Neurocomputing 165 (2015) 222–227

Contents lists available at ScienceDirect

Neurocomputing

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

Brief Papers

Classifying cervical spondylosis based on X-ray quantitative diagnosis

Xinghu Yu [a,b], Ming Liu [b], Lingzhi Meng [b], Liangbi Xiang [b,*]

[a] Liaoning Medical University, General Hospital of Shenyang Military Area Command Training Base for Graduate, No. 83, Wenhua Road, Shenhe District, Shenyang 110016, China

[b] Department of Orthopedics Surgery, General Hospital of Shenyang Military Area Command, No. 83, Wenhua Road, Shenhe District, Shenyang 110016, China

ARTICLE INFO

Article history:
Received 16 October 2014
Received in revised form
8 February 2015
Accepted 4 March 2015
Available online 14 March 2015

Keywords:
Cervical spondylosis
X-ray
Maximum likelihood
Quantitative diagnosis

ABSTRACT

The traditional diagnosis method of cervical spondylosis is based on X-ray reading. However, some divergences often take place on the type classification for there exist some deficiencies in the definition of the X-ray, the experience of clinicians in X-ray reading and clinic work and so on. To cope with the matter, we put forward a method based on maximum likelihood theory to solve the type classification of cervical spondylosis in the article. We firstly establish the X-ray quantitative diagnosis model according to analysis of 1034 clinical cases, and then carry it out with 60 cases of the test group. Although there is no statistically significant difference in the rate of diagnosis, slightly higher is observed in the aspect of accuracy when comparing the maximum likelihood method with a X-ray reading method 80.0% *vs* 68.3%, so the maximum likelihood method based on X-ray quantitative diagnosis is an efficient approach in the type classification of cervical spondylosis.

1. Introduction

In recent years, lots of changes have taken place in our work and life with the rapid development of economy all over the world. People spend more time using computers to do desk jobs and enjoy the air-conditioner; the long-term tension and cold stimulation are associated with cervical spondylosis (CS). The epidemiological surveys show that the morbidity of CS is on the rise and more and more people get CS that once is considered the old proprietary. Therefore, the researches on cervical spondylosis diagnosis and treatments have been a really hot topic recently [1–4].

At present, the following methods [5,6,27–29] are involved in the domestic and foreign objective examination of cervical spondylosis: clinical examinations, spinal angiography, vertebral artery angiography, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), etc. Among all the methods, X-ray is still given priority to when patients go to the hospital because it is considered as the most cost-effective imaging modality to diagnose the cervical spondylosis. X-ray has its advantages, such as lower costs, lower radiation dose, and more flexibility to image spine in different poses (up-standing, extension, bending, flexion, and torsion position) and so on [7,8]. Therefore, the cervical vertebra X-ray is very important for the clinical diagnosis of cervical spondylosis.

As we all know, the accuracy of clinical diagnosis of cervical spondylosis mostly depends on the medical knowledge and clinical experience of the clinicians. So, different clinicians and radiologists may give different diagnosis results when they read the same X-ray image. Therefore, if the cervical spondylosis could be detected by computer [31–33], and if radiologists and clinicians could use the detection results gained by computer as "second opinion", the accuracy of detection of cervical spondylosis by radiologists and clinical doctors will be improved on spinal X-ray radiographs. Meanwhile, it helps simplify the process of diagnosis, so patients can ask for self diagnosis based on applications. Further, early stage diagnosis of cervical spondylosis will become possible. In a conclusion, the method will not only reduce the work intensity of clinicians and radiologists but also help patients to achieve self diagnosis, finally improving the efficiency and accuracy of cervical spondylosis diagnosis.

However, we will find that some changes of X-ray film of the patients with early stage cervical spondylosis are so minor to observe in the process of actual clinical diagnosis and treatments, which makes visual diagnosis a very difficult job that maybe require more experienced clinical doctors and radiologists. From this aspect, we really need experienced experts or software which can guide our clinical diagnosis work. To our disappointment, this problem is still unsolved until now. As we know, the model of computer-aided diagnosis to classify cervical spondylosis during the clinical diagnostic practice has not been explored in this diagnostic area. Now we try to establish a model with characteristics extracted from X-ray radiographs by using improved maximum likelihood way to classify cervical spondylosis [9–12].

Based on the above discussion, we put forward one method of improved maximum likelihood which can be used to classify the cervical spondylosis depending on X-ray. The improved maximum

* Corresponding author.
E-mail address: Xiangliangbi2014@126.com (L. Xiang).

http://dx.doi.org/10.1016/j.neucom.2015.03.012
0925-2312/

likelihood is based on lots of orthopedic surgery experts and radiologists who are experienced in classifying cervical spondylosis. It increases the clinical classification diagnostic level [10,13] and makes the results of cervical spondylosis classification more objective.

In this paper, our database was obtained from 1034 spinal radiographs patients, and all of diseases were diagnosed definitively by X-ray, CT, MRI and surgical, respectively and eventually. The improved maximum likelihood can be used in the clinical diagnosis of cervical spondylosis. On the basis of clinical statistical data analysis, the improved maximum likelihood can establish a standard table. Then we can get a precise conclusion of classifying cervical spondylosis through calculating with the application of improved maximum likelihood table. The mathematical model we established in the paper can implement quantitative diagnosis when connected with the computer, which can assist the clinical doctors and radiologists to increase the accuracy of cervical spondylosis based on the X-ray and provide certain guiding value.

This paper is organized as follows. Sections 2 and 3 provide the background of cervical spondylosis and improved maximum likelihood. Section 4 shows how to obtain the main regions of interests (ROIs) from the spine X-ray imaginations and how to establish the improved maximum likelihood and radiographs processing with the X-ray of spine. Section 5 shows our experiments which were proposed and put into practice just in order to evaluate the proposed improved maximum likelihood method to be a diagnostic tool of classifying cervical spondylosis.

2. Background of cervical spondylosis

Cervical spondylosis (CS) is defined as an osteoarthritis degeneration of the cervical spine. “Wear and Tear” because of years of motion and activity is the most common etiology for the cause of degeneration to occur in cervical spine [14]. Lots of clinical studies have shown that excessive motion and repetitive trauma may accelerate cervical disc degenerative changes [15–17].

In China, all the changes which happen in the cervical spine can result in directly compressive and entire dysfunction which we can mainly classify as four types of cervical spondylosis. The first type is cervical spondylosis radiculopathy (CSR), the second type is cervical spondylotic myelopathy (CSM), the third type is vertebral artery type of cervical spondylosis (VACS), and the fourth type is sympathetic cervical spondylosis (SCS).

All the above four types of cervical spondylosis can be categorized by different local symptoms during their early stage. Accurate knowledge of the natural history of cervical spondylosis is always essential to clarify the types of cervical spondylosis. For instance, patients complaining of symptoms of dizziness, headache, tinnitus, and blurred vision, facial flushing and sweating, palpitations are quite often in spinal clinical examination [18,22–26].

In the traditional clinical diagnosis, we usually make a final decision depending on the symptoms which we mentioned above. The accuracy of diagnosis is based on X-ray, CT, MRI, careful clinical examination, complete interview of patients and their relatives and so on. As we all know, different type of cervical spondylosis need to be treated with different therapies. Therefore, from an economic and social point of view, it is imperative to diagnose the cervical spondylosis as soon as possible in order to treat it in a right way. X-ray is the most common way to classify the types of cervical spondylosis. But there are many minimal changes in the X-ray images which may make visual diagnosis more difficult for clinical doctors and radiologists and may decrease the accuracy of diagnosis. However, there is no a perfect method to solve and improve it. Here, in this paper, we try to propose one effective automated and convenient diagnosis algorithm in order to classify cervical spondylosis.

3. Improved maximum likelihood

In recent years, a great of complex problems have been solved with developing computational intelligence systems. Maximum likelihood has been proved to be a powerful tool as decision-making systems, for example, expert diagnostic platform and pattern classification systems [9,19,34].

3.1. The foundation of improved maximum likelihood

We collected X-ray image data from the patients with cervical spondylosis who were first coming to orthopedics clinics, a total of 1034 cases, all of which were eventually diagnosed by physical examination, imaging data and surgery as patients with cervical spondylosis, and composed of a large sample data, and then we could form a criteria according to the X-ray signs of frequency and the corresponding score values (Table 1). Specific steps are as follows:We refer to the high qualification doctors who are above the deputy director and discuss the X-ray image and choose the most common 10 kinds of X-ray signs to be the research target, and we need to do statistics with the X-ray signs of the number of cases, respectively.

With reference to Wang etc. used method (Table 2) [20], 10 kinds of X-ray signs (ROIs) which we extracted based on the experienced clinical doctors and radiologists are calculated for their frequency in different type of cervical spondylosis. Then change its frequency into corresponding scoring value (Table 3), its computation formula is as follows:

$$P_j(S_i/A_i) = P(S_1/A_i) \times P(S_2/A_i) \ldots \times P(S_m/A_i), \quad i = 1,2,3 \ldots k \tag{1}$$

In the above formula, i represents the number of patient; $S_1 \ldots S_m$ stand for indicators which have different values to identify types of diseases. Sign of S_i is on behalf of the patients with A_i set. $P_j(S_i/A_i)$ represents the sign set total probability of S_i that numbers for A_i patient who belongs to the j type of cervical spondylosis.

For patients of A_i, we need to calculate assumptions as four types of cervical spondylosis which appeared signs of S_i total probability value size, respectively. The most value size of cervical spondylosis category is discriminant result. For the convenience of calculation and comparison, we often take logarithm on both sides of the above formula, which is converted to the following formula:

$$L_i = \sum_{n=a}^{m} 10\left(1 + \log \frac{S_m}{A_i}\right) \tag{2}$$

L_i stands for the cumulative score value of the indicators.

4. X-ray radiographs acquisition and processing

4.1. X-ray radiographs acquisition

In the clinical diagnosis of cervical spondylosis, X-ray images have been used for a long time. In clinical diagnosis, doctors and radiologists read the X-ray images regularly and extract the characteristic structures to classify the four types of cervical spondylosis. In this article, we establish a modified maximum likelihood model in order to simulate the doctor's reading habit and mimic the doctor's diagnostic process that extracting the characteristics of X-ray images for the diagnosis of cervical spondylosis.

Patients general information: 1034 cases in all, 598 male and 436 female, respectively. Age: from 20 to 89 years old, average 56.3 years old, including CSR 679 cases, CSM 142 cases, VACS 142 cases, SCS 110 cases. All the cases are confirmed as cervical spondylosis with examination of X-ray, CT, MRI and clinical body examination. There are different degrees of neck pain, shoulder pain and occipital pain; and neck shoulder pain radiates into the