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Texture Analysis – A New Method of Differentiating Prostatic Carcinoma from Prostatic Hypertrophy

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Summary. This study compares the results of a new computer assisted evaluation programm of sonographic images of the prostate with the histological examination of the operative specimen. This computer program is based on the fact that the human eye is not capable of distinguishing picture distribution points which differ in higher than second order statistics. The sensitivity of the method was 89%, the specificity 86% and the diagnostic accuracy 88%. The results are discussed by comparing them to results of transrectal sonography and digital palpation as reported in the literature.

Key words: Texture analysis – Prostatic Hypertrophy – Prostatic Carcinoma

Introduction

Prostatic carcinoma is the most frequent male urological cancer, with a rising incidence dependent on age. The earlier the diagnosis is made, the better are the chances of cure. Unfortunately, in the early stages of the disease there are no "warning symptoms" and the patient remains well. This puts the emphasis on screening for early cancer detection. Until a relatively short time ago the index-finger was the only non-invasive method of diagnosis. Since Watanabe et al. [11] first published the application of transrectal ultrasonography much work has been done to improve the method. Now cancer of the prostate can be detected with high reliability using transrectal ultrasound equipment [4, 6, 9]. Considering the fact that this technique is rather time-consuming (15–20 min per patients) [8], it use as a screening method is limited. The aim of this study was the application of a technique which is non-invasive, easy and rapid in differentiating prostatic carcinoma from prostatic hypertrophy with an accuracy higher than that of digital examination.

Because transabdominal scanning is the simplest method of imaging the prostate by ultrasound and is truly non-invasive [5] we developed a method which is more reliable than the human eye in judging the echo-pattern of the gland.

Patients and Method

In a prospective study 83 patients were evaluated, 47 as having a prostatic carcinoma and 36 a benign prostatic hypertrophy. All patients were operated on (either transurethral resection or suprapubic enucleation) and the operative specimens were histologically evaluated for absolute diagnosis.

Preoperatively the prostate gland of all patients was examined sonographically by a transabdominal, transvesical approach using a mechanical sector scanner with a frequency of either 3 or 5 MHz (Squibb medical systems UM4). The investigation was recorded on a VHS-videotape and later digitized at the Institut für Medizinische Computerwissenschaften. The investigating urologist marked the "region of interest" or in other words the exact area for the later processing (digitization) on the frozen picture while performing the sonographic investigation. Since the exact method has already been described elsewhere [10, 12] we mention only the basic principles, in this account.

Texture analysis is a computerized method of describing structures in a quantitative manner. For this purpose a great variety of mathematical formulae were developed to characterize certain properties of a texture, based on relationships between the single picture elements which constitute the specific patterns. According to the underlying model of pixel-interrelationship the measurements can be summarized into categories such that measurements within the same category employ the same mathematical principle and that measurements of a different category describe the texture in a fundamentally different way.

For this study measurements from 5 such categories were used to account for the fact that various textures do not necessarily differ in all parameters. In contrast to the straight-forward approach we do not calculate just one number from the total region of interest to describe the area as a whole but we rather compute such a number for equally spaced points of the ROI (region of interest) using a local area of a user-defined size. Of course, only those points are taken into account whose local areas are thoroughly embedded in the area under consideration.

The reason for using a whole series of textural values to describe the texture of a ROI is that ultrasound is a space-variant

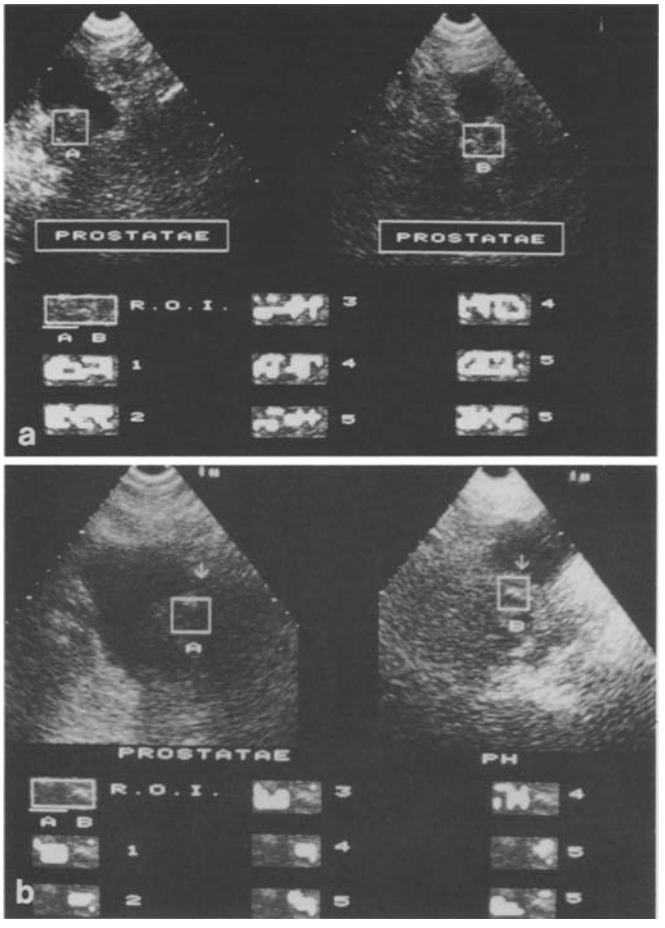

Fig. 1. **a** Texture analysis of 2 samples (histologically confirmed prostatic carcinoma); *A* and *B*: sample areas of 2 different patients; *R.O.I.*: region of interest; *1* to *5*: texture categories; result: random pattern indicating textural homogenity. **b** Texture analysis of 2 samples (histologically confirmed prostatic carcinoma (prostatae) and prostatic hypertrophy (PH)); *A* and *B*: sample areas, arrow points to sample area; *R.O.I.*: region of interest; *1* to *5*: texture categories; result: texture pattern clusters in one of the 2 sample areas indicating 2 different tissues

imaging technique and the visual impression and consequently the pixel values themselves depend on external factors such as the parameter setting of the scanner. Besides, for biological reasons the texture cannot be guaranteed to be homogeneous throughout the entire region of interest. This accounts for the inadequacy of numerical values in describing biological tissues mapped by ultrasound. However, when normalized textural values of relatively small areas are used and tested for consistency over the entire ROI, any variation of the computed values should lack regularity. Such variations can be made visible by coding those pixels which have comparatively extreme values in a different colour. With homogeneous ROI's this should exhibit a rather random pattern. The same holds true if two samples of the same texture are jointly compared (Fig. 1a).

The situation, however, is radically different when two different textures are compared to each other. Assuming that the chosen measure is capable of reflecting the difference in texture the local values from one texture will differ significantly from those of the other, apart from random fluctuations. Consequently, the visualization process will result in a clearly clustered pattern (Fig. 1b).

This idea is being used in comparing the tissue under consideration to verified tissue samples of both hypertrophy and carcinoma.

Table 1. Results of texture analysis compared with histological examination of operative specimen

Texture analysis \ Histology	Carcinoma	BPH	*n*
Carcinoma	42	5	47
BPH	5	31	36
Total	47	36	83

The procedure must produce a clustered pattern with one tissue and a random distribution with the other to arrive at a valid diagnosis.

For this study textural values of the following categories were used: (1) textural edgeness, (2) relative extremer density, (3) spread, (4) gray tone run length, (5) co-occurence.

Two typical results of this approach are shown in Fig. 1a and b. The two sample areas which are to be checked for textural consistency are labeled A and B in the corresponding ultrasonic images respectively. The compound area which is finally analyzed is inserted below the left ultrasonic image (labeled ROI). The results of 8 various parameters from the 5 categories are also shown (The number on the right indicates the category from which the actual parameter was choosen).

Results

83 patients were evaluated; the results are shown in Table 1. A sensitivity of 89% was achieved and the specificity was 86%. The diagnostic accuracy was 88%, the rate of false negative results was 10.6%; the false positive results 13.9%.

3 patients who had a clinical diagnosis of benign hyperplasia preoperatively were found on histopathological examination to harbour a carcinoma. All 3 patients were diagnosed correctly by the means of textural analysis.

The digitized pictures of all patients were first compared with a test area of known prostatic hypertrophy and thereafter with a known prostatic carcinoma.

Discussion

The results of digital palpation and transrectal sonography in a large search of the literature must be compared to find out if texture analysis is a useful diagnostic tool. Brooman et al. [3] presented a comparison between digital palpation and transrectal sonography in 242 patients with histological confirmation of the diagnosis. To our knowledge, only in this paper are the figures quoted sufficient to allow statistical analysis. Their data revealed a sensitivity of 86.87 percent in digital palpation and a specificity of 39.16 percent. The diagnostic accuracy was 58.68 percent. The relevant data for transrectal sonography were 91.9 percent, 79.02 percent and 84.30 percent respectively. Hence it

follows that compared to digital palpation textural analysis is better in all three parameters. Compared to transrectal sonography our method is slightly better in specificity and slightly worse in sensitivity. At the moment it looks quite in favour of texture analysis that the percentage of false positive results is astonishing low. Brooman and Co-workers [3] quoted a false positive rate of 60.84 percent for digital palpation and 20.98 percent for transrectal sonography. Still, the number of our patients is too small to give a definite statement. The rate of false negative results in our series was 10.6 percent compared to 3% with transrectal sonography and 5 percent with digital palpation.

The interesting point is the ability of a method to diagnose subclinical cancer (stage A or T_0). Regarding this point the value of transrectal sonography seems to be equivocal. Some workers could not predict preoperatively the presence of clinical undetected cancer [2, 7]. However Brooman et al. [3] could diagnose 11 patients out of 13 with subclinical cancer correctly by the means of transrectal sonography. All our 3 patients with subclinical cancer were diagnosed correctly by means of textural analysis. The self-limiting factor of diagnostic accuracy of the method becomes evident if one recalls the diagnostic procedure. Ultrasound makes a picture of the prostatic gland and marks an area for further processing on the frozen picture. This area is analyzed. The smaller the area under consideration the higher the sensitivity of the method will be. Due to the fact that a carcinoma does not necessarily involve all parts of the prostate there remains the uncertainity of not knowing if the appropriate area is being tested. Since all diagnostic methods are measured against the histological specimen for assessment of accuracy the same problem exists. One must bear in mind that there is an uncertainity of not knowing if a needle biopsy has sampled the appropriate area [1] or if the pathologist has overlooked a carcinoma in the operative specimen.

Since the chances to cure a patient with a prostatic carcinoma are best in early tumor stages a suitable screening method would be of great help. Up to now only digital palpation is easy enough to perform as screening method. Transrectal sonography has a clearly higher diagnostic accuracy but due to the fact that expensive special equipment is needed and that the examination is rather time-consuming (15 to 20 min) [8] the method might not succeed as screening method. Textural analysis requires about 5 min and standard ultrasound machine in combination with a videorecorder was used. It might be possible to combine an ultrasonic scanner with a personal computer which would facilitate the process.

Compared to other methods in computerized tissue classification texture analysis has the following advantages:

1) There is no absolute dependence on certain ultrasound equipment since only relative differences are evaluated.

2) Inhomogenous tissues are no problem, since only relative differences are evaluated.

3) The area of the analysis can be chosen by the investigator.

4) The method is robust against outliers.

5) The result of the classification can be also shown as echo distribution so that it can be examined visually by the investigator.

It has always been a challenge in medicine to find diagnostic procedures with maximum non-invasiveness and high reliability. The preliminary results of the method described in this paper are promising but a greater number of patients will be needed to elicit the exact diagnostic value.

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