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Application of Digital Image Processing to Chemical Component Prediction

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The purpose of this paper was to discuss the possibility of predicting chemical components of stones in urinary system with digital image processing technique. The paper adopts the method of scanning and analysing multiple stones with a diameter of more than 15mm in urinary system by using related digital image processing technique, and mainly, predicating the chemical components by CT illumination. Results indicate that the CT values presented by the stones of the urinary system under different voltages are not completely consistent, and the CT value under the voltage of 120KV is closest to the actual value. A conclusion can be drawn that the chemical components of the stones in urinary system can be predicted by using the digital processing technique, and the prediction results are the most accurate when the prediction is performed under the voltage of 120kv.

1. Introduction

At present, the digital image processing technique has been widely applied to the prediction of the chemical components in various industries, in particular the clinical treatment, and provides data basis for more scientific and highly efficient pathologic treatment approaches. This paper mainly detects multiple patients with the stones in urinary system through spiral CT scanning and analyzes a relation between the chemical structure of the stones and the CT value through data collection.

2. Literature review

Image processing refers to the behaviour of processing image information to satisfy human psychological, visual or application needs. In general, there are two kinds of image processing methods: optical method and digital method. With the continuous development of science and technology and the widespread popularization of digital products such as computers, the application of digital image processing is becoming more and more extensive. The digital image processing technology is to use various digital hardware and computer to carry out corresponding mathematical operation of the electrical signal obtained by the conversion of the image information, such as image de-noising, image segmentation, edge detection, image restoration, image compression, image coding and so on, so as to improve the practicability of the image. Its characteristics are high processing accuracy, and it can improve the processing software to optimize the processing effect and the operation is more convenient. At present, with the rapid development of computer hardware technology, its calculation and processing speed is greatly improved, which greatly promotes the development of digital image processing technology.

Urinary calculi are common diseases and frequently occurring diseases in the department of urology. 17 years ago, the urinary calculi began to occupy the first place in the department of urology inpatients in the southern hospitals of China. With the continuous improvement of the material living standard and the gradual change of the diet structure and habits, the incidence of urinary calculi at home and abroad is rising. According to reports, the annual incidence rate of urinary calculi in China is 150-200/10 million, and the number of patients in Europe and America is about 100-400/10. Urinary calculi are divided into four kinds: kidney stone, ureteral stone, bladder stone and urethra stone. The first two are called upper urinary calculi, and the latter two are lower urinary calculi. Four kinds of urinary calculi take ureteral calculi as the most prominent clinical symptom.

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Because of their pain, hematuria, recurrent urinary tract infection or kidney, ureteral water or even no urine, it greatly affects the living quality of the patients, so that much attention is paid to it. At present, there are 5%-15% people suffering from urinary calculi in the world. Ureteral calculi account for about 33%-54% of urinary calculi. However, primary ureteral stones are rare. Most ureteral stones are caused by obstruction and inflammation of the ureter during the discharge of kidney stones. They are renal colic, hematuria, urinary tract infection or dilatation of kidney and ureter, and even renal failure.

The CT value is the attenuation value of all directions after a certain thickness of the X-ray ring detecting a certain thickness of the body, and the degree of X-ray absorption depends on the density of the stone. Compared with KUB, it has the advantages of more precise, detailed, clear, stereoscopic, unaffected by the intestinal gas and the structure of the bone around the stone. More importantly, it can measure the CT value of the stone by measuring the attenuation value of X-ray through the stone, thus reflecting the density of the stone. Liu et al. studied and believed that the best CT critical value of the X-rays of CT and KUB cannot penetrate the stone for 630HU, and the stones that cannot be displayed by CT are not visible on KUB. The CT values of the stones measured by NCCT are helpful for the analysis of the stone composition, because the "hardness" of the stones is quantified. Although the CT value determined is only an average range of averaging stones, it was able to distinguish 0.5% of the stone density differences, ten times higher than the X - ray film that was only 5% of the difference in the density of the stones. By measuring the CT value of the stone before the lithotripsy, the density of the stone can be reflected and the density difference of 0.5% can be accurately divided. It is helpful for predicting the hardness of the stone and the fragility of ESWL, so as to further evaluate the stone composition and predict the therapeutic effect of ESWL after the calculi (Liu et al., 2018). Mihaljevi and so on found that the effect of the coupling agent on the coupling agent bottle was far less effective than that of the gravel coated with the self-coupling agent. In the past, the high-frequency tissue injury also improved with the reduction of frequency. They also found that the frequency of 60 times of lithotripsy was obvious, and the damage of soft tissue was low. The rate of graded energy increase could increase the success rate of crushed stones, reduce the damage of blood vessels and the tissue damage, and reduce the probability of complications such as hematoma and haemorrhage (Mihaljević et al., 2017). Zumstein and so on, according to the in-vitro test, proposed that the CT value of urinary calculi can predict the brittleness of the stone, and estimate the number of ESWL shocks required for the comminuted stones. It is suggested that the low CT value of the stone is easily broken, and the number of shocks required is less (Zumstein et al., 2018). Largo and others believed that the NCHCT value can predict the clearance of ESWL for urinary calculi, and the success rate of lithotripsy in low CT stones is much higher than those of high CT (Largo et al., 2016). Liao et al. studied and believed that CT value >1000HU can be considered as a predictor of ESWL failure, while Amr and other studied and suggested that the CT attenuation value (SAV))≥956HU is not an ideal treatment. And it is not an ideal treatment for 500-1000HU body mass index (BMI) >30 kilogram / square meters and lower renal calyx stones. The size of stones, location of stones, residence time of stones, and renal function all need to be considered (Liao et al., 2016). Leng and other studied and suggested that CT values can be used as a parameter for quantitative analysis of the density of urinary calculi. The average CT value of the stone is closely related to the hardness of the stone. The higher the average CT value is, the greater the hardness of the stone is and the more difficult the stones to be crushed. They further confirmed that the higher the CT value of the mixed stone is, the more fragile it is, and the worse its fragility is (Leng et al., 2016). Wang and others believed that the fragility of the ESWL stone is related to the stone composition and related structure. It is suggested that the CT value<900HU of the stone is the fragility index of the lithotripsy in vitro. It is considered that the NCCT value of the stone can be used to determine the main component of the stone, which can be used as one of the reference indexes for evaluating the effect of ESWL lithotripsy (Wang et al., 2017). The results of Wang and other studies showed that the non-enhanced spiral CT (NCHCT) value could predict the crushing rate and emptying rate of the stones after ESWL in the upper urinary tract. The stones with low CT value were easily crushed and emptied after ESWL, and the crushing rate and emptying rate of the stones with high CT values were significantly decreased (Wang et al., 2017).

To sum up, the above research is mainly about the prediction of chemical composition, but the researches on the application of digital image processing technology in the prediction of chemical composition is very few. Therefore, based on the above research status, the method of scanning and analyzing multiple stones with a diameter of more than 15mm in urinary system are applied, and the chemical components are predicted by CT illumination. The results show that the CT values presented by the stones of the urinary system under different voltages are not completely consistent, and the CT value under the voltage of 120KV is closest to the actual value. As a result, the chemical components of the stones in urinary system can be predicted by using the digital processing technique.

3. Research Material and Method

3.1 Main Advantages of Digital Image Processing Technique

(1) The digital image processing with good reproducibility mainly differs from simulation image processing in that it will not cause degradation of the image quality due to a series of transformation operations of storage, transmission or copy of an image. As long as the image accurately presents the original draft when digitalized, the digital image processing will always reappear the image.
(2) Modern scanners can quantize the gray scale of each pixel into 16 bits or more, which means that the digitalization precision of the image will meet any application requirements. For computers, the processing program is almost the same regardless of an array size and the number of bits of each pixel. In other words, in principle, no matter how high the image precision is, the processing can always be realized as long as the array parameters in the program is changed during processing. Rethinking the simulation processing of the image, in order to improve the processing precision by one order of magnitude, a processing device needs to be improved greatly, which is extremely uneconomic.
(3) Wide applicability, the image may come from multiple information sources, they may be visible light images, and may also be invisible spectrum images (for example, X ray images, ray images, ultrasonic images or infrared images, etc.). It can be seen from an objective entity dimension reflected by the image that the image can be as small as an electron microscope image and can be as large as an aviation picture, a remote sensing image or even an astronomical telescope image. For example, the RGB images are formed by combining red, green and blue gray scale images, and can all be processed by a computer. That is, as long as corresponding image information collecting measures are adopted for different image information sources.
(4) The high flexibility image processing is generally divided into image quality improvement, image analysis and image reconstruction, each section contains rich contents. Since the image optical processing can only be subjected to linear operation in principle, the targets that can be realized by optical image processing are greatly restricted. While digital image processing not only can realize linear operation, but also can realize nonlinear processing, that is, any operation that can be expressed by mathematical formulas or logical relations can be realized by digital image processing.
Thirty patients of urinary stones from July 2009 to July 2013 were selected from Xiushui County People's Hospital, including twenty-one males and nine females, aged from five to seventy-five years old, fourth years old in average. There were 16 cases of kidney stone (including 6 cases of kidney ureteral stone), 9 cases of ureteral stone (including 6 cases of kidney ureteral stone), 5 cases of bladder stones. The thirty patients all had simple chemical composition stones (i.e., the main chemical composition accounted for more than 90%) with a stone diameter of more than 10mm and were treated by surgery.

3.2 Measurement method

The lightspeed4ct scanner of ge company was adopted to perform CT plain scan on the patient, parameters are 120kv, 104mA, and the reconstructed layer thickness and layer distance after volume scan was 3mm; on a visible stone layer, repeated scan was performed at 80kx without changing other parameters, and the stone CT values under 80 and 120kv were measured. The stone samples were taken via a surgery and were cleaned, dried and then grinded into power, and the chemical components were analyzed via titration of standard urinary stone analytic liquid. The specific operation procedure was as shown in Figure 1.

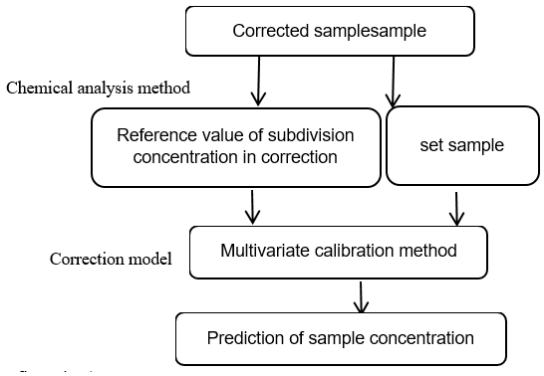

Figure 1: Operation flow chart

3.3 Statistical method

Ssps17.0 statistic software was adopted. Metering material was represented with x±s, and the stone CT values with different chemical components were compared by adopting analysis of variance, and the difference was $p<0.05$, which had statistical significance. The analytic results for different kinds of stones were as Table 1.

Table 1: Analysis of different types of stones

Classification of stone	Actual CT value	Operation times	Test value
High density stone	197.3±58.17	12	134.2±14.9
Low density stone	-20.16±11.38	13	-27.3±14.78
Medium density stone	159.47±79.23	5	16.67±5.36

3.4 Results

The measurement result of the chemical components of stone samples in surgery was: twelve cases of mainly calcium oxalate, five cases of calcium phosphate, five cases of uric acid, five cases of magnesium ammonium phosphate and three cases of cystine. The comparison of CT values of the stones of various chemical components under the voltages of 80 and 120kv was shown in Table 2, and the result indicated that the sequence of CT values from low to high of the stone under the voltages of 80 and 120kv is uric acid, magnesium ammonium phosphate, cystine, calcium oxalate and calcium phosphate. The comparison difference of the stone CT values of respective chemical components under the voltage of 80kv has statistical significance ($p<0.01$), and the stone CT values of respective chemical components were not overlapped, the comparison difference of the stone CT values of respective chemical components under the voltage of 120kv has statistical significance ($p<0.05$), however, the CT values of calcium oxalate, calcium phosphate and cystine were partially overlapped.

Table 2: Comparison of CT values of stones of various chemical compositions under 80 and 120kV

	CT value under 120kV	CT value under 80kV
chemical composition	Range xs	Range xs
calcium oxalate	713-1087 951	1030-1445 1216
calcium phosphate	1025-1215 1128	1449-1728 1582
uric acid	547-684 628	373-722 452
P	< 0.05 < 0.01	

The chemical component analysis of the stones has important clinical significance in prevention and treatment of the stones. The treatment of the urinary stones is related to many factors, wherein the chemical component analysis of the stones has important significance in clinical conservative treatment and relapse prevention, for example, the medicine such as oral citric acid salts can be used for stone dissolving treatment on most uric acid stones and part of cystine stones; when in-vitro microwave lithotripsy is adopted to treat the calcium phosphate, cystine and calcium oxalate stones, the successful rate is lower due to larger hardness, while the treatment effect is more obvious if percutaneous nephrolithotomy is adopted. The urinary stones are not only high in occurrence rate, but also high in relapse rate. How to prevent stone relapse is greatly related to the chemical components of the stones, for example, the patient with the stones mainly comprising the calcium chemical component should be restricted from taking food and beverage rich in oxalic acid, and takes a diuretic to reduce urinary calcium when necessary; the patient with the stones mainly comprising the uric acid chemical component should be restricted from taking meat products and the food rich in purine, such as animal giblets and fish and shrimps, etc. and takes the medicine such as citrate and sodium bicarbonate to alkalize the urine when necessary; the patient with the stones mainly comprising the cystine chemical component should be restricted from taking the food rich in methionine to reduce the cystine concentration in the urine, and a method of alkalizing the urine can also be adopted for prevention; and for the patient with the stones mainly comprising the struvite chemical component, the most critical measure is to prevent and treat infection of the urinary system. Even some stone chemical components possibly hint some systematic or familial metabolic diseases, and in such case, special treatment is required, for example, the cystine stone patient may prevent the cystine stones by a dilution method and a urine alkalizing method; Gout patients can prevent and treat uric acid stones through low purine diet, allopurinol and alkali urine method. In the statistical process of related data, the relation between the CT voltage and a predicted accurate value was discovered as shown in Figure 2.

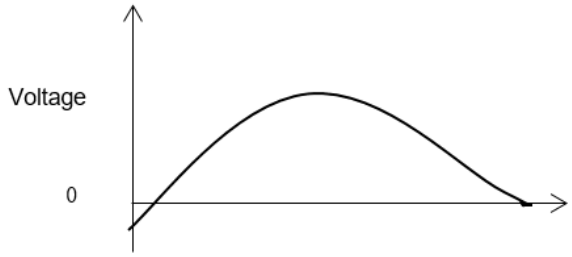

Figure 2: Prediction accuracy

In recent years, there are many studies on the images of the stone chemical components, and related technologies are kept in archives according to certain flow (as shown in Figure 3), however, most of them are based on dual-source CT scan and energy spectrum CT examination. But the most popularized examination in primary hospitals in our country is spiral CT, and the international attention to the radiation dosage is also very high. Therefore, the primary hospitals may select the spiral CT for the stone patients who are difficult to diagnose by ultrasonic waves, for example, patients with stones in the middle and lower section of a ureter or fat patients with stones in the kidney ureter.

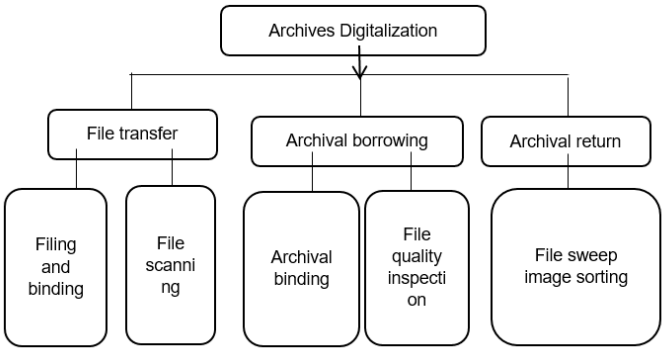

Figure 3: File digitization flow chart

The spiral CT has advantages of high speed, high sensitivity, high accuracy and high repeatability for the urinary system examination, the CT can well display the positive stones and negative stones, the difference of the stones of different chemical components mainly depends on the ray attenuation degree, and is quantized and identified with the CT values, while the ray attenuation of the stones of different chemical components is decided by their absorption and scattering of the rays. In the energy range of the x rays used by diagnostic CT, the x rays are mainly attenuated by a photoelectric absorption effect and a compton scattering effect in a process of penetrating through human body tissues, the intensity of the photoelectric absorption effect is related to the atom mass of an exposed substance and the energy of photons of the x rays, the photoelectric absorption effect is the main mode that high atomic substance such as calcium skeletons and iodinated contrast mediums attenuates the photon energy of the x rays, while the Compton scattering effect is unrelated to the atom mass of the substance and the energy of the incident x rays, is in a functional relation with an electron density of the measured substance, and mainly occurs in soft tissues. Therefore, the stone value is obviously changed along with the energy change of the x rays. Such value change relation is shown in the figure 4.

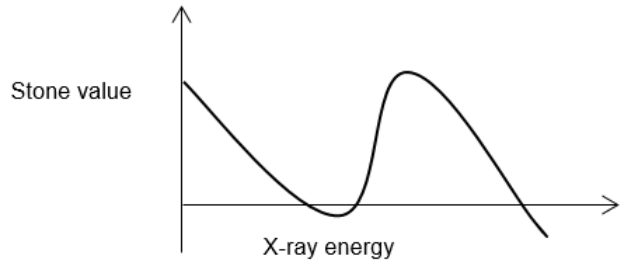

Figure 4: Energy change diagram of the stone value with the X-ray

4. Conclusions

This study adopted spiral CT to detect thirty urinary stone patients and discussed the difference of the CT values of the stones of different chemical components, to provide a reference value for the diagnosis and treatment of the urinary stone patients. 120kv was the most common condition applied to the daily working of the CT examination, and was mainly used for discovering stones in this study, and 80kv was only used for low radiation dosage and only used for rescanning the maximal layer surface of the stones. The study result indicated that the sequence of the stone CT values from low to high under the voltages of 80 and 120kv is uric acid, magnesium ammonium phosphate, cystine, calcium oxalate and calcium phosphate. The comparison difference of the stone CT values of respective chemical components under the voltage has statistical significance ($p<0.05$ or $p<0.01$).

The result also showed that the stone CT values of respective chemical components under voltage of 80kv were not overlapped, but the CT values of the calcium oxalate, the calcium phosphate and the cystine stones under 120 kv were partially overlapped, which indicated that the chemical components of the stones could be accurately judged by the spiral CT under the voltage of 80kv, which was consistent with the study result of matlaga et al. In order to reduce the influence of body position movement and the volume effect during examination on the patients, the diameters of the stones in all cases selected in the study were larger than 10mm, the scan was performed when the patients held the breath after inhaling in calmness, but the samples of this study were limited, and only the pure stones were taken as the study objects, therefore, more endeavor was required for truly clinical application and popularization.

Reference

Largo R., Stolzmann P., Fankhauser C.D., 2016, Predictive value of low tube voltage and dual-energy CT for successful shock wave lithotripsy: an in vitro study, Urolithiasis, 44(3),1-6, DOI: 10.1007/s00240-015-0824-y

Leng S., Huang A., Cardona J.M., 2016, Dual-Energy CT for Quantification of Urinary Stone Composition in Mixed Stones: A Phantom Study, Ajr Am J Roentgenol, 207(2), 1-9, DOI: 10.2214/ajr.15.15692

Liao W., Xiong Y., Yang S., 2016, Efficacy and functional outcome of flexible ureteroscopy for renal stones in patients with a solitary kidney, Surgical Practice, 20(1), 13-17, DOI: 10.1111/1744-1633.12155

Liu S., Wang H., Feng W., 2018, The value of X-ray digital tomosynthesis in the diagnosis of urinary calculi, Experimental & Therapeutic Medicine, 15(2), 1749-1753, DOI: 10.3892/etm.2017.5531

Mihaljević M., Cajner H., Runje B., 2017, Analysis of the couplant influence on the ultrasonic thickness measurement of the steel grade S355J0, Materialwissenschaft Und Werkstofftechnik, 48(8), 803-813, DOI: 10.1002/mawe.201700050

Wang J., Hwang T., Jung D., 2017, In vitro Estimation of The Hounsfield Units and The Volume and Void of Canine Struvite Stones as Predictors of Fragility in Extracorporeal Shock Wave Lithotripsy, Journal of Veterinary Clinics, 34(3), 178-184, DOI: 10.17555/jvc.2017.06.34.3.178

Wang J., Hwang T., Jung D., 2017, In vitro Estimation of The Hounsfield Units and The Volume and Void of Canine Struvite Stones as Predictors of Fragility in Extracorporeal Shock Wave Lithotripsy, Journal of Veterinary Clinics, 34(3), 178-184, DOI: 10.17555/jvc.2017.06.34.3.178

Zumstein V., Betschart P., Hechelhammer L., 2018, CT-calculometry (CT-CM): advanced NCCT post-processing to investigate urinary calculi, World Journal of Urology, 36(1),117-123, DOI: 10.1007/s00345-017-2092-7