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Knowledge-Based *In Vivo* Analysis of Kidney Concretions from Digitized X-Rays

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Abstract: To make a right choice of a treatment approach in patients with nephrolithiasis it is very important for the clinicians to know the composition and structure of calculus. Conventional radiographic techniques and computerized tomography (CT) give information about the location and size of concretions, but not for their composition and structure. In the present study we investigated the gray-level values of chemical substances in concretions. It was established the appropriate X-ray exposure for subsequent image analysis. A method for intracorporal analysis of composition and structure of kidney concretions is proposed.

Introduction

The biggest part of diagnostic information in urology is from visualizing modalities such as X-ray radiography, computer tomography (CT), ultrasound, cystoscopy etc. They give information about the location, form and size of concretions, but not for their composition and structure.

Use of computer techniques and software for image analysis and processing could enhance the image quality and visualization of medical objects [1, 2]. For precise analysis and intracorporal determining the composition and structure of kidney concretions it is necessary to be created new methods based on knowledge about chemical substances [3]. This is of great importance for the physicians to take the right therapeutic approach.

In the present study the authors propose method for in vivo analysis the composition and structure of kidney concretions. Used knowledge and created methods are arranged in an expert system VIDEOEXPERT 2.0

Materials and methods

It was examined 130 concretions collected in the Department of Urology at Military Medical Academy. Each concretion was made X-ray in vivo and after its elimination. Conventional X-ray modality was used. Exposition was done with beam energy 44/25 mA/s (subexposition). A specialized laser scanner for transparent objects (FS/U-1) has been used for the digitalization of the X-rays.

Image analysis of the digitized X-rays was processed by VIDEOEXPERT 2.0. Besides the standard methods of image analysis [4] in the system are included knowledge about the gray-level values of chemical substances that compose the concretions; method for segmentation - using a look-up table pixels which have similar attributes are grouped into regions (region-based segmentation); algorithm for background filtering; color coding of separate components using method of J.R. Jacobs and S.B. Connor [5].

To verify the computer analysis the results were compared to those of radiospectral and radiostructural analysis.

Radiospectral microanalysis is based on the principle of accelerated electrons with great energy (5-50 kV). The focusing is done by electromagnetic lens in a thin cone beam with diameter up to 0.1 μm. Electrons interact with the atoms of objects. They become activated and escape from the nearest to the nucleus shells (K, L, M - levels). Thus the atoms generate Rö-radiation. Each object affected with this radiation gives a specific spectrum by which it can be recognized [6].

Radiostructural analysis uses X-rays with wave length commensurate with the inter atomic distances. This give opportunity to determine the interplane distances, to index the surfaces and to examine other structure characteristics of the analyzed substance [6].

It was used cross sections of polished specimens and profile scanning so that all zones of the object could be analyzed in details was done.

Results and discussion

In our study we analyzed 16 components of the kidney concretions. All the concretions have a complex structure. In most cases the separate components composing the concretions are concentrically placed. In other some of the substances are dispersed in the basic corp.

On fig. 1 it is shown a concretion analyzed by VIDEOEXPERT. Clearly are distinguished several layers that corresponding to the substances composed the concretion. From outside towards inside they are: STRUVIT (two layers of different concentration), DAALIT, VITLOKIT (two different concentration), VEDELIT, VEVELIT and APATIT in the center (with two layers of different concentration).

Another case with six layered structure and background filtering is shown on fig. 2. The layers correspond to the following compounds: NUBERIT, VEDELIT, STRUVIT (two layers of different concentration), DAALIT, APATIT (in the center).

A 3D display of a concretion in which some of compounds are dispersed in the basic corps is shown in fig. 3.

In all analyzed concretions the composition and structure are exactly determined. Two substances (uric acid and monoamonium urate) have identical gray-value levels and are indistinguishable by computer analysis. This fact is of no importance for the physicians because the therapeutic approach is the same when one or both substances are available in the calculus.

In most of the cases the concretions are composed of 4, 5 or more components concentricaly arranged. Some objects consist dispersed substances in the basic corp.

The results of computer analysis of the kidney concretions were conformed by those from radiospectrum and raidostrucural analysis.

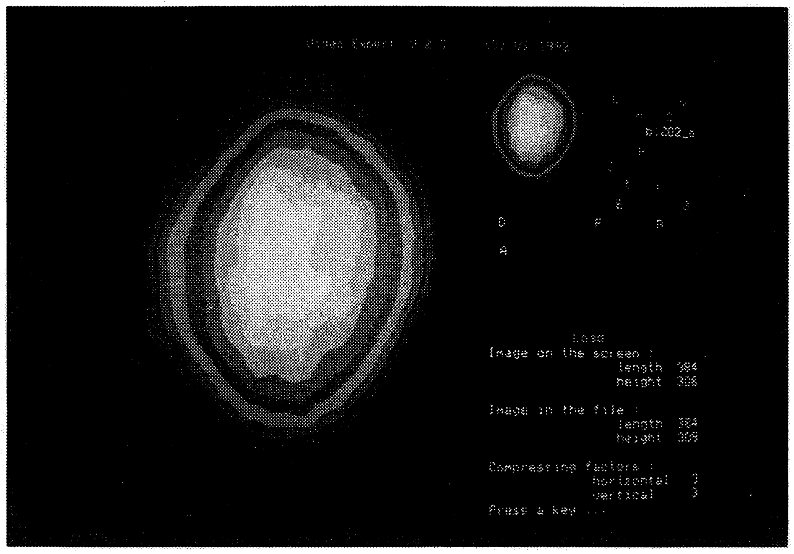

Fig. 1. Structure of kidney concretion with color coding of its components (without background filtering).

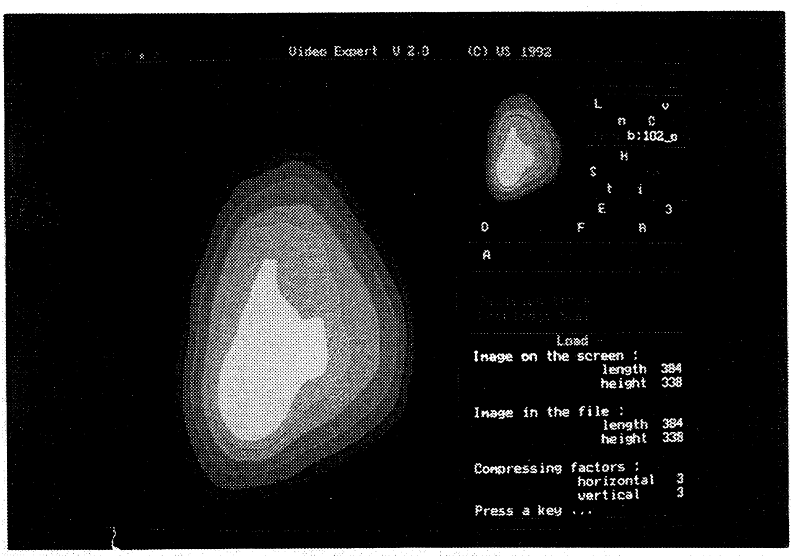

Fig. 2. Kidney concretion with six layered structure (background filtering is processed).

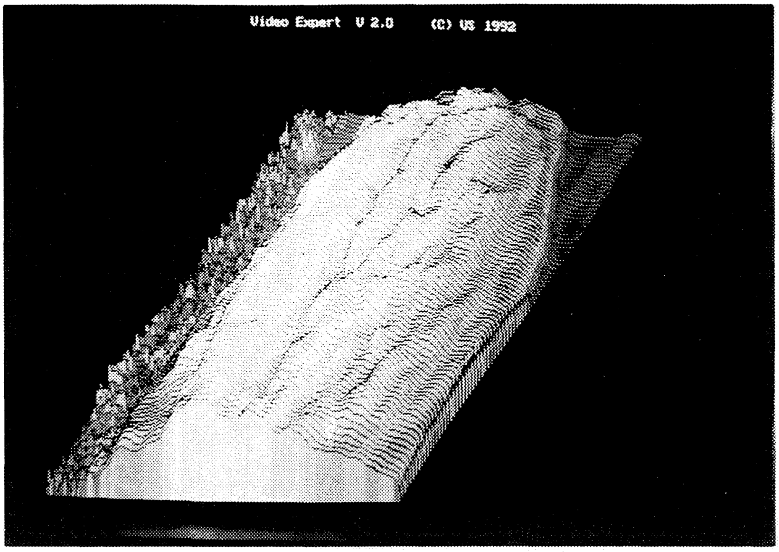

Fig. 3. 3D display of kidney concretion.

Conclusion

In our investigation we found out that concretions change the parameters of X-rays specifically according to their composition and structure. This is more obviously in radiographs with subexposition. Each substance (except two mentioned above) has different gray-value level and could be determined by computer analysis. This gave us the opportunity to designed a knowledge based system for intracorporal image analysis of kidney concretion from digitized X-rays.

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