Computers in Biology and Medicine 52 (2014) 41–48

Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: www.elsevier.com/locate/cbm

Computer-aided diagnosis system for the Acute Respiratory Distress Syndrome from chest radiographs

Nesrine Zaglam [a,b,*], Philippe Jouvet [a], Olivier Flechelles [a], Guillaume Emeriaud [a], Farida Cheriet [a,b]

[a] Sainte-Justine Hospital Research Center, Montreal, QC, Canada H3T 1C5
[b] The Department of Computer Engineering, Ecole Polytechnique de Montréal, Montreal, Canada H3T 1J4

ARTICLE INFO

Article history:
Received 3 March 2014
Accepted 12 June 2014

Keywords:
Chest radiographs
Acute Respiratory Distress Syndrome (ARDS)
Texture analysis
Automatic classification
Computer-aided diagnosis system

ABSTRACT

This paper presents a computer-aided diagnosis (CAD) system for the assessment of Acute Respiratory Distress Syndrome (ARDS) from chest radiographs. Our method consists in automatically extracting intercostal patches from chest radiographs belonging to the test database using a semiautomatic segmentation method of the ribs. Statistical and spectral features are computed from each patch then a method of feature transformation is applied using the Linear Discriminant Analysis (LDA). A training database of 321 patches was classified by an expert in two classes, a class of normal patches and a class of abnormal patches. Patches belonging to the test database are then classified using the SVM classifier. Finally, the rate of abnormal patches is calculated for each quadrant to decide if the chest radiograph presents an ARDS. The method has been evaluated on 90 radiographs where 53 images present ARDS. The results show a sensitivity of 90.6% at a specificity of 86.5%.

1. Introduction

The Acute Respiratory Distress Syndrome (ARDS) is an acute inflammatory disease of the lungs associated with severe hypoxemia mostly due to pneumonia, sepsis, aspiration of gastric contents and major trauma [1,2]. Despite a mortality rate between 18% and 35% [3,4], ARDS is still underdiagnosed in intensive care [5]. Early diagnosis of ARDS counts among the measures that should improve the management of this disease including an early initiation of a lung protective ventilator support.

The diagnosis of ARDS is based on four criteria [6]:

- Acute situation.
- $PaO2/FiO2 < 200$ mmHg.
- No clinical evidence of left heart failure.
- Fluid overload and bilateral infiltrates (alveolar damage) on chest radiograph (white spots as shown in Fig. 1) [7].

The alveolar damage appears in chest radiograph in the form of opacities. This is due to the fact that the alveoli, which are responsible for air transfer between the outside and the blood, are filled with inflammatory fluid and/or are collapsed. These criteria are difficult to highlight simultaneously, which usually leads to a false diagnosis, and among them, Angoulvant et al. [8] demonstrated that the inter-observer variability on the chest radiograph, which corresponds to the fourth criteria, was very high (kappa = 0.3) and was a limiting factor in the early diagnosis of ARDS. In fact, the difficulty of diagnosing this disease is probably due to both the quality of the chest radiograph and the intensivist's interpretation which usually depends on his own experience. In order to assist clinicians in the early diagnosis of ARDS, the development of an automatic system has proven to be essential.

1.1. Computer-aided diagnosis system for chest radiograph

The chest radiograph is an essential tool for diagnosing ARDS. Its low cost, portability, speed, and its use of a moderate dose of radiation make it the most adequate imaging tool. A computer-aided diagnosis (CAD) system to detect ARDS (diffuse abnormalities) in chest radiographs is a new area that has not been previously studied, even though CAD is one of the major research areas in medical imaging and diagnostic radiology [9] where several CAD systems have already been developed in order to help radiologists in chest radiographs diagnosis [10]. The computerized analysis of chest radiograph in these CAD systems is based on size measurements, detection of nodules (low-contrast white circular objects) or texture analysis [10]. Texture analysis is the best approach that assesses diffuse patterns in chest radiographs and can be used for ARDS diagnosis.

* Corresponding author at: The Department of Computer Engineering, Ecole Polytechnique de Montréal, Montreal, QC, Canada H3T 1J4.
E-mail address: nesrine.zaglam@polymtl.ca (N. Zaglam).

http://dx.doi.org/10.1016/j.compbiomed.2014.06.006
0010-4825/

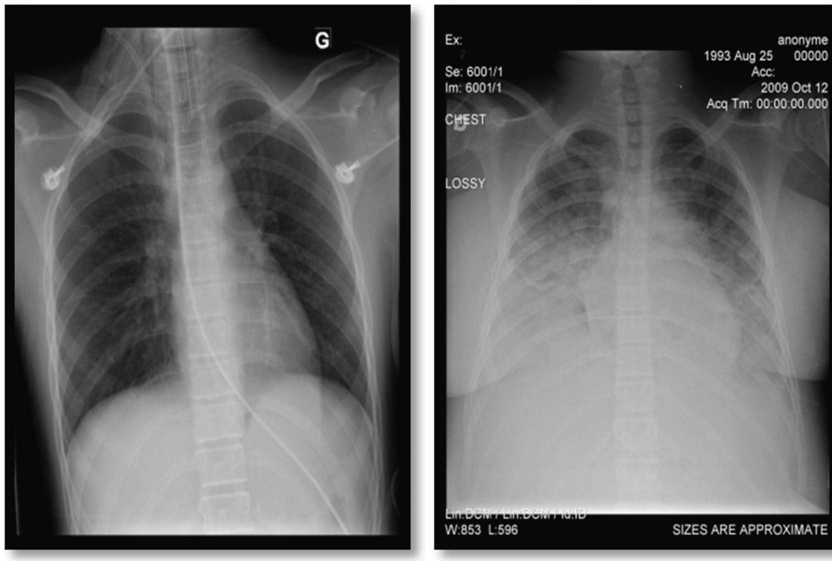

Fig. 1. Left chest radiograph: normal case; right chest radiograph: ARDS case (Ref: Sainte Justine Hospital).

1.2. *Texture analysis of chest radiographs*

The texture analysis plays a very important role in CAD systems [11]. There are several approaches to represent the texture. The main ones are divided into three categories namely statistical, structural, and spectral [12]. In the 1970s, the texture analysis has been applied in chest radiographs in order to detect the pneumoconiosis using the Fourier spectrum [13]. More recent work has realized a fully automatic CAD scheme for pneumoconiosis using the histogram and co-occurrence matrices features [14]. Ginneken et al. [15] used as features the moments of responses to a multiscale filter bank in order to detect tuberculosis (TB) and interstitial disease. Chest radiographs also include normal structures that may distort the analysis of the lungs. To address this, several studies have performed their analysis exclusively on the Regions Of Interest (ROI) that may contain the lesions. Kruger et al. [16] used the characteristics of the co-occurrence matrix and the Fourier spectrum extracted from the manually selected intercostal regions (ROI). Katsuragawa et al. [17] used the variation of Root Mean Square (RMS) and the first moment of the Fourier spectrum as features extracted from small automatically selected intercostal regions. They developed an algorithm to eliminate the posterior ribs by first selecting a large number of squares (ROI) in the chest radiograph and then eliminate those that contain sharp rib edges, using edge gradient analysis. However, in [16,17], the areas containing anterior ribs were not eliminated, when selecting intercostal regions for analysis. This can distort the ensuing analysis because these areas are visually similar to the lesions.

1.3. *Aim of our study*

In the present work, we developed a computer-aided diagnosis system for the detection of ARDS based on statistical and spectral texture features and using an SVM classifier. We applied a method of semiautomatic segmentation of the ribs in order to exclude them because of their similarity with opacities. This allowed an automatic selection of intercostal regions for analysis.

2. Materials

Chest radiographs have been selected from a previous clinical database (TARD study: Transfusion Associated Respiratory Distress), which included children in Pediatric Intensive Care [18]. Patients who participated in the TARD study were aged between 7 days (newborns) and 18 years. Given the inter-observer variability in the diagnosis of ARDS shown in the literature, a study of the variability in reading chest radiographs for the diagnosis of ARDS in children was necessary in order to optimize the reading method and to create in the end, a test set of chest radiographs diagnosed with consensus to validate precisely our automatic decision system.

2.1. *Optimization of reading*

To optimize the diagnosis of our database, in the first evaluation, two intensivists have initially agreed on the criteria for chest radiographs reading based on the 1994 definition of the Consensus Conference on ARDS [6] and from a panel of X-rays from the literature [19]. Then, they classified a set of 120 chest radiographs as ARDS positive or negative. In the same process, they determined the positions of the affected quadrants for each chest radiograph [20]. To establish the basis of a diagnosis consensus, chest radiographs showing disagreement between the two intensivists were reviewed by a third one. In case of disagreement among the three intensivists on the location of the damage, the three observers performed an evaluation together to determine the final diagnosis.

3. Methods

The methods for the development of a CAD to detect ARDS are described in this section and shown in Fig. 2.

3.1. *Training database*

3.1.1. *Manual extraction of intercostal patches*

Opacities in ARDS are bilateral and diffuse. To analyze the normal and abnormal regions, we manually selected normal and abnormal patches of size 32×32 pixels in the intercostal regions with the help of an intensivist (PJ) in order to create the training set. 321 patches were thus selected and diagnosed (avoiding the anterior and posterior ribs) from 9 radiographs. 4 radiographs presented ARDS and 5 others did not (4 normal cases and 1 case with left lung affected). A patch is considered abnormal if about 90% of its surface contains opacity.