)	57 (5.3%)
Atelectasis	0 (0%)	13 (1.2%)
Interstitial markings	7 (0.9%)	6 (0.6%)

Figure 2-1 Flow Chart for Study Selection and Inclusion for a Full Text Review



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3 Chapter 3: Chest Radiographs in Acute Asthma

3.1 Abstract

3.1.1 Objectives

Chest x-rays (CXR) are variably ordered for adult patients with acute asthma in the emergency department (ED). A systematic review showed a high proportion of these patients currently receive a CXR, while positive outcomes for pneumonia and pneumothorax/mediastinum are infrequent. There is a scarcity of evidence on factors associated with CXR ordering and its impact on patient outcomes. This study filled this knowledge gap and examined factors associated with CXR ordering in Canadian EDs, and the impact of the CXR ordering on patient outcomes.

3.1.2 Methods

An ED dataset was developed from two prospective studies of adult patients (age > 16 years) discharged from the ED following management for acute asthma. The database was examined for CXR ordering and reported as proportions. Factors associated with CXR ordering and impact of CXR ordering on patient outcomes were reported as odds ratio with 95% confidence interval (CI).

3.1.3 Results

The database contained 887 patients; most were young (median age: 29 years; female: 57.6%). Forty-eight percent (95% CI: 44.7, 51.3) of adult patients with acute asthma in these Canadian EDs received a CXR prior to discharge. CXR ordering was not associated with most clinical and demographic factors; however, patients who reported fever,

purulent sputum and patients for whom an ECG was ordered were more likely to receive a CXR. CXR ordering was also associated with a longer length of stay in ED.

3.1.4 Conclusions

A high proportion of adult patients who are well enough to be discharged home following treatment for acute asthma in Canadian EDs receive a CXR. Radiographic ordering is independent of most clinical/demographic factors and does not influence future relapse; however, it is associated with a longer length of stay in the ED.

3.2 Introduction

A prior systematic review of studies up to 2016 (no language restriction and based on an *a priori* protocol), examined chest x-ray (CXR) ordering for adult patients with acute asthma seen in the ED and estimated: the proportion of patients who received a CXR, the proportion of positive CXRs for adult asthma patients in the ED and the most important clinical outcomes (See Chapter 2 for more detail on this systematic review). The weighted proportion of CXR ordering was 60.0% (95% CI: 47.0, 72.2) for patients seen in the ED and 87.6% (95% CI: 81.0, 93.1) for hospitalized patients with more severe asthma presentations. The weighted proportion of positive outcomes was 9.5% (95% CI: 7.1, 12.4) for patients seen in the ED and 26.0% (95% CI: 6.1, 53.0) for hospitalized adult patients with acute asthma. The most commonly reported clinical outcome for adult patients with acute asthma was pneumonia (7.1% for patients seen in the ED, and 7.0% for hospitalized patients). The proportion of pneumothorax/mediastinum reported was exceedingly low (0.1% for ED patients and 0.2% for hospitalized patients).

Despite this evidence summary, it is unclear what factors are associated with ED CXR ordering, the influence of CXRs have on in-ED outcomes (e.g., management, length of stay in the ED) and their impact on patient management and post ED visit outcomes (e.g., management and relapse). The current study is a secondary analysis of Canadian ED data from previous prospective clinical studies, in order to examine factors associated with CXR ordering for adult patients with acute asthma and determine the impact of CXRs on management, the length of stay in the ED and post-ED discharge management and relapse. The overall objective was to better understand CXR ordering and impact in order to design

an intervention to reduce CXR ordering in the future for adult patients presenting to the ED with acute asthma.

3.3 Methods

This study examined the available evidence for the use of CXR in diagnosis and management of adult acute asthma patients in the emergency department (ED) and estimated:

a) The percentages of CXR's obtained in the ED in adults with acute asthma.
b) The factors associated with CXR ordering for adult patients with acute asthma in the ED.
c) The impact of CXR on adult acute asthma outcomes (relapse, length of stay, death and hospitalization) after discharge from the ED.

3.3.1 Study design

A secondary analysis of clinical database from previous clinical studies was carried out to assess the factors associated with CXR ordering for adult patients with acute asthma assessed and managed in the ED and also identify differences in post-ED visit outcome between patients who received CXR and those who did not.

The data for the study was an emergency department dataset; the Anti-inflammatories in Relapses of Asthma (AIR) and The Lung Attack Alert (TLAL) merged datasets, which were collected between November 2003 and March 2007 and April 2011 to May 2012, respectively. In other to ascertain the association between CXR ordering and other adult

acute asthma diagnostic and management procedures in the ED, this study investigated the association between:

- CXR ordering and demographic factors (such as age, sex, duration of asthma, employment status etc.);
- CXR ordering and asthma signs/symptoms (such as sputum production, sputum color and fever);
- CXR ordering and initial acuity (measured by Canadian Triage and Acuity Score {CTAS} score);
- CXR ordering and presentation factors (such as time of day, duration of symptoms, vital signs {e.g., T > 37.9° C});
- CXR ordering and objective measures of lung function such as forced-expiratory volume at 1 second (FEV_1) and peak expiratory flow (PEF);
- CXR ordering and the treatment received by patients in the ED;
- CXR ordering and length of stay, other tests and discharge care (including the use of antibiotics);
- CXR ordering and relapse of adult patients following discharge from the ED.

3.3.2 Settings for AIR study

The AIR study was a prospective cohort study of the frequency of asthma relapse and the factors associated with relapse after ED visits. Patients were enrolled in 20 EDs across Canada between November 2003 and March 2007. Sixteen of the participating hospitals were urban tertiary hospitals, while four were community hospitals. The median ED census

for the participating hospitals was 50,000 patients per year, all participating centers were Canadian Association of Emergency Physicians' (CAEP) recognized research institutions.

3.3.3 Settings for TLAL study

The TLAL study was a randomized control trial (assessed the difference in post ED visit outcome between patients who received a standard referral to a primary care provider and those who received a more personalized lung attack letter when referred to a primary care provider) conducted at the University of Alberta Hospital and other emergency departments in Alberta.

The University of Alberta Hospital is one of the largest tertiary health care facilities in Canada, with an estimated ED visit census of 65,000 adults (17 year old and above) per year. The University of Alberta hospital is a trauma centre which serves the Northern part of the province and receives referrals from western Saskatchewan, north-eastern British Columbia, the Yukon Territories and the western half of the Northwest Territories.

3.3.4 Subjects

This subjects were adult (≥16 years of age on the day of the ED visit) asthma patients who were seen in ED for acute asthma and consented to participate in the AIR or TLAL study.

3.3.5 Data Collection

The data for this study were collected in a standardized manner using similar questions, forms and approaches in both studies. The baseline information on each patient was collected at ED presentation by trained research staff for both studies; however, ED diagnosis and management of patients in both AIR and TLAL studies were left to the

discretion of the treating emergency physician**.** Emergency department information systems (EDIS) and nursing notes at each site were used to obtain treatment information and time stamps for important ED events (physician assessment, first treatments, discharge time, etc.). Outcomes were assessed by telephone and EDIS/electronic medical records to determine important post-ED events (e.g., relapse, hospitalization and death).

3.3.6 Data collected

The AIR and TLAL datasets were merged into a single dataset which included:

i. Pre-ED data, (collected at the time of ED presentation): smoking status, age, marital status, sex, duration of asthma diagnosis, height, weight, race, employment status, education, relevant clinical history (e.g., number of ED visits in the past 2 years), chronic asthma management medication (e.g. short-acting beta-agonist {SABA}, short-acting anticholinergic{SAAC}, inhaled corticosteroid {ICS}, long-acting beta-agonist {LABA} and leukotriene receptor antagonist {LTRA} use);

ii. Patient signs/symptoms (e.g., cough, sputum, chest pain, fever, chills, and coryza);

iii. Objective measurement such as the PEF, FEV_1, respiratory rate, temperature, and other testing in the ED setting (e.g., arterial blood gas, electrocardiogram);

iv. ED medication management (e.g., SABA, SAAC, and systemic corticosteroid use;

v. Patients' outcomes: length of stay in the ED and relapse (within 4 weeks of the initial ED visit).

3.3.7 Outcome

The main outcome variable of interest was CXR ordering in the ED.

3.3.8 Other variables of interests

The other variables of interest in the study were: age, sex, number of ED visits in the past 2 years related to acute asthma, smoking status, PEF, sputum production/color/nature, duration of asthma diagnosis, race, marital status, employment status, medication history, fever, CTAS, chest pain, chills, and management (e.g., SABA and/or SAAC, corticosteroid use).

3.3.9 Analysis

Continuous data are reported as medians (with interquartile range {IQR}) while categorical data are reported as proportions (percentage). Continuous variables included in the logistic regression were categorised using clinically meaningful cut-off points. This study initially explored the data for an association between CXR ordering and the exposure variables using descriptive statistics (proportion). In order to estimate the adjusted odds ratio and determine the multivariable predictors of CXR ordering for adult patients with acute asthma in the ED, a univariate analysis of the predictors of CXR ordering in the ED was initially completed using logistic regression, and odds ratios (OR) with 95% confidence intervals (CI) were estimated. False positive results are a concern in this study, due to the number of clinical factors in the reduced model (multiple comparisons). A relatively large sample size, multi-variable modelling and model fitness reduced the chance of false positive. This also negates the need for a more conservative (Bonferroni correction) p-value for statistical significance for each variable in the multivariable model, using

Bonferroni correction may also lead to false negative results.[157] Finally, all clinical factors with p-value less than 0.1 were entered into a multivariable logistic regression model using a purposeful selection method. Potential confounding variables were assessed and excluded if they produced at least 15% change in the estimated coefficients of the other variables in the reduced model. Potential interaction of the plausible effect modifying variables in the final reduced model was also assessed. An adjusted ORs (aOR) with 95% CI for the final multivariable logistic were subsequently estimated and reported. Discharge PEF was excluded from the multivariable model, because expert clinicians felt flow measures at discharge do not influence the decision to order a CXR for adult patients with acute asthma. Multicollinearity for variables in the model were assessed by computing the tolerance statistics for each variable in the model, while model fitness was assessed using Hosmer-Lemeshow goodness of fit test. Missing data were imputed by considering how the data were collected in the ED. For example, while a "no" (patient does not have the signs/symptom) for certain variables (especially signs/symptoms and pre-ED medication) were recorded as zero on the standardized data collection form, some data collectors may not record missing data. Statistical analysis was carried out using Stata 13 (StataCorp LP, Texas USA).

3.4 Ethics

This is a secondary analysis of data from two other studies, the TLAL and AIR studies. The AIR study was reviewed and approved by the institutional research or ethics board of each site which participated in the studies, while the TLAL study was reviewed and approved by

the University of Alberta Health Research Ethics Board. No new data were collected for this sub-study. Participants in both studies received verbal and written information on the studies and each study subjects provided a voluntary and written informed consent.

3.5 Results.

3.5.1 Demographic factors

The merged dataset had a total of 887 patients with acute asthma. The median age of included patients was 29 years (IQR: 23, 39). Overall, 57.6% of the patients in the two studies were female.

3.5.2 Proportion of Radiographs Ordered

Four hundred and twenty-five (48%; 95% CI: 44.7, 51.3) of the patients assessed in the ED and deemed well enough to be discharged received a CXR.

3.5.3 Demographic and lifestyle factors associated with CXR ordering in the ED

In a univariate analysis, there was no statistically significant association between CXR ordering and patient's age ≥ 50 years and compared to 16-49 years (OR = 1.0; 95% CI: 0.6, 1.9), smoking status (OR {former smokers} = 1.0; 95% CI: 0.7, 1.3; OR { present smokers } = 1.0; 95% CI: 0.7, 1.3) compare to patients who have never smoked, female sex (OR = 0.9; 95% CI: 0.7, 1.2), patients' ethnicity (OR = 0.9; 95% CI: 0.4, 2.0) and employment status (OR {employed} = 1.0; 95% CI: 0.8, 1.3). None of these variables met the criteria for inclusion in a multivariable logistic regression model. From the univariate analysis result, it appears patients who were single were less likely to receive CXR compare to others (OR = 0.7; 95%

CI: 0.5, 0.9); however, this association was not statistically significant in a multivariable logistic regression (***See Table 3-1***).

3.5.4 Pre-ED visit clinical/medication

Univariate analysis results suggest CXR ordering was associated with ED visits in the prior two years (OR = 0.7; 95% CI: 0.6, 1.0), patient's use of pre-ED SABA (OR = 0.8; 95% CI: 0.6, 1.1), and patient's use of pre-ED systemic corticosteroids (OR = 4.0; 95% CI: 1.5, 11.0) (***See Table 3-2***). These variables, however, failed to reach statistically significant association in a multivariable logistic regression analysis (***See Table 3-7***).

3.5.5 Symptoms

Univariate analysis results suggest CXR ordering was significantly associated with patient's signs and symptoms at ED presentation, such as: chest pain (OR = 1.6; 95% CI: 1.2, 2.1), reported fever (OR = 2.2; 95% CI: 1.6, 3.0), purulent sputum (OR = 1.5; 95% CI: 1.1, 1.8), documented fever (T ≥ 37.8° C; OR = 11.7; 95% CI: 3.5, 38.5), pulse rate (OR = 1.3; 95% CI: 1.0, 1.7) and chills (OR = 1.6; 95% CI: 1.2, 2.1). A multivariable model failed to show an association between most of these variables and CXR ordering. In the multivariable analysis, physicians ordered more CXRs for patients with fever (aOR = 1.5; 95% CI: 1.0, 2.2), documented fever (37.8 °C; aOR = 7.2; 95% CI: 2.0, 25.7) and purulent sputum (aOR = 1.5; 95% CI: 1.1, 2.1).

3.5.6 Airway Obstruction

The result of the multivariable analysis shows that patients who received early PEF are less likely to receive CXR (aOR = 0.7; 95% CI: 0.5, 0.9) and ECG ordering for adult patients with

acute asthma was statistically associated with CXR ordering (aOR = 3.3; 95% CI: 1.7, 6.6). (***See Table 3-7***).

3.5.7 CXR utilization and other testing

The univariate analysis result suggest ABG ordering is statistically associated with CXR ordering (OR = 5.5; 95% CI: 1.2, 25.3); however, this association was not confirmed in the multivariable logistic regression.

3.5.8 CXR ordering and ED Treatment

There was no statistically significant association between CXR ordering and treatment factors such as; SABA use, SAAC use (***See Table 3-5***) and systemic corticosteroids use (OR = 0.8; 95% CI: 0.4, 1.6). The univariate analysis result shows a statistical association between use of magnesium sulfate and CXR ordering (OR = 3.6; 95% CI: 1.2, 11.1); however, a multivariable logistic regression failed to confirm this association.

3.5.9 CXR and LOS in the ED

Figure 3-1 shows CXR utilization appears to differ across different strata of ED length of stay; as the length of stay increased, the percentage of adult patients with acute asthma who received a CXR increased. There was a statistically significant association (***see Table 3-7***) between length of stay in the ED and CXR ordering. Patients who spent between 4 and 8 hours (OR = 3.0; 95% CI: 2.1, 4.2) and patients who spent a minimum of 8 hours (OR = 3.8; 95% CI: 2.0, 7.5) in the ED were more likely to have received a CXR compare to patients who spent less than 4 hours in the ED; however, the temporal relationship between CXR ordering and ED length of stay is unclear.

3.5.10 The impact of CXR on post ED visit outcome

There was no statistically significant association (***see Table 3-6***) between post ED visit outcome (relapse within 4 weeks post-ED visit) and CXR ordering in the ED. For example, there was no difference in the proportion who relapsed between those who received CXR and those who did not receive CXR {OR = 1.0; 95% CI: 0.7-1.4).

3.5.11 Model fitness and Multicollinearity

Hosmer - Lemeshow chi-square goodness of fit test for the final reduced multivariable model was not statistically significant (p = 0.15), and there was no evidence for multicollinearity of the variables in the model.

3.6 Discussion

There is a scarcity of evidence on factors associated with CXR ordering for adult patients with acute asthma in the ED, and the impact of CXRs on patient outcome. Using a large, detailed and comprehensive database of patients discharged from Canadian EDs, this report examined data for CXR ordering, factors associated with CXR ordering and the impact of CXRs on post-ED outcome of adult patients with acute asthma, such as length of stay (patients spent a minimum of 4 hours in the ED before discharge or admission) and relapse (within 4 weeks of ED visits).

Several important observations arise from this study. First, nearly 50% of adult patients with acute asthma presenting to these EDs in Canada received a CXR. This finding is consistent with the range of value from prior studies included in the Chapter 2 systematic

review (including one Canadian study).[147] Taken together, given the cost, ED delays and radiation risks associated with CXR ordering (especially in young women), these results suggest that reducing CXR ordering in acute asthma represents a potential target for improved quality of care (e.g., effectiveness, efficiency, safety and timeliness) in the ED. What were unknown prior to this study were the factors associated with ordering a CXR in adult patients presenting to the ED with acute asthma.

The results from a multivariable logistic regression of factors associated with CXR ordering suggest decisions to order a CXR were independent of socio-demographic factors such as the patients' age, race, sex, marital status, employment status and smoking status. Studies have shown that both smoking status (current and former smokers) and aging decrease mucociliary clearance and consequently decrease the expulsion of mucous from the respiratory tract, resulting in bacterial colonization and infection. Yet, this study found no statistical association between CXR ordering and smoking status and age.[158-160] There was also no difference observed for CXR ordering between males and females, despite the fact that previous studies have shown males are at a higher risk of lower respiratory tract infection.[161] These results suggest that the patient's sex had no influence on the decision by emergency physicians to order a CXR for adult patients with acute asthma.

There were no statistically significant associations between CXR ordering and clinical and medication history (***see Table 3-7***) such as: prior ED visit (a minimum of one ED presentation for asthma in the prior 2 years), duration of asthma diagnosis and patient's asthma medication history (e.g., use of ICS, ICS/LABA, SABA, SAAC, systemic corticosteroid and LTRA). This suggests that physicians do not employ chronicity and outpatient severity

in deciding on the need for a CXR. Moreover, since ICS and ICS/LABA use were not associated with more CXR ordering, this also suggests that recent data suggesting an association between long-term use of ICS agents and an increased pneumonia risk in some patients with respiratory conditions (i.e., COPD) may not have filtered down to emergency physicians or influenced practice.[162-163]

CXR ordering was also independent of the CTAS score assigned upon presentation in the ED. Patients whose airway obstruction (early PEF) were assessed at presentation were less likely to receive a CXR (***See Table 3-7***). This result suggests patients whose degree of airway obstruction was assessed early upon presentation in the ED and determined to be minimal or characteristic of an asthma exacerbation may not have received a CXR. This further highlights the need for spirometry prior to treatment for adult patients with acute asthma, as it could help reduce unnecessary diagnostic procedures and enhance ED evidence-based treatments, while optimizing the timeliness and efficiency of the overall care provided.

CXR ordering was also independent of most signs and symptoms of patients when they presented to the ED, such as; oxygen saturation, respiratory rate, pulse rate, chest pain, cough, coryza and chills. There was however a statistically significant association between CXR ordering and purulent sputum and body temperature > 37.8°C at ED presentation. Since pneumonia is a comorbidity, which many physicians wish to diagnose, it is not unexpected that clinical factors associated with a possible pulmonary infection increased CXR ordering (*See Table 3-3*). This result does suggest factors associated with lower

respiratory tract infection influenced the ED physicians' decision to order CXRs for adult patients with acute asthma.

Chest radiography ordering was independent of ABG ordering; however, patients who received an ECG were more likely to also receive a CXR. This suggests that some physicians are focusing on markers of complexity (asthma with chest pain) and severity (as measured by ordering an ABG) as important factors used to decide on CXR ordering. Nine percent of adult patients with acute asthma received an ECG; this can be attributed to the high proportion of patients (63.5%) who reported chest pain upon presentation in the ED.

There were no statistically significant association between CXR ordering and management decisions in the ED, such as the use of: SABA, SAAC, magnesium sulfate and systemic corticosteroids (***See Table 3-5***). Once again, such a finding is surprising since management often reflects the severity of the asthma presentation and the duration of treatment in the ED.

The results suggest the longer an adult patient with acute asthma stays in the ED, the higher their chance of receiving a CXR. This association may have been confounded by patient's severity at ED presentation and patient's response to therapy. Both of these observations may influence a patient's length of stay in the ED and the decision to order CXR. Nonetheless, patients remaining in the ED for longer periods experienced an increasing chance of CXR ordering (reaching a high of 74% after 8 hours).

Finally, and importantly, receiving a CXR had no influence on the outcome for patients discharged from the ED. For example, there was no difference in relapse (ED presentation within 4 weeks of discharge) between patients who received a CXR and those who did not.

This is important for both patients and physicians and could help encourage both groups to consider reducing CXR ordering in the future. According to most international guidelines for asthma management, a CXR should only be ordered in the presence of suspected pneumonia/consolidation and chest pain (e.g., suspected pneumothorax/mediastinum).[2, 50]

In order to ensure appropriate ordering of CXRs for adult patients with acute asthma in the ED, consideration must be given to the impact of ordering a CXR on the timeliness of care, its effectiveness in ruling out comorbidities/complications, patient ED disposition and its impact on ED work flow, safety and costs. Other factors worthy of consideration include the patient's perception of the value of a CXR, patient and physician dialogue on CXR impact on acute asthma management and CXR safety (especially for frequent ED users, who may receive multiple CXRs within a short period of time).

The results suggest physician concerns for pneumonia and pneumothorax/medistinum were the main reasons for CXR ordering. While approximately half of the patients with acute asthma received a CXR, the ordering was not associated with most of the commonly recorded clinical and sociodemographic factors for patients with asthma. The results suggest that some clinical factors, such as fever and purulent sputum, were taken into consideration prior to ordering a CXR. This suggests that a concern for a lower respiratory tract infection at ED presentation was the main reason for CXR ordering for adult patients with acute asthma in the ED. Surprisingly, severity at presentation did not influence CXR ordering. A moderate or severe/life threatening triage score was not statistically associated with CXR ordering (***See Figure 3-2***).

Fever and purulent sputum are both markers of lower respiratory tract infection, while ECG use points to severe chest pain as a major complaint of the patients, which may motivate doctors to order a CXR to rule out cardiovascular and thoracic diseases. On the other hand, other indicators of lower respiratory tract infection, such as ICS/LABA and/or ICS use, chills and a complaint of chest pain itself did not influenced CXR ordering. With these factors taken into consideration, it appears CXR ordering for adult acute asthma patients in the ED also does not follow a hospital protocol (if any exists) or established guideline.

The high proportion of ED CXR ordering may indicate the need for additional guidelines for ordering of CXR for adult patients with acute asthma in Canadian EDs. This study did not have sufficient data to examine complications (e.g., pneumothorax/mediastinum) and comorbidities (e.g., pneumonia/consolidation) which may necessitate CXR ordering. A prior systematic review, however, shows that a positive CXR outcomes for heart failure, pneumothorax/mediastinum (0.2%) are rare and radiographic findings for pneumonia, though more frequent, are also quite low (7.1%).

Several factors may contribute to diagnostic test overuse in the ED. Physician-specific issues would include: concerns for diagnostic uncertainty, litigation/complaint concerns, standard or learned practice, lack of physician experience, non-adherence or lack of knowledge of guidelines and lack of awareness/appreciation of the risks and costs associated with such diagnostic testing.[164-165] Another potential factor is the lack of a hospital protocol on CXR ordering for adult patients with acute asthma. Since these studies did not survey physicians, nor collect physician-specific information, further research in

this area will be needed in order to understand the relative influence of all of these potential issues.

In terms of impact on patient outcome, CXR ordering was associated with short-term delays, such as an increase in length of stay when compared to patients who did not receive a CXR(***see Figure 3-1***). As stated above, this may be due to clinical judgment on the part of the physicians. CXR ordering was not associated with long-term post-ED visit outcomes such as relapse (4 weeks after ED presentation).

Taken together, these results suggest there is an overuse of CXR for adult patients with acute asthma in Canadian EDs. Furthermore, they highlight the need to consider this a Choosing Wisely® target and develop interventions to reduce CXR ordering for adult patients with acute asthma in Canadian ED. Studies have shown there is diagnostic test overuse in Canadian hospitals and estimated 10 to 50% of diagnostic and laboratory tests in Canada may be unnecessary.[166-167] In a recent survey of ED physicians conducted in the United States, 85% of respondents acknowledged patients in their ED received too many diagnostic tests, 97% of respondents admitted personally ordering medically unnecessary tests.[168] Factors which have been cited for this include the aging population, the level of competence in using evidence based diagnostic tests, fear of missing a diagnosis and fear of litigation (in the USA).[168] In our study, most clinical factors, including patient age, were not associated with CXR ordering.

These results do not assess or disregard a physician's acumen in the management of adult patients with acute asthma in the ED. However, one has to consider the impact of excessive CXR ordering on patients and the overall health care system. Inappropriate CXR ordering,

just like other inappropriate testing in all medical settings, may lead to patient discomfort, produce false-positive outcomes, overburden finite healthcare resources, lead to inefficiencies in the healthcare system, undermine the quality of healthcare and significantly increase the cost of care, without a commensurate increase in benefit to the patients and overall healthcare system.[164]

According to the Canadian Institute of Health Information (CIHI), health care costs and per capital spending on health care in Canada will continue to rise. Canadian per capital spending on healthcare in 2013 was well above the Organization for Economic Cooperation and Development's (OECD) average ($6,105 per Canadian to $3566 for other OECD countries).[169] The Conference Board of Canada estimated hospital spending on asthma (excluding physician payments and drug costs) in 2010 was $250 million, accounting for 25.5% of the direct cost of asthma. This figure is projected to increase to $340 million in 2020 (25.3%).[29] Considering the low proportion of adult patients with acute asthma who are hospitalized, one can attribute most of these costs to the cost associated with ED care. The high proportion of adult patients with acute asthma who receive CXRs in Canadian ED may also have significantly contributed to this cost.

This study shows the evidence for the use of CXR for adult patients with acute asthma is weak, it does not contribute positively to important patient outcomes; however, it is associated with an increased length of stay in the hospital. There is obviously a mismatch between CXR ordering (which is 40-50%, from a systematic review and a Canadian ED dataset) and the proportion of positive findings. There is a need for a more tailored and restricted ordering of CXRs for adult patients with acute asthma in Canadian EDs.

In the absence of clear signs and symptoms of pneumonia (e.g., fever/chills, cough with sputum, chest pain, focal ausculatory findings on examination) a CXR is not required for most adult patients with acute asthma who are appropriately triaged, have spirometry performed upon presentation and receive appropriate evidence-based ED management. In addition, since pneumothorax/mediastinum, though very rare, are still of concern for physicians and important to patients, signs of severe chest pain and/or subcutaneous emphysema may be another indication for a CXR. Restricting CXR ordering to adult asthma patients with clear signs and symptoms of pneumonia is a potential target for ED physicians. Such a strategy should not only contribute to reducing the cost of care of the patients, it may also help improve ED efficiency by reducing the strain on the ED resources, reducing false positives CXRs and help avoid unnecessary testing and its impact on patient wellbeing and the overall healthcare system.

Choosing Wisely® approach provides a framework to implement this recommendation in order to better tailor ED CXR ordering for adult patients with acute asthma treated in Canadian EDs. There is a need for a more patient-centered dialogue and collaboration between ED physicians and adult patients with acute asthma. This could help ensure a mutual understanding of the effectiveness, impact and safety of CXRs in the care for adult patients with acute asthma in the ED.

3.7 Study Limitations

There are several limitations of this study that need to be addressed. First, for practical reasons, a variable recruitment time for AIR and TLAL study was employed. Data collection

for both AIR and TLAL dataset were carried out using a standardized and similar questionnaire. Treatment decisions were also at the discretion of the ED physicians on duty for both studies. We did not include all patients and admitted patients, so this is likely a conservative estimate of all CXRs ordered for patients with acute asthma. It is reassuring that CXR ordering from this study is consistent with the range of values of prior studies (including two Canadian studies, whose data were collected at a much later date).[13]

Third, this study may not be generalizable to all ED settings, which are different from these large-volume academic Canadian EDs. The readily accessible, universal and comprehensive health care coverage may make Canadian ED physicians more or less inclined to order CXR than ED physicians in other settings and countries.

Fourth, patients were mostly recruited between 08:00 and 23:00 on weekdays and 10:00 to 18:00 on weekends, patients were not recruited between 12:00am and 8:00am. This might have influenced the ED physicians decision to order CXR for patients; however, this is likely to have reduced the proportion of CXR ordered, since ED physicians may opt for more intense diagnostic and management plans for asthma patients who present at night. Nocturnal asthma is associated with a more severe form of the disease and a higher rate of morbidity and mortality, patients who presented to the ED at night or very early morning (before 08:00) may have suffered from more severe asthma.[170-171] This may prompt the physician to order more diagnostic tests (consequently, more CXRs), their absence from this database may have underestimated the overall proportion of CXRs ordered.

Fifth, there may have been a misclassification of data, since patient's perception of symptoms might have influenced information provided especially pre-ED clinical history as

well as symptoms of asthma. This might have affected the observed association between these factors and CXR ordering, but may not have influenced the patient's ED length of stay and relapse. The use of trained research staff and standardized questions would have reduced the bias associated with this concern.

Sixth, all included patients discharged from the ED received oral corticosteroids (for approximately 5-7 days after ED discharge) and ED physicians were encouraged to also add ICS agents (either as ICS monotherapy, or as combination ICS/LABA therapy). This likely limited the influence of management variability on outcomes and would be less likely in a pragmatic trial. A varying non-adherence to these medications by patients who did or did not receive CXRs may have affected the proportion of relapse observed for both groups.

Seventh, CXR ordering was at the discretion of the attending physician and we did not survey physicians at the time regarding their reasons for CXR ordering. While one might expect decisions would be driven by patient factors (e.g., severity, symptoms or signs, response to therapy, etc.), since few of these factors were associated with CXR ordering, physician preference/practice variation must have played an important role. Future studies should require physician interviews in order to understand ordering preference.

3.8 Conclusion

A high proportion of adult patients with acute asthma received a CXR in Canadian EDs, and efforts to reduce the use of CXR in this setting seem warranted. Most of the clinical, demographic, diagnostic, pre-ED and ED treatment factors were found to be unassociated

with CXR ordering. This suggests that CXR ordering for adult patients with acute asthma were not protocol, guideline or care map driven. CXR ordering was associated with fever, purulent sputum production and ECG ordering. Moreover, while CXR ordering was associated with increased ED length of stay, they did not influence important clinical and patient-centered outcomes such as relapse. This study suggests CXRs are over-used in Canadian EDs for adult patients with acute asthma. Consequently, there is a need to consider appropriate interventions to reduce CXR ordering in adult patients with acute asthma who do not have clear signs of pneumonia or pneumothorax/mediastinum. Further work is required to validate this strategy.

Table 3-1 Association between CXR Ordering and Demographic and Lifestyle Factors (Univariate Analysis)

Clinical Factors	CXR (%) 425 (48)	No CXR (%) 460(52)	Unadjusted OR	95% CI	P_value
Age (n {%}) **16-49 years (Reference)**	395 (93.2)	431 (93.7)			
>50Years	29 (6.8)	29 (6.3)	1.1	0.6-1.9	0.748
Female Sex (n {%}) (Reference: Male)	237 (55.9)	271 (58.9)	0.9	0.7-1.2	0.365
Aboriginal (n {%}) (Reference: All other races)	12 (2.8)	14 (3.0)	0.9	0.4-2.0	0.847
Marital status single (n {%}) (Reference=others)	170 (40.1)	229 (50.0)	0.7	0.5-0.9	0.004
Working for a salary (n {%}) (Reference: Not working for a salary)	237 (55.9)	254 (55.3)	1.0	0.8-1.3	0.867
Smokers (n {%}) **Former smokers (Reference: Never smoked)**	124 (29.3)	136 (29.6)	1.0	0.7-1.3	0.841
Current smokers (Reference: Never smoked)	135 (31.9)	150 (32.6)	1.0	0.7-1.3	0.774

Note: CXR = Chest X-Ray; CI = Confidence Interval; OR = Odd Ratio.

Table 3-2 Association between CXR Ordering and Demographic and Pre-ED Visit Clinical and Medication History (Univariate Analysis)

Clinical Factors	CXR (%) 425 (48)	No CXR (%) 460(52)	Unadjusted OR	95% CI	P-value
Duration of asthma diagnosis (n {%}): 15 years and above (Reference: 1-<15years)	242 (61.0)	285 (63.5)	0.9	0.7-1.2	0.451
Number of ED visits in the past 2 years (n {%}) (Reference: no ED visit of at least 8 hours in the past 2 years)	216 (54.6)	269 (61.8)	0.7	0.6-1.0	0.033
Pre-ED ICS use (n {%}) (Reference=No pre-ED ICS use)	172 (40.5)	168 (36.5)	1.2	0.9-1.5	0.228
Pre-ED SABA ≥ 8 puffs (n {%}) (Reference= SABA Puffs < 8)	216 (52.2)	256 (56.6)	0.8	0.6-1.1	0.188
Pre-ED LABA use (n {%}) (Reference=No pre-ED LABA use)	8 (2.1)	15 (3.6)	0.6	0.2-1.4	0.222
Pre-ED SAAC use (n {%}) (Reference=No pre-ED SAAC use)	14 (3.3)	15 (3.3)	1.0	0.5-2.1	0.968
Pre-ED ICS/LABA use (n {%}) (Reference=No pre-ED ICS/LABA use)	134 (31.5)	164 (35.7)	0.8	0.6-1.1	0.195
Pre-ED LTRA use (n {%}) (Reference=No pre-ED LTRA use)	29 (6.8)	24 (5.2)	1.3	0.8-2.3	0.316
Pre-ED systemic corticosteroids use (n {%}) (Reference=No pre-ED systemic corticosteroids use)	18 (4.3)	5 (1.1)	4.0	1.5-11.0	0.006

Note: CXR = Chest X-Ray; CI = Confidence Interval; OR = Odd Ratio; ED = Emergency Department; ICS = Inhaled Corticosteroids; SABA = short-acting beta-agonist; LABA = long-acting beta-agonist; SAAC = short-acting anticholinergic; ICS/LABA = Inhaled Corticosteroids/ long-acting beta-agonist; LTRA = leukotriene receptor antagonist

Table 3-3 Association between CXR Ordering and Signs and Symptoms (Univariate Analysis)

Clinical Factors	CXR (%) 425 (48.0)	No CXR (%) 460 (52.0)	Unadjusted OR	95% CI	P_value
Chest pain (n {%}) (Reference: No chest pain)	295 (69.4)	268 (58.3)	1.6	1.2-2.1	0.001
Reported fever (n {%}) (Reference: No fever)	151 (35.5)	92 (20.0)	2.2	1.6-3.0	0.001
Cough (n {%}) (Reference: No cough)	375 (88.2)	388 (84.4)	1.4	0.9-2.1	0.095
Purulent sputum (n {%}) (Reference: no purulent sputum)	256 (60.2)	235 (51.1)	1.5	1.1-1.9	0.006
Coryza (n {%}) (Reference: No running nose)	264 (62.1)	296 (64.4)	0.9	0.7-1.2	0.492
Chills (n {%}) (Reference: No chills)	199 (46.8)	164 (35.7)	1.6	1.2-2.1	0.001
Documented fever ≥ 37.8°C (n {%}) (Reference: Temperature<37.8)	31(7.5)	3(0.7)	11.7	3.5-38.5	0.001
Pulse ≥ 101 (n {%}) (Reference: Pulse<101)	200(47.2)	183(40.0)	1.3	1.0-1.7	0.033
Early Oxygen saturation ≥ 95 (n {%}) (Reference: Oxygen saturation <95)	123(29.0)	136(29.8)	1.0	0.7-1.3	0.791
Respiratory rate ≥ 20 (n {%}) (Reference: Respiratory rate <20)	305(74.4)	337(74.7)	1.0	0.7-1.3	0.911

Note: CXR = Chest X-Ray; CI = Confidence Interval; OR = Odd Ratio.

Table 3-4 Association between CXR Ordering and Signs and Diagnostic Factors (Univariate Analysis).

Clinical Factors	CXR (%) N= 425	No CXR (%) N= 460	Unadjusted OR	95% CI	P-value
CTAS (n {%})					
Mild (Reference): CTAS = 4-5	68 (18.2)	95 (23.0)	-	-	-
Moderate: CTAS = 3	209 (55.9)	224 (54.2)	1.3	0.9-1.9	0.153
Severe: CTAS =1-2	97 (25.9)	94 (22.8)	1.4	0.9-2.2	0.089
PEF documented (n {%}) (Reference: no PEF)	292 (68.7)	348 (75.8)	0.7	0.5-0.9	0.018
Arterial blood gases (n {%}) (Reference: did not receive ABG)	10 (2.4)	2 (0.4)	5.5	1.2 -25.3	0.028
Electrocardiogram (n {%}) (Reference: no ECG)	57 (13.4)	18 (3.9)	3.8	2.2 - 6.6	0.001
Discharge PEF (n {%})					
% Predicted < 50%(Reference)	81 (22.7)	57 (14.7)	-	-	-
Discharge % Predicted: 50%-70%	91 (25.5)	74 (19.0)	0.9	0.5-1.4	0.535
Discharge % Predicted >70%	185 (51.8)	258 (66.3)	0.5	0.3-0.7	0.001

Note: CXR = Chest X-Ray; CI = Confidence Interval; CTAS = Canadian Triage and Acuity Score; PEF = Peak Expiratory Flow; Arterial Blood Gases; ECG = Electrocardiogram; OR = Odd ratio.

Table 3-5 Association between CXR Ordering and ED Treatment Received By the Patients (Univariate Analysis).

Clinical Factors	CXR (%) 425 (48.0)	No CXR (%) 460 (52.0)	Unadjusted OR	95% CI	P-value
SABA (n {%}) (Reference: no SABA)	412 (96.9)	449 (97.6)	0.8	0.3-1.8	0.542
SAAC (n {%}) (Reference: No SAAC)	369 (86.8)	385 (83.7)	1.3	0.9-1.9	0.191
Received systemic corticosteroids (n {%}) (Reference: No systemic corticosteroids)	407 (96.0)	444 (97.8)	0.5	0.2-1.2	0.127
Magnesium sulphate (n {%}) (Reference: no magnesium sulphate)	13 (3.1)	4 (0.9)	3.6	1.2-11.1	0.026

Note: CXR = Chest X-Ray; CI = Confidence Interval; SABA = short-acting beta-agonist; SAAC = short-acting anticholinergic; OR = Odd Ratio

Table 3-6 Impact of CXR Ordering On Length of Stay in the ED and Post ED Relapse (Univariate Analysis).

Clinical Factors	CXR (%) 425 (48.0)	No CXR (%) 460 (52.0)	OR	95% CI	p-value
LOS (n {%}): **< 4 hours (Reference)**	147 (34.9)	295 (64.6)	_	-	_
LOS: ≥4 to <8 hours	225 (53.4)	145 (31.7)	3.1	2.3-4.2	0.001
LOS: ≥ 8 hours	49 (11.6)	17 (3.7)	5.8	3.2-10.3	0.001
Relapsed (n {%}) (Reference: No relapse)	73 (17.3)	80 (17.5)	1.0	0.7-1.4	0.935

Note: LOS = Length of Stay; CXR = Chest X-Ray; OR = Odds Ratio; CI = Confidence Interval

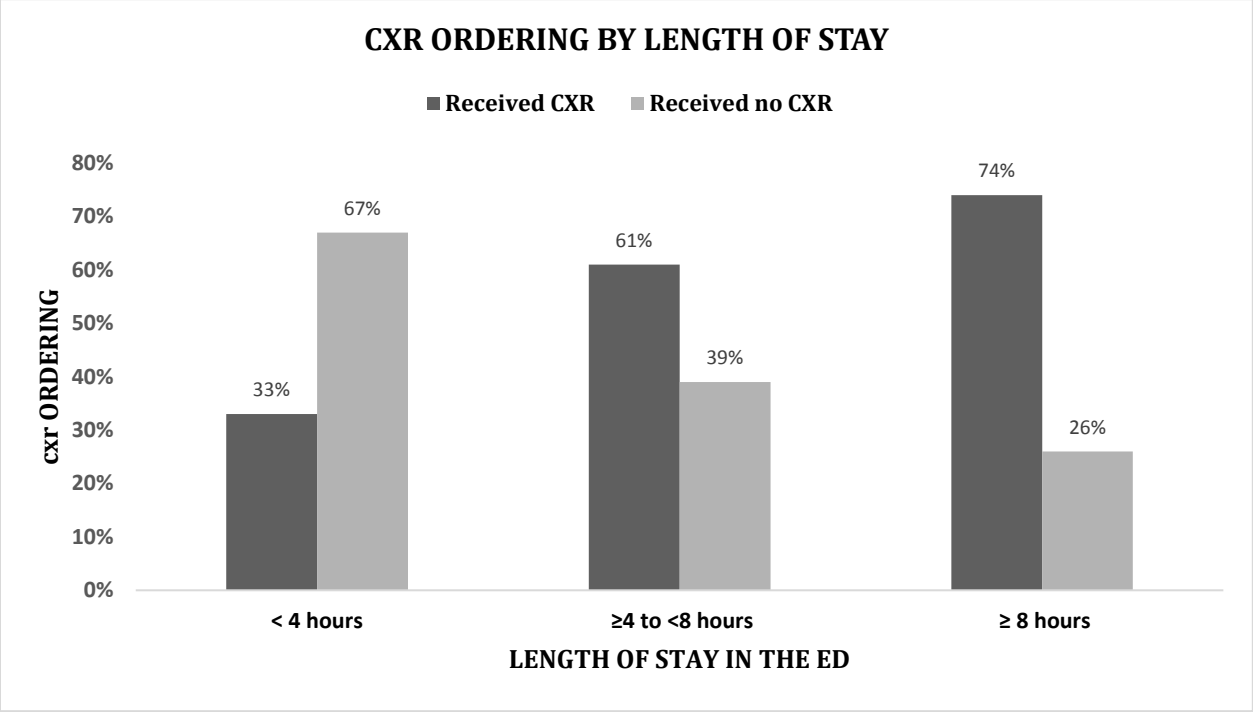
Table 3-7 Multivariable Predictors of CXR Ordering in the Ed

Domain	Clinical factors	Adjusted OR†	95% CI	p-value
Symptoms at ED presentation	Reported fever (Reference: No fever)	1.5	1.0-2.2	0.036
Symptoms at ED presentation	Purulent sputum (Reference: no purulent sputum)	1.5	1.1-2.1	0.018
Signs at ED presentation	Documented fever ≥ 37.8°C (Reference: Temperature < 37.8°C)	7.2	2.0-25.7	0.002
Exam at ED presentation	Received early PEF (Reference=did not receive early PEF)	0.7	0.5-0.9	0.025
Exam at ED presentation	Electrocardiogram (Reference: no ECG)	3.3	1.7-6.6	0.001
Time spent in the ED	LOS: ≥ 4 to < 8 hours (Reference: LOS < 4 hours)	3.0	2.1-4.2	0.001
Time spent in the ED	LOS ≥ 8 hours (Reference: LOS < 4 hours)	3.8	2.0-7.5	0.001

†: Adjusted for prior ED visit (at least one ED visit in the prior two years), Pre-ED systemic corticosteroids use, and CTAS.

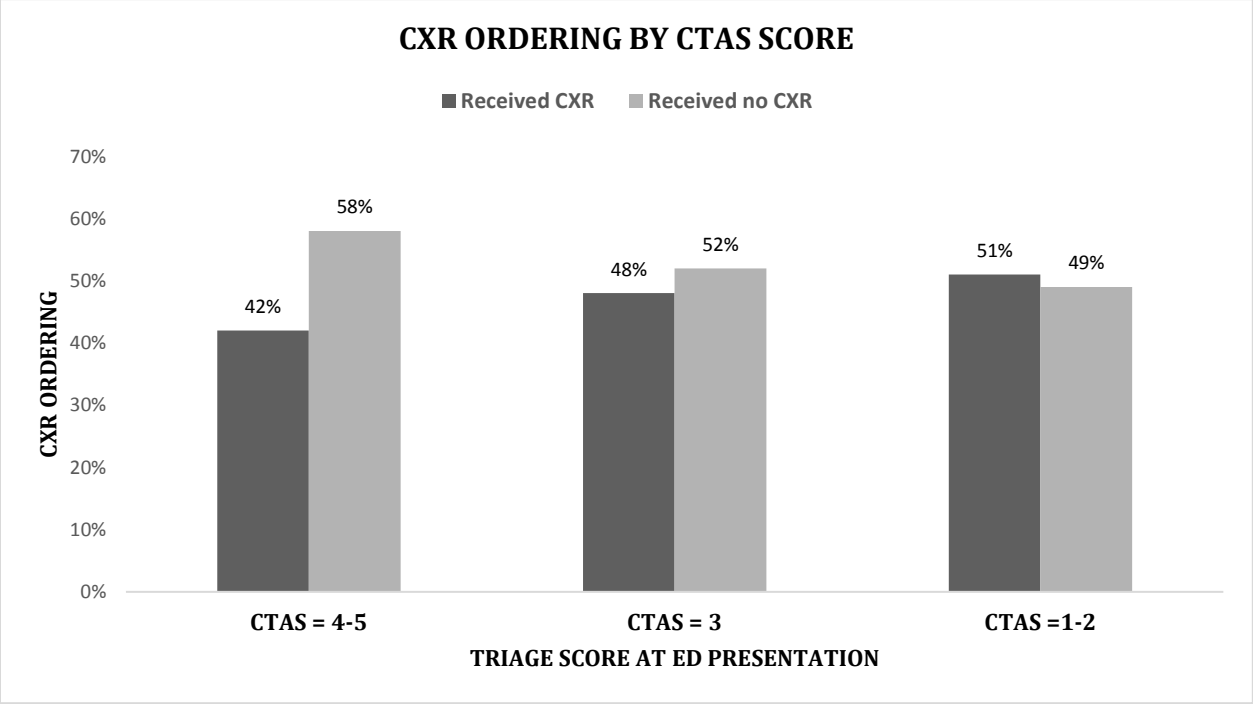
Note: ED = Emergency Department; LOS = Length of Stay; OR = Odds Ratio; CI = Confidence Interval; PEF = Peak Expiratory Flow.

Figure 3-1 CXR Ordering and ED Length of Stay



Note: ED = Emergency Department; CXR: Chest X-Ray

Figure 3-2 CXR Ordering and Canadian Triage and Acuity Score (CTAS)



Note: ED = Emergency Department; CXR: Chest X-ray.

4 Chapter 4: Relevance, Conclusions, and Future Directions for Research

Asthma is a reversible chronic disease of the airway characterized by intermittent or persistent wheezing, dyspnea, occasional sputum production, cough and chest tightness. [1-2] Acute asthma is a persistent deterioration from baseline, which may result in emergency department (ED) visit, hospitalization or, very rarely, death. Acute asthma may present with severe airway obstruction, often typified by a very low peak expiratory flow (PEF) and forced expiratory volume in one seconds (FEV_1).

Asthma is one of the most common chronic diseases in North America, with an estimated 8% of the United States' population suffering from the disease, and it is estimated that approximately 3 million Canadian suffer from asthma.[22] In Canada, thousands of adult asthma patients present to the ED with asthma exacerbations; while only a small proportion (~10%) of these patients will require hospitalization, their care represents a significant burden to the health care system.[30, 116, 172]

When patients present to the ED with acute asthma, physicians often order a chest radiograph (CXR) to rule out complications and comorbidity.[47, 137] Given the high proportion of adult asthma patients who present to the ED with acute exacerbations of asthma, an understanding of the factors associated with CXR ordering and its impact on patients' outcomes will enhance patient's care, optimize ED resource utilization, and improve ED flow and efficiency.

Prior research mainly reported CXR ordering, and its outcomes for adult patients with acute asthma; however, there is a scarcity of evidence on factors associated with CXR ordering for

adult patients with asthma in the ED and the impact of CXR ordering on patients' outcomes such as length of stay and relapse.

This thesis focused on adult patients with acute asthma with the objectives of examining: 1) the literature for CXR ordering in the ED setting; 2) factors associated with CXR ordering; and 3) the impact of CXR ordering on patient outcomes. This thesis consists of: a systematic review of available literature on CXR ordering on asthma patients, and a secondary analysis of ED database from previous clinical studies for factors associated with CXR ordering and its impact on patients' outcomes.

The quality of care for asthma follows the Institute of Medicine (IOM) model of being safe, patient-centered, effective, efficient, timely, accessible, and equitable (Table 1 presents these factors in decreasing order of significance).[173] The effectiveness of CXR ordering in ruling out comorbidity and complications, CXR safety, patients' role in test ordering, its impact on ED timeliness and efficiency, as well as its influence on patients' outcome should be considered. There are also ethical factors, such as: accessibility and equity in CXR ordering for all adult patients with acute asthma in the ED. These quality of care indicators are influenced by other factors such as the health care system, patient, and physician perspectives.

The decision to perform any investigations (e.g., CXR ordering) represents a balance among these patient, physician and system factors. For example, in a nursing outpost without imaging facilities, the decision not to order a CXR may be very simple. In most Canadian EDs, access to CXR imaging is unencumbered, consequently, factors other than availability influence the ordering decision. Patients also have their own expectations and demands when they present to ED with exacerbations of asthma, these expectations are often dictated

by past experiences. If a CXR was ordered in all previous visits and/or the patient has had a previous episode of pneumonia, then their expectations and demands may influence MD CXR ordering. Patients desire a prompt recovery from their asthma exacerbation, and a minimal disruption from their daily lives. On the other hand, physicians want to be thorough in patient assessment and, for personal satisfaction and reputational reasons, not miss any important abnormality, and consequently often over-estimate the value of investigations. While missing a pneumonia or a small pneumothorax may not result in worse outcomes or litigation, those fears commonly exist. The health system wants evidence-based care at a reasonable cost, and aims to reduce the volume of patients in the ED, reduce ED delay and enhance ED efficiency. The quality of care an asthma patient receives in the ED is influenced by these factors, as such, a unifying model for investigation ordering in adult patients with acute asthma is needed to understand the final decision to order an investigation (***See Figure 4-1***).

As shown in **Figure 4.1**, the decision to order a test, such as a CXR, for adult patients with acute asthma, is multi-factorial. Since these factors do not always align with each other, patient-centered care should aim to strike a balance in the best interest of the patients, without an excessive compromise on ED flow, and an increased burden on the ED resources and the general health care system. In order for this to happen, there is a need for physician education regarding the evidence, encouragement of patient-physician dialogue, and leadership among the key stakeholders in the health care system.

4.1 Overview of Thesis Results

4.1.1 Systematic Review of CXR Ordering for Adult Patients with Acute Asthma in the ED

Guidelines are inconsistent for CXR ordering for adult patients with acute asthma in the ED. In Chapter 2, a systematic review was conducted to identify the current state of CXR ordering for adult patients with asthma, factors associated with CXR ordering, the outcomes for CXR ordering and the impact of CXR ordering on patients' outcomes. Using an *a priori* protocol, a search strategy to mitigate publication bias and methods to limit selection bias, 16 (including the unpublished data from the AIR study) unique studies that reported on CXR ordering for adult patients with acute asthma were identified. These studies were mostly low quality retrospective chart reviews of ED data and reported the proportion (percentage) of adult patients with acute asthma who received CXR in the ED. The total sample size was 5093 patients. Nearly 50% (8 out of 16 studies) of these studies were conducted using data collected between 2001 and 2010. Thirteen of these studies reported data on CXR ordering, while 10 studies reported on the outcome of CXR ordering for adult patients with acute asthma in the ED. There was heterogeneity in the included studies' design; however, they all reported the percentage of adult patients with acute asthma who received CXR in the ED and in admitted patients with more severe asthma presentation. In other to assign greater significance to studies with larger sample size and avoid Simpson's paradox, weighted proportions of CXR ordering were reported. The weighted proportion of adult patients with acute asthma who received CXR in the ED and the weighted proportion of positive outcomes for these CXRs were 60.0% (95% CI: 47.0, 72.2) and 9.5% (95% CI: 7.1, 12.4), respectively (***See Figure 4-2***). When only admitted patients were considered, the weighted proportion for

CXR ordering and outcomes were 87.6% (95% CI: 81.0, 93.1) and 26.0% (95% CI: 6.1, 53.0), respectively. The most commonly reported outcomes in these studies was pneumonia (7.1% and 7.0% for ED and hospitalized patients respectively), the percentage of pneumothorax/mediastinum reported was very low (0.1% and 0.2% for patients in the ED and hospitalized patients respectively). Though pneumonia and pneumothorax/mediastinum are the major comorbidity and complications ED physicians wish to detect, data shows that these outcomes are uncommon.

Overall, the result from this systematic review suggests, a high proportion of adult patients with acute asthma (both seen in the ED and hospitalized patients) receive a CXR. The proportion of CXR ordering and positive outcomes was higher among hospitalized patients compared to patients seen and discharged in the ED, suggesting a higher likelihood of CXR ordering and positives outcomes for patients with more severe asthma presentation requiring admission; however, positive outcomes for CXRs were infrequent for pneumonia and pneumothorax/mediastinum for both subgroups of patients. The included studies, however, failed to report factors associated with CXR ordering and the impact of CXR ordering on patients' outcomes, and this leaves a significant knowledge gap.

4.1.2 CXR ordering and its impact on the outcome of adult patients with acute asthma in Canadian ED over a four and half years period

Using a large secondary clinical database from previous studies, factors associated with CXR ordering for adult patients with acute asthma in the ED were explored and the impact of CXR ordering on patients' ED disposition was assessed. There are no prior reports on factors associated with CXR ordering and how CXR influences the outcomes of adults' patients with acute asthma in Canadian ED. Prior studies reported 43% of adult patients with acute

receives CXRs in Canadian ED, this was consistent with findings of the systematic review reported in Chapter 2.[147] From the result of this review evaluation of acute ED cases across Canada, clinicians appear to order CXR for adult patients with acute asthma in the ED to rule out pneumonia, and pneumothorax/mediastinum; however, a prior systematic review (See Chapter 2) showed positive outcomes for pneumonia and pneumothorax/mediastinum are very uncommon.

Using the IOM quality of care model; the high rate of CXR ordering suggests the need for caution, especially for frequent ED users and pregnant women, although a CXR poses a minimal radiation risk (10% of annual radiation exposure for the average person) to patients. There were no data on patients' contribution to the decision to order CXR. Nearly 50% of Canadian adult patients with acute asthma received CXR in the ED, this is consistent with findings of the systematic review (See Chapter 2) and other Canadian studies.[145, 147] Surprisingly few of the clinical, demographic, diagnostic, pre-ED and ED treatment factors were found to be associated with CXR ordering, suggesting MD preference drives ordering. Moreover, while CXR ordering was associated with increased ED length of stay (temporal relationship with CXR ordering is not clear), it did not influence important outcomes, such as relapse. CXR ordering was also independent of race, sex and employment status, suggesting inequity in CXR ordering was uncommon (***see Table 4.1***)

These results indicate that the rationale for CXR ordering for adult patients with acute asthma in Canadian EDs reflects clinicians' concern for pneumonia and other rare thoracic complications, and adds to the accumulating evidence that suggests CXRs are over-used in Canadian EDs.[10] There is a need for interventions to reduce the use of CXRs, as well as

increased dialogue between physicians and patients, in order to enhance mutual understanding of the limited role of CXRs ordering for adult patients with acute asthma in the ED. Choosing Wisely® efforts to safely reduce the use of CXR in this setting seem warranted.

Choosing Wisely® Canada (CWC) is part of an international initiative designed to more appropriately use investigations, procedures and treatments in all care settings. Using slogans such as "More is not better", "Do I really need that test?", "Why use two, when one will do" (for transfusions), and other such efforts to initiate and improve dialogue between patients and physicians regarding the necessity for these management options. Simple and advanced imaging have been a large target for many of the CWC societies including emergency medicine. While avoiding CXR in acute asthma is contained on the CAEP list (Brian Rowe, personal communication), the issue was not selected in the Top-5 list released in June 2015. Nonetheless, interventions are needed to reduce CXR ordering in adult patients with acute asthma who do not have clear signs of pneumonia or pneumothorax/mediastinum. There is, however, a knowledge gap on physicians' rationale for ordering CXRs for this patients segment and patients' perspective on the impact of CXRs.

4.1.3 Implications for Patients

CXR should be restricted to patients with clear signs of pneumonia (i.e., fever, sputum production, chest pain, crackles, and unilateral auscultation findings), and pneumothorax/mediastinum (severe chest pain). This will lead to less discomfort for patients, a reduction in unnecessary exposure to ionizing radiation (especially for frequent ED users), and briefer lengths of stay without negative consequences on outcomes. Early PEF

assessment is associated with less chance of CXR ordering for adult patients with acute asthma in the ED, it also has the advantage of objectively assessing the degree of airway severity for adult asthma patients. Unfortunately, not all patients who presented to ED with acute asthma receive spirometry.[45] Patients should be educated on the limited influence of CXR on outcome, as well as the low proportion of positive results, as this could aid their understanding of the need for CXR and its limited impact on their short- and long-term clinical outcomes.

4.1.4 Implications for Physicians

The primary concerns of physicians when they order CXR in patients with acute asthma is the detection of comorbidities (pneumonia) and complications (pneumothorax/mediastinum). The results of systematic review shows these outcomes, especially pneumothorax/mediastinum, are exceedingly rare for adult patients with acute asthma in the ED. Efforts to restrict CXR in adult patients with acute asthma should focus on traditional markers of pneumonia in an attempt to reduce burden on ED resources and enhance the timeliness and efficiency of care in the ED. The result of the study show that CXR ordering was associated with symptoms of pneumonia (e.g., purulent sputum production and fever), CXR ordering was not associated with other risk factors for pneumonia, such as outpatient use of inhaled corticosteroids, chills, chest pain, age, smoking status, and cough. This indicates a need for additional guidance on CXR ordering for adult patients with acute asthma in the ED. Adding recommendations to current paper and electronic guidelines, care maps or order sets to remind physicians of the evidence may encourage physicians to tailor CXR ordering to cases with high pre-test probability of pneumonia (presence of crackles) or

pneumothorax/mediastinum. While these interventions may be theoretically sensible, they would need to be evaluated and deemed successful prior to widespread implementation.

4.1.5 Implications for Health Policy

Chest radiographs are one of the most frequent tests ordered in an emergency setting.[174] From a health system perspective, unnecessary tests generate costs, limit access for patients who truly need the imaging modality, expose patients to ionizing radiation, and add to delays in ED care. For patients with acute asthma seen in the ED, widespread reduction in CXR ordering could reduce the cost of care and reduce the burden on ED resources. Support from funding agencies for patient and provider investigations into barriers and facilitators of patient-oriented decision-making should be encouraged, support from Medical associations to encourage adoption of the CWC model and incentive programs (e.g., pay-for-performance, shared savings) should be explored to facilitate the uptake of CWC approaches. Punitive measures, while not popular, may also need to be considered as health care spending escalates.

4.1.6 Proposed Solution

Combining these thoughts together leads to discussion about the possible solutions to "avoid" CXR in patients presenting to the ED with acute asthma. A general statement using CWC wording might read: ***Avoid chest radiographs in patients with acute asthma unless signs or symptoms of pneumonia (e.g., fever, purulent sputum, chest pain, and crackles) or pneumothorax/mediastinum (e.g., severe chest pain) are present.*** Implementation of this recommendation would require tool for practice, such as the one depicted in **Figure 4.2**.

Other options for implementation include slide decks, lectures, clinical practice guidelines and computerized decision support tools.

4.2 Research Implications:

4.2.1 Patient-Focused Research

It would be of interest to obtain feedback from patients on CXRs they receive in the ED, as well as their opinion on the impact of CXR on their care when they present to ED with acute asthma. There is a need for research which focuses on obtaining patients' perspective on CXR ordering, its impact on their asthma outcomes, and the safety of CXR (especially for frequent ED users and pregnant women). This research would also aid their understanding of the role of CXRs in acute asthma exacerbations, and help practitioners understand patients' expectations. Patients' input will also aid the development of an effective protocol to reduce CXR ordering for adult patients with acute asthma.

4.2.2 Physician-Focused Research

Research designed to understand physicians' perspective of CXR ordering for adult patients with acute asthma is warranted. Since one cannot ignore physician's judgment when it comes to how these patients are managed, it should be beneficial to understand physicians' reasons for ordering CXR for adult patients with acute asthma. A survey of ED physicians and a facilitated discussion could aid the integration of physicians' perspective with existing evidence on CXR ordering, and facilitate a Choosing Wisely intervention for adult patients with acute asthma in the ED.

4.2.3 Health Policy Research

There is a need for research on policies aimed at reducing CXR ordering in Canadian EDs, these policies can be implemented in multiple phases, or restricted to specific institution and/or setting in order to validate them, prior to system-wide implementation. Research on incentives program, such as a shared savings model, monitoring and public reporting of key diagnostic imaging utilization, physician audit and feedback (including hospital report cards) and punitive policies, such as special authorization protocol on CXR ordering are needed. These research can also assess the impact of these interventions on patients' outcome.

4.3 Conclusion

Chest radiographs are ordered for a high proportion of adult patients with acute asthma in Canadian EDs; while existing evidence points to low proportion of positive outcomes, it appears concerns for pneumonia and pneumothorax/mediastinum (which are both rare positive outcomes) drive ordering. Chest radiograph ordering appears to increase the length of stay and does not reduce relapse, and these findings suggest the need for a more restricted ordering of CXR for adult patients with acute asthma in the ED. This thesis offers the evidence required to enter the next stage of the research process: a formal understanding of provider and patient perspectives on radiography ordering in patients with acute asthma presenting to the ED. In addition, there is a need to integrate these thoughts into existing evidence, in a bid to implement Choosing Wisely® intervention for adult patients with acute asthma in the ED.

Table 4-1 Institute Of Medicine CXR Assessment

Aim	Result from Canadian ED data
Safety	It poses a minimal risk (one CXR is equivalent to 10 days of natural background radiation). It should not be overlooked for frequent ED users and pregnant women.
Patient-centeredness	No data
Effectiveness	A systematic review showed the proportion of positive outcomes for pneumonia and pneumothorax/mediastinum
Efficiency	Nearly 50% CXR ordering for adult patients with acute asthma and few are positive
Timeliness	CXRs ordering appears to be associated with the length of stay in the ED and reduces the availability of the test for others
Equity	CXR ordering was not influenced by sex, race, employment status

Figure 4-1 Patient, Physician And Health System Factors Contributing To Ordering Test In Patients Managed In The Emergency Department.

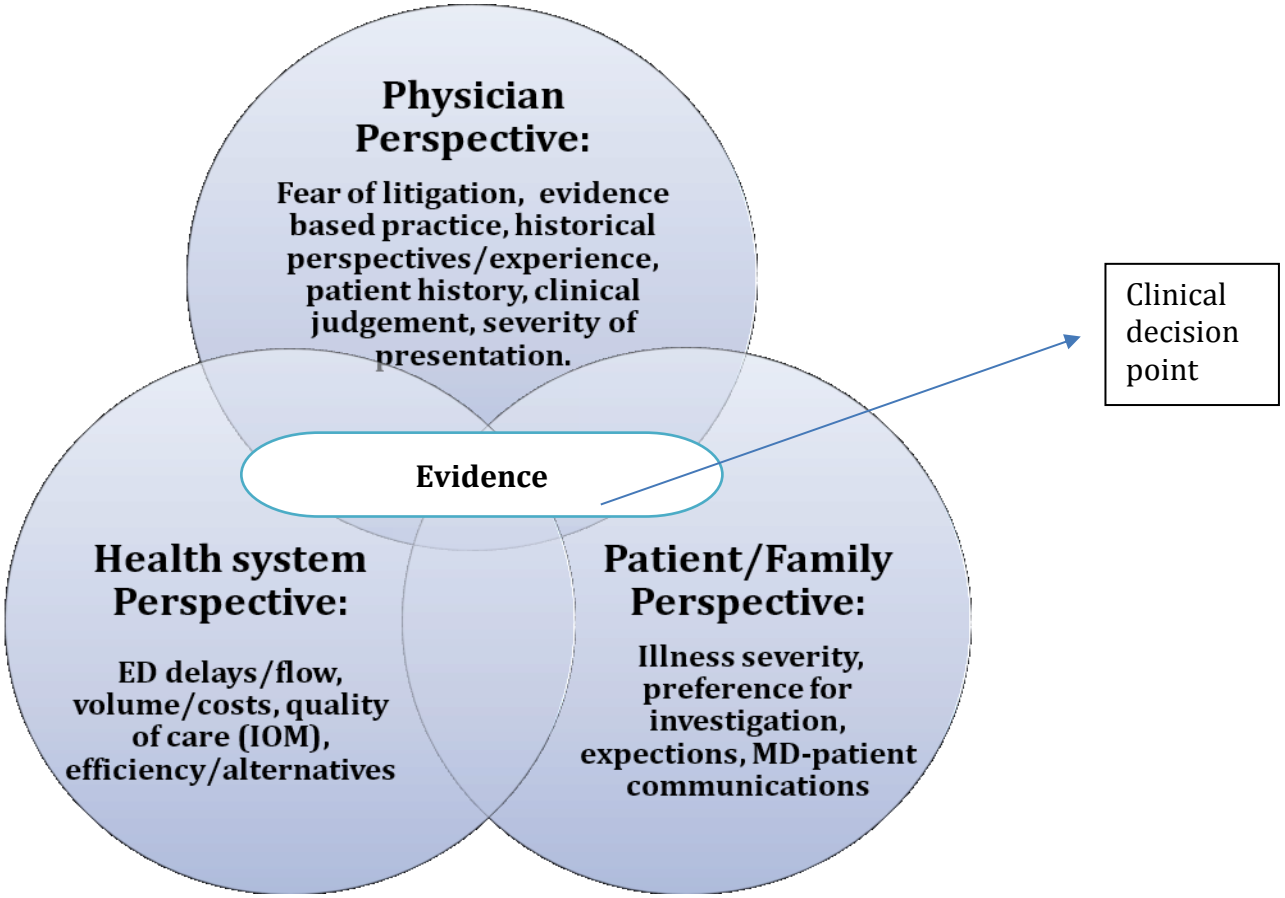
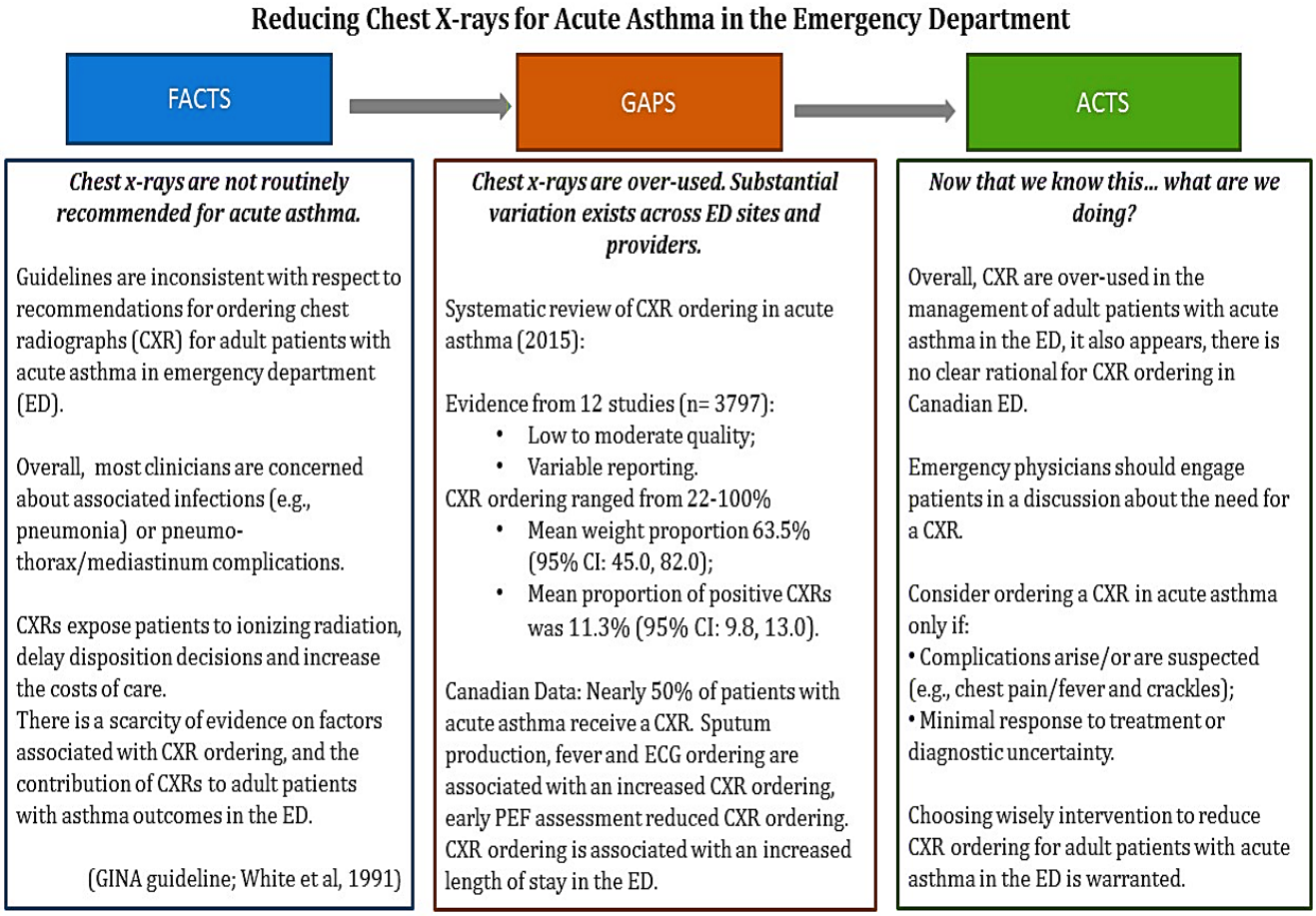


Figure 4- 2 Proposed Knowledge Translation Tool for the Intervention



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Appendix A: Literature search strategy for systematic review

1. exp Asthma/

2. asthma*.mp.

3. 1 or 2

4. radiography, thoracic/ or bronchography/

5. (((thoracic or thorax or chest or lung* or pulmonary) **adj2 (x ray* or radiograph*)) or cxr or *bronchograph*).**mp.

6. 4 or 5

7. 3 and 6

8. exp Emergency Service, Hospital/

9. **(ed or emergency or urgent care or trauma cent*).mp. or emergency.jw,nw.**

10. 8 or 9

11. 7 and 10

12. limit 11 to "all adult (19 plus years)"

13. (adult* or middle age* or elderly or older or men or women or man or woman).mp.

14. 11 and 13

15. 12 or 14

16. limit 11 to medline

17. 11 not 16

18. 15 or 17

19. limit 11 to "all child (0 to 18 years)"

20. (child* or p?ediatric* or adolescen* or infan* or boy* or girl*).mp.

21. 11 and 20

22. 19 or 21

23. 15 or 22

24. 11 not 23

25. 18 or 24

Ovid EMBASE, 1974-Present

1. exp *asthma/ or asthma*.ti,ab.

2. thorax radiography/ or bronchography/ or cavernosography/ or lung angiography/

3. (((thoracic or thorax or chest or lung* or pulmonary) adj2 (x ray* or radiograph*)) or cxr or bronchograph* or cavernosograph* or lung angiograph* or pulmonary angiograph*).mp.

4. 2 or 3

5. 1 and 4

6. exp emergency ward/

7. (ed or emergency or urgent care or trauma cent*).mp. or emergency.jx.

8. 6 or 7

9. 5 and 8

10. limit 9 to (adult <18 to 64 years> or aged <65+ years>)

11. (adult* or middle age* or elderly or older or men or women or man or woman).mp.

12. 9 and 11

13. 10 or 12

14. limit 9 to (infant or child or preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)

15. (child* or p?ediatric* or adolescen* or infan* or boy* or girl*).mp.

16. 9 and 15

17. 14 or 16

18. 13 or 17

19. 9 not 18

20. 13 or 19

Scopus, 1960-Present

((TITLE-ABS-KEY(asthma*) AND TITLE-ABS-KEY((thoracic or thorax or chest or lung* or pulmonary) and ("x ray*" or radiograph* or cxr or bronchograph* or cavernosograph* or angiograph*)) AND TITLE-ABS-KEY(ed or emergenc* or "urgent care" or "trauma cent*") AND TITLE-ABS-KEY(adult* or middle age* or elderly or older or men or women or man or woman))) or ((TITLE-ABS-KEY(asthma*) AND TITLE-ABS-KEY((thoracic or thorax or chest or lung* or pulmonary) and ("x ray*" or radiograph* or cxr or bronchograph* or cavernosograph* or angiograph*)) AND TITLE-ABS-KEY(ed or emergenc* or "urgent care" or "trauma cent*") AND NOT TITLE-ABS-KEY(child* or pediatric* or paediatric* or adolescen* or infan* or boy* or girl*)))

EBSCO CINAHL Plus with Full-text, 1937-Present

S7 S5 AND S6

S6 adult* or middle age* or elderly or older or men or women or man or woman

S5 S3 AND S4

S4 (ed or emergency or urgent care or trauma cent*) OR SO emergency

S3 S1 AND S2

S2 ((MH "Radiography, Thoracic") OR (MH "Bronchography")) OR ((thoracic or thorax or chest or lung* or pulmonary) nj2 (x ray* or radiograph*) or cxr or bronchograph* or cavernosograph* or "lung angiograph*" or "pulmonary angiograph*")

S1 (MH "Asthma+") or asthma*

ProQuest Dissertations & Theses Full-text, 1861-Present

Nothing retrieved as of June 25th, 2014.

asthma* [Anywhere except full-text]

AND

(thoracic OR thorax OR chest OR lung* OR pulmonary) AND ("x ray*" OR radiograph* OR cxr OR bronchograph* OR cavernosograph* OR angiograph*) [Anywhere except full-text]

AND

ed OR emergenc* OR "urgent care" OR "trauma cent*" [Anywhere except full-text]

LILACS

So few retrieved that I did not add ‘adult’ terms.

asthma

AND

"x ray*" OR radiograph OR radiography OR cxr OR bronchograph OR bronchography OR cavernosograph OR cavernosography OR angiograph OR angiography

AND

ed or emergency or "urgent care" or "trauma centre" or "trauma center"

Web of Science Core Collection, 1900-Current and Biosis Citation Index, 1926-Current

S3 #1 OR #2

S2 **TOPIC:** (asthma*) *AND* **TOPIC:** ((thoracic OR thorax OR chest OR lung* OR pulmonary) AND ("x ray*" OR radiograph* OR cxr OR bronchograph* OR cavernosograph* OR angiograph*)) *AND* **TOPIC:** (ed or emergency or "urgent care" or "trauma cent*") *NOT* **TOPIC:** (child* or pediatric* or paediatric* or adolescen* or infan* or boy* or girl*)

S1 TOPIC: (asthma*) *AND* **TOPIC:** ((thoracic OR thorax OR chest OR lung* OR pulmonary) AND ("x ray*" OR radiograph* OR cxr OR bronchograph* OR cavernosograph* OR angiograph*)) *AND* **TOPIC:** (ed or emergency or "urgent care" or "trauma cent*") *AND* **TOPIC:** (adult* or middle age* or elderly or older or men or women or man or woman

Appendix B: Inclusions/exclusion form for systematic review.

INCLUSION CRITERIA

Does the utilization of chest x-ray impact the outcome of adult patients that present to ED with acute exacerbation of asthma compare to standard care?

Reviewer: _____ **Reference #:** _____ **Date:** _____

Instructions: please complete the form on each study. If you reach a "no" response, exclude that study.

A. CRITERIA	**YES**	**NO**	**UNSURE**
1. Study Design			
Prospective RCT/Cohort/CCT?	[ ]	[ ]	[ ]
2. Study Population			
Are patients aged ≥ 18?	[ ]	[ ]	[ ]
Treated for Acute Asthma?	[ ]	[ ]	[ ]
Patients presenting to the ED?	[ ]	[ ]	[ ]
3. Study Intervention			
Patients received chest x-ray (CXR)	[ ]	[ ]	[ ]
4. Outcome Measures			
Did the study report one or more clinical outcomes?	[ ]	[ ]	[ ]
[ ] Pneumonia?			
[ ] Hypoxemia?			
[ ] Respiratory acidosis?			
[ ] Pleural Infusion?			
[ ] Heart Failure?			
[ ] Lung mass/Cancer?			
[ ] Length of stay (LOS) in the ED?			
[ ] Health services (e.g., admission/discharge, relapse)?			
[ ] Safety (cumulative radiation dose)?			
[ ] Costs?			
[ ] Death?			

B. DECISION OF REVIEWER

Is this study potentially relevant for this review? [ ] [ ] [ ]

Appendix C: Data extraction form for systematic review.

DATA EXTRACTION FORM:

Does the utilization of chest x-ray impact the outcome of adult patients that present to ED with acute exacerbation of asthma?

A1. Study ID: ___5____ A2. Country: _United States_A3. Study Type: _Prospective Obs___

A4. Reviewer: SK ☐ ☐ Other: _____

A6. Year(s) of data collection: _Mar 1987 to Aug 1987_____ to _____ ☐ N/A

A6. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria

A7. Source of funding:

Grant: ☐ Pharmaceutical: ☐ Other: ☐ None stated: ☐

Name of funding provider if provided:_____

A8. Setting

ED: YES Other (please specify):

A9. Intervention

Intervention
Chest ray, CXR (not MRI, not CT scan, not V/Q scan)

Results

B1. Patient Demographics

	Number (N)	Age (years) (mean±SD)	Sex (male) (%) (n/N)	Sex (female) (%) (n/N)	Ethnicity: White (%) (n/N)	Ethnicity: Black (%) (n/N)	Ethnicity: Hispanic (%) (n/N)

Chest ray, CXR (not MRI, not CT scan, not V/Q scan)	**125** **44 complicated, 81 for uncomplicated**	**49 for complicated, 62 for uncomplicated**	**59(47.2)**	**66(52.8)**			

	Ethnicity: Other (%) (n/N)	**Smoker (%) (n/N)**	**Smoker pack years**	**Duration of study:**	**Tool used to assess quality:**	**Sample size**	**method**	**Role of investigators**
Chest ray, CXR (not MRI, not CT scan, not V/Q scan)		**66(52.8)**						

	Other:	**Other:**	**Other:**	**Other:**	**Other:**	**Other:**	**Other:**
Chest ray, CXR (not MRI, not CT scan, not V/Q scan)							

B2. Asthma Severity

Severity of Asthma					
Mild	**(%) (n/N)**	**Moderate**	**(%) (n/N)**	**Severe**	**(%) (n/N)**

COMPLICATED AND UNCOMPLICATED ASTHMA	
Complicated asthma	**Uncomplicated asthma**
49 (all the outcome that influenced management occurred here)	**62**

B3. Primary/secondary outcomes

Outcomes	(%) (n/N)	+ve outcome/n
Pneumonia	**9**	
Hypoxemia		
Respiratory acidosis		
Pleural infusion		
Heart Failure	**2**	
Lung mass/ Cancer? (explain):		
Health services (e.g., admission/discharge, relapse)? (explain): _____	**1**	
Length of stay (LOS) in the ED? (explain): _____		
Safety (cumulative radiation dose)? (explain): specify if any safety concern		
Costs?		
Death?		
Other (explain): Infiltrate(Pneumonia) and CHF	**1**	
Other (explain):Nodular density	**1**	
Other (explain): _____		
Other (explain): _____		

C1: Interpretations or conclusions of the authors.

Did CXR findings influence management of the asthma attacks (If Clearly stated in the paper)

Did CXR findings influence management of the asthma attacks (if not clearly stated in the paper)	
LIKELY YES IF:	**LIKELY NO IF:**
(%) (n/N)	**(%) (n/N)**
Pneumothorax	**Bronchial Wall thickenings**
Pneumomediastinum	**Hyperinflation**
Consolidation, Pneumonia 9	**Perihilar markings**
Oedema	
Respiratory Acidosis	
Lung mass/ Cancer 1	
Hypoxia	
Pleural effusion	
Heart Failure 2	
Heart failure + Pneumonia 1	

C2. Additional comments: