UNIVERSITY OF MEDICINE AND PHARMACY CRAIOVA
DOCTORAL SCHOOL

PhD THESIS
-ABSTRACT-

THE EFFECTIVENESS OF LOW DOSE COMPUTED TOMOGRAPHY IN THE DIAGNOSIS OF UROLITHIASIS

PhD SUPERVISOR
Prof.univ.dr. ANDREI BONDARI

PhD STUDENT
Dr. MIREALA IONELA RADU (MARIA)

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CT – computed tomography

HU –Hounsfield units

CTDI – weighted CT dose index

DLP – dose length product

E – effective dose

ESWL – extracorporeal shock wave lithotripsy

Gy - Gray

kV – kilovolts

mAs – milliampere/second

MDCT – multi detector computed tomography

MIP – maximum intensity projection

MPR – multiplanar reconstructions

NLP – percutaneous nephrolithotomy

P - pitch

RI – reconstruction interval

RRVS – KUB X-ray

SC – section collimation

SSD – smooth signed distance surface reconstructions

Sv - Sievert

TF – table feed

UIV – intravenous urography

URSR – retrograde ureteroscopy

VRT – volume rendering technique

INTRODUCTION

Urinary lithiasis is currently an important health problem worldwide. It is estimated that the prevalence in the general population reaches 2-3% and that the relapse rate in a lifetime is approximately 50%. The apparent increase in the incidence may be the result of real growth, but also of the detection of asymptomatic stones due to more efficient imaging investigations.

In the current diagnostic protocol of pacients with suspected renal colic there is a tendency to use computed tomography as a first line investigation. This imaging investigation is much used due to its high sensitivity and specificity, being recommended by most authors.

Computed tomography performed in these patients brings valuable data in the setting of diagnostic elements such as, firstly, determining the presence of the calculus and establishing its location or dimensions. This data guides the clinician in determining the therapeutic conduct. KUB x-rays and abdominal ultrasound are used as classical methods of diagnosis, but they can not always help to clarify the diagnosis.

Given that currently, the number of CT investigations increases and therefore the risk that patients receive a high dose of radiation throughout life is higher, the tendency is to minimize the doses applied using low-dose CT.

The objective of this paper was to assess the performance of low-dose CT technique in diagnosing urolithiasis. I am grateful for the support given to me in developing this thesis to my science leader, Prof. Univ. Dr. Andrei Bondari, whose extensive training and professional experience is an example for any initiated in medical practice.

I. Current state of knowledge

Urinary lithiasis is a disease known ever since antiquity, and its prevalence is between 2% and 3% [1], the probability for a man to develop calculi until the age of 70 being of 1 to 8 [2]. The incidence of urolithiasis was about three times higher in men compared to women, lately the ratio reaching 1.7: 1 [3].

Native CT has become the standard method for evaluating flank pain and suspected urolithiasis [4]. The sensitivity and specificity of native CT is 97, respectively 96% [5].

Multiple detector computed tomography (MDCT) is the latest progress made in CT technology. It uses a multiple detector array instead of a single detector array as in spiral CT scan [6]. This new CT scanners, which have low rotation time (0.5 seconds at 360 degrees rotation), allow a scan of 2 to 25 times faster than a spiral CT, while producing just as good images [7, 8].

Non-contrast spiral computed tomography is widely used to assess the kidneys and the urinary collecting system, in particular for the detection of urinary calculi. Multiple detector computed tomography has certain advantages, among them, the fact that images can be produced in multiple stages of renal parenchyma contrasting as well as in the excretory phase after administrating a single dose of contrast agent [8].

In patients with a body mass index (BMI) lower than 30, the low dose CT has been shown to have a sensitivity of 86% for detection of stones smaller than 3 mm, and 100% for those greater than 3 mm [9]. A meta-analysis of prospective studies showed that low-dose CT scan diagnosed kidney stones with a cumulative sensitivity of 96.6% and a specificity of 94.9% [10]. The risk of radiation can be reduced through the use of low dose CT examinations [11].

At the level of the skin, mucous membranes, bone marrow and spermiogenesis, cell renewal rate is increased, but there is a rapid reduction of mitosis after irradiation. At doses under 1-2 Sv, the reduction of the mitosis rate is reversible. A few hours after exposure to radiation in the range mentioned there is an increase of the capacity of mitosis, whereas at higher doses, these processes are irreversible [12]. In consequence, the cell proliferation reduces while the natural apoptosis goes on. Whole body irradiation at doses of 2 Sv or higher, results in marked changes in bone marrow, so that there is a decrease in blood cells in the periphery [13].

II. The importance of the addressed problem

The incidence of urolithiasis is growing, more individuals requiring investigation and surgical treatment for stone disease. This is reason for trying to find more complete and rapid methods of diagnosis and provide the best possible prediction of future therapeutic measures, in order to streamline and reduce the cost of treating these patients. CT scanning is currently considered the standard imaging investigation for diagnosis of urolithiasis, providing accurate information about the size, location and, very importantly, the density of calculi (hardness), measured in Hounsfield units (HU).

CT is used to differentiate radiolucent filling defects by using density measurement in Hounsfield units, so that it can differentiate stones from tumors or clots [14]. The ability to detect differences in density up to 0.5% is tried to be used to determine the composition and the fragility of urinary calculi [15].

Given that currently, the number of CT investigations increases and therefore the risk that patients receive a high dose of radiation throughout life is higher, the tendency is to minimize the doses applied using low-dose CT.

So we compared the effectiveness of the two computed tomography techniques, their effectiveness being reported to a diagnosis of certainty obtained by the urologist after specific therapuetic act. As I stated above, this objective can lead to kidney stones diagnosis being obtained by applying low radiation dose, the clinician being able to further find the treatment method from which he will have the greatest benefit.

We started from the premise in the current diagnostic protocol of pacients with suspected renal colic there is a tendency to use computed tomography as a first line investigation. This imaging investigation is much used due to its high sensitivity and specificity, being recommended by most authors.

Computed tomography performed in these patients brings valuable data in the setting of diagnostic elements such as, firstly, determining the presence of the calculus and establishing its location or dimensions. This data guides the clinician in determining the therapeutic conduct. KUB x-rays and abdominal ultrasound are used as classical methods of diagnosis, but they can not always help to clarify the diagnosis.

III. Study objectives

This study, entitled " The effectiveness of low-dose computed tomography in the diagnosis of urolithiasis", has as first objective the assessment of the accuracy of the technique called low-dose computed tomography compared with standard radiation doses applied, in the diagnostic protocol for patients with suspected renal colic.

IV. Material and methods

The retrospective study conducted during October 2012-March 2013, evaluated 150 patients diagnosed with urolithiasis who were further treated in the urology department of St. Antonius Hospital Kleve.

Patients were divided into two groups, depending on the diagnostic method used: 82 patients were in group A (who underwent low-dose CT) and 87 patients were in group B (who underwent standard native CT). There were 19 patients who underwent both methods if low dose CT scan was negative.

The study included patients who had suspected ureteral lithiasis or ultrasound suggestive of obstructive pathology, hydronephrosis and / or hydroureter. We used a Siemens SOMATOM Emotion 16 CT Scanner to performe standard dose or low-dose CT examinations in all patients.

In patients who underwent standard CT, 5 mm sections were obtained (pitch 1), table speed being 5 mm per second, using 130 kV and 120mAs. In patients who underwent low-dose CT features of the investigation were: 5 mm section thickness, pitch 1.25, 130 kV tube potential and tube load 30 mAs per rotation. This latter parameter is calculated as: 75mA x 0.5 s / 1.25 = 30 mAs.

Calculation of effective dose, according to data provided by the manufacturer for the used CT scan, radiation dose was estimated using the weighted CT dose index nCTDIw in air of 0.07 mGy / mAs at 120 kV. Radiation exposure was calculated as follows:

DLP (mGy x cm) = CTDI vol × L, where DLP is dose length product, CTDI vol is the volume CT dose index and L is the total length of the scan.

Primary and statistical analysis of the data was performed using MS Excel software and MedCalc 10.2 (MedCalc Software bvba, Belgium).

We conducted these methods of investigation and treatment taking into account ethical and professional principles of the Helsinki Declaration of Human Rights, the most important factors taken into account the wellbeing and safety of subjects. All subjects have agreed to voluntary participation, as presented.

V. Results

a. Epidemiological data

During the 12 months study, which took place between October 2012 and March 2013, there were included a total of 150 patients who underwent CT examinations, 136 being diagnosed with renal or ureteral stones in the St. Antonius Hospital Kleve.

Following epidemiological analysis statistically significant differences between the two study groups regarding mean age, distribution by age, sex, origin or urological history were not identified. All these data can be seen in Table 1.

Category	Group A (n=82)	Group B (n=87)	Differences
Age [years]	50.2±14.8	50.7±14.8	p = 0.9629 (ns)
Sex ratio (B:F)	2.15:1	1.17:1	p = 0.1635 (ns)
Urban [%]	56.7	43.3	p = 0.6637 (ns)
Medical history [%]	44.2	55.8	p = 0.3203 (ns)

Table 1. Epidemiological data of patients within the two groups

b. Clinical data

From the clinical point of view, of the total 150 patients, 73 (48.7%) presented with pain, 45 (30%) had renal colic, 38 patients (25.3%) had macroscopic hematuria, 22 patients (14.7%) had diffuse abdominal pain, and a total of 21 patients (14%) presented after having performed a routine ultrasound for detection of other diseases.

Renal ultrasound proved to be remarkably effective in highlighting calculi in the 99 patients with kidney stones , the examination being suggestive in 83 of the 99 cases - Sn = 83.8%.

Of the 82 patients who underwent low dose CT, 68 patients had renal and ureteral calculi and only 63 were diagnosed by this method, which means a sensitivity (SN) of the method of 92.6%. Regarding patients diagnosed by CT with standard doses, of the total 87 patients, 73 were diagnosed with urolithiasis, Sn = 100%, the remaining 14 patients had other conditions and did not have any calculi.

c. CT data

By all 136 patients diagnosed with renal and ureteral stones size, location, specific calculus density, body mass index (BMI), the duration of the procedure, the radiation dose received by the patient were analyzed. All these parameters were analyzed separately and correlated with the results of the diagnostic method used.

Regarding the location of calculi, of the 136 patients, 62 (45.6%) had right urolithiasis and 74 patients (54.4%) had a calculus on the left side. 39 patients (28.7%) had pyelic calculi, 18 (13.2%) had upper calyceal calculi, 17 patients (12.5%) had middle calyceal calculi and 25 patients (18.4%) had lower calyceal calculi. 37 patients (27.2%) presented with ureteral stones.

In the 63 patients who underwent low dose CT, the average calculus size was 11.8±3.8 mm, and in the 73 patients who underwent standard CT was 10.7 ± 3.9 mm, without statistical significance (p = 0.1086 p Student), Figure 1.

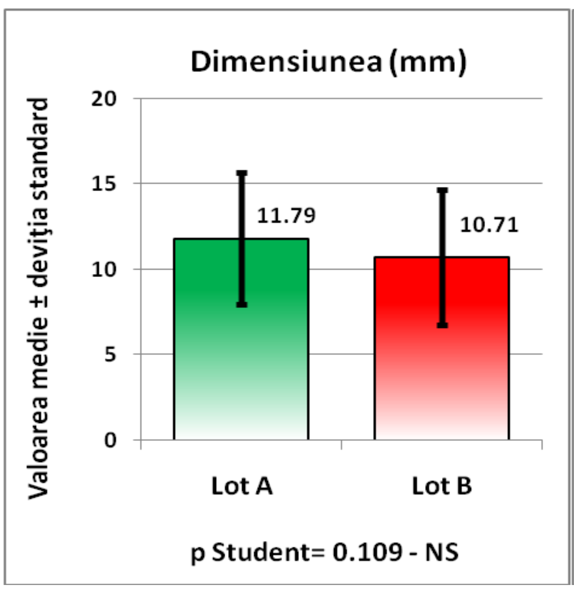


Figure 1. Comparison of the two groups depnding on the calculus size

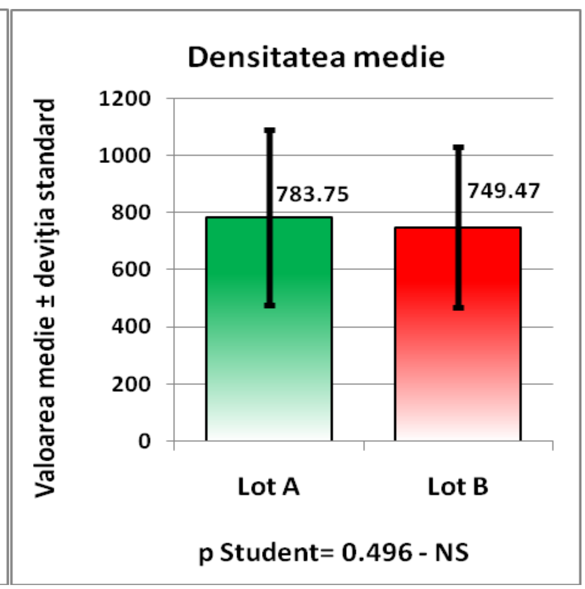


Figure 2. Comparison of the two groups depending on the specific calculus density

For the 136 patients diagnosed with urolithiasis the density of the calculi was 765.3 ± 291.6 HU, while in group A the calculus density was 783.7 ± 305.5 HU, while in group B the calculus density was 749.5 ± 280.2 HU with no statistically significant differences (p = 0.496, p Student) ,data that can be seen in Figure 2.

We emphasized that the weights of the patients investigated using the "low dose" method (27.34 kg / m²) are substantially lower than those of patients investigated using the standard method (29.46 kg / m²), this result being consistent with data from the literature. The difference between the mean values of BMI is highly significant, Student test p <.001.

In patients diagnosed using low dose CT, procedure duration was 11.15 ± 2.2 min, greatly reduced compared to standard CT scan duration 19.59 ± 2.6 min (p <0.001), Figure 3.

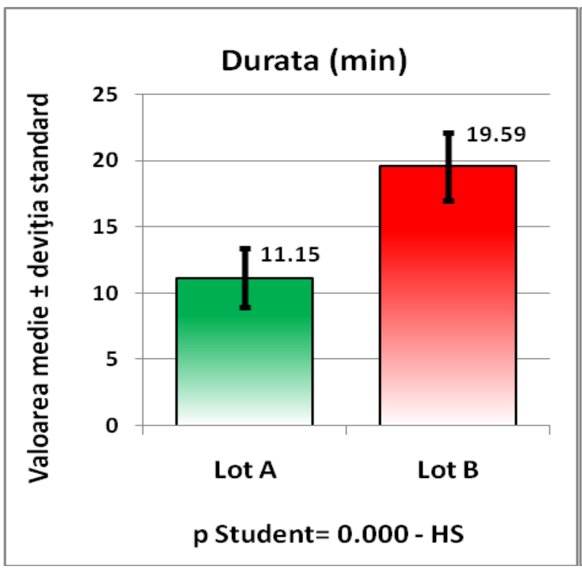


Figure 3. Comparison of the two groups according to the duration of the examination

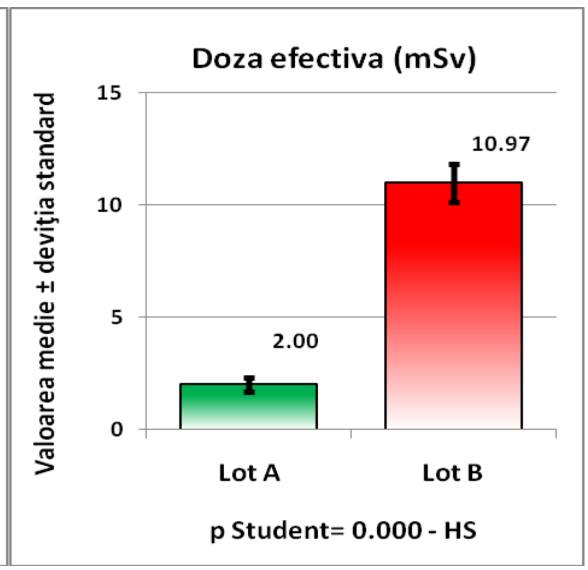


Figure 4. Comparison of the two groups on the basis of the effective dose

Doza efectivă de iradiere aplicată prin metoda “low dose” este în mod înalt semnificativ mai scăzută decât doza utilizată prin metoda standard, rezultatul obținut prin testul t Student fiind p <0,001. Pentru lotul A aceasta a fost 2±0.3, iar pentru lotul B a fost 10.9±0.9, toate aceste rezultate pot fi observate în Figura 4.

The effective radiation dose applied using the low dose method is highly significant lower than the one applied using the standard method, the result obtained by the Student t-test $p < 0.001$. For group A it was 2 ± 0.3 and for the batch B was 10.9 ± 0.9, these results can be seen in Figure 4.

d. Low dose and standard CT examinations

In this section I will present a series of computed tomography images of both groups surveyed, which were analyzed for diagnosis.

In Figure 5 native low dose CT (289 DLP) reveals pelvicalyceal dilatation grade II on the right and the presence of a distal, intramural calculus on the same side in a patient who presented with specific symptoms of obstructive uropathy and positive ultrasound.

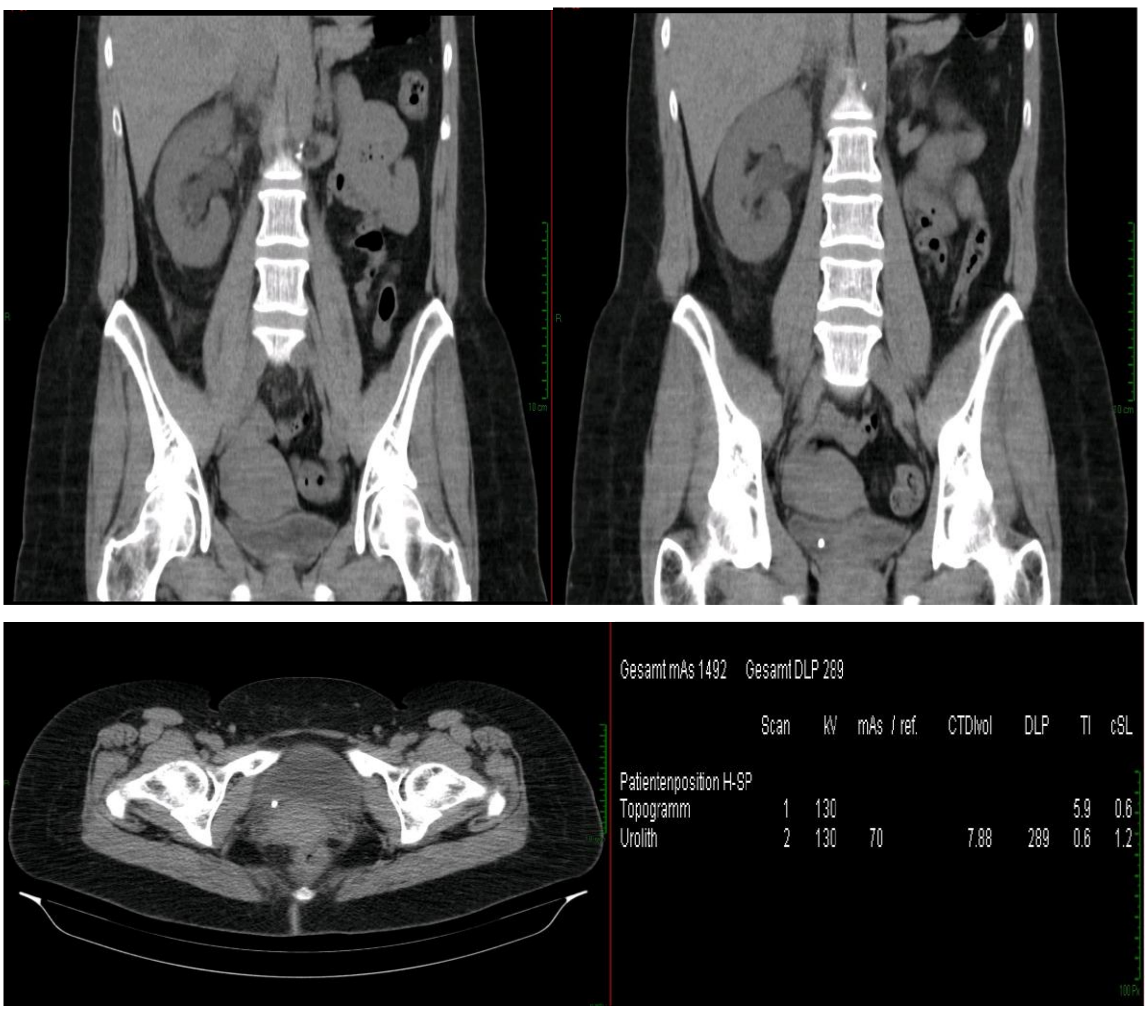
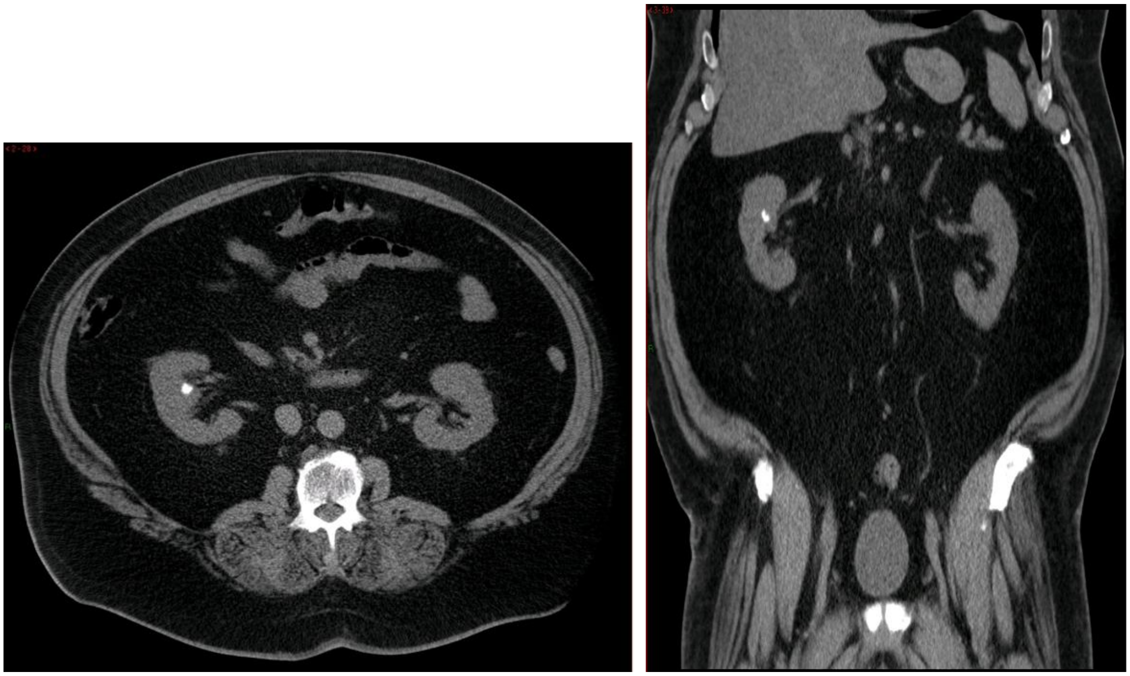
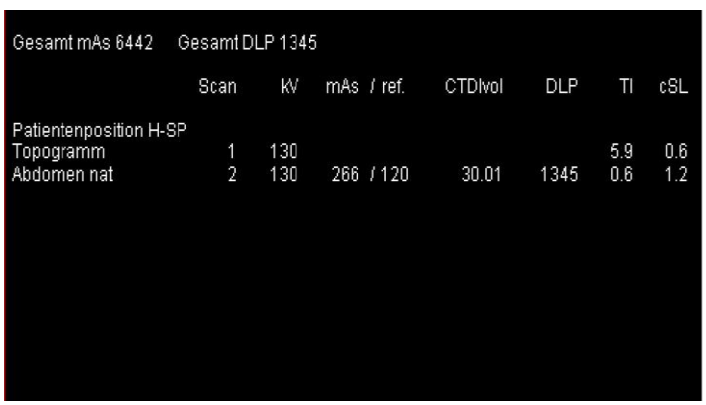


Figure 5. Native low dose CT (289 DLP) - pelvicalyceal dilatation grade II on the right and distal intramural calculus on the same side

In Figure 6, native standard dose CT (DLP 1345), conducted as first line investigation from a patient with BMI> 33, reveals calcification in the right upper calyceal group, possible aspect of calculus. As a differential diagnosis we considered parenchymal calcification.





Gesamt mAs 6442 Gesamt DLP 1345

	Scan	kV	mAs / ref.	CTDIvol	DLP	TI	cSL
Patientenposition H-SP							
Topogramm	1	130				5.9	0.6
Abdomen nat	2	130	266 / 120	30.01	1345	0.6	1.2

Figure 6. Native standard dose CT (DLP 1345) - calcification in the right upper calyceal group (calculus, DD: parenchymal calcification)

VI. Discussion

As multi-detector CT devices were developed in the early 2000s, manufacturers have turned their attention to the radiation dose. The question that the risk of malignancy may increase in children who underwent CT was raised [16, 17].

Focal spot tracking: techniques with improved control of the movement of the focal spot of the X-ray tube and the beam collimation, improve the efficiency of the scanner (overbeaming is reduced because the beam is stabilized on the detectors which allow an X-ray exposure profile narrower than the profile of the detected x-ray and radiation dose associated with multidetector row CT is reduced) [18].

CT is a significant source of irradiation of the population and accounts for more than 40% of the medical cause radiation [19].

The software of recent scanners allow the doses to be reduced by lowering tube current [20, 21].

The effective radiation dose is directly proportional to the tube current (mA) and therefore increases linearly with the tube current. The relationship between the effective dose and the tube potential (kV peak) is non-linear and more complex because at high peak values of kV more X-rays pass through the body and cause less absorption [22]. The relationship between pitch and radiation dose is different for normal CT and MDCT. In MDCT systems, measured radiation doses are the same for all the sections [23]. Keeping the noise level constant tube current must be increased to compensate for the higher pitch. The effective radiation dose is independent of the pitch at a constant noise level [24]. Alternatively, for single-slice helical CT if pitch increases, the measured radiation dose decreases [25].

There are two alternative ways to reduce the dose applied to the patient; one assumes that the examiner selects the most optimal parameters and protocols for all CT examinations. For example, reducing the mAs value allows the detection of most calculi with lower radiation doses [26], but performing multiple sets with small collimators significantly increase radiation. Given that patients with urolithiasis are relatively young and not suffering from malignancies, any radiological investigation should try to limit the dose of radiation and to be performed only if clearly indicated.

Another option for reducing radiation applied to the patient is to develop effective systems for the dosage of radiation. To this end automatic tube current modulation was applied. This system allows you to adjust the tube current along the x and y axes (angular modulation) or along the z-axis (z-axis modulation) appropriate to the size and attenuation characteristics of the segment undergoing the scan, thus obtaining quality images with reduction of the CT dose [21]. Using this method the initial results show a decrease of 20-60%, depending on the anatomical region scanned, with increased image quality [21]. It is important to assess the benefit versus risk in patients receiving any imaging study or CT guided procedure to avoid unnecessary exposure to radiation [27]. Initial studies indicate that the MDCT allow optimum adjustment of the imaging parameters in order to reduce the radiation applied to the patient.

VII. Conclusions

- This paper addresses a current topic of great interest, which combines clinical and laboratory aspects, of particular importance due to the large number of cases, the increased possibility of adverse developments, providing a real public health problem.
- Computed tomography detects more small calculi than traditional methods.
- Whatever the size of the calculi, the examination duration using the "low dose" method is lower than the standard method examination and it is not influenced by the size of the calculi for either method.
- The only statistically significant difference between the two groups in terms of the location of ureteral calculi was for the ureteral location, standard CT scan revealing more calculi than the low dose CT ($p < 0.05$).
- Irrespective of the calculus density, the examination duration using the "low dose" method is much lower than the standard method examination, the examination duration not being influenced by the calculus density for either method.
- In patients with reno-ureteral lithiasis and BMI >30, standard-dose CT examination is recommended as a first line investigation in order to avoid false negative results.
- In patients diagnosed using low dose CT procedure duration was much lower compared with standard CT scan duration ($p < 0.001$).
- The effective dose of radiation applied by using the "low dose" method is highly significantly lower than the dose used by the standard method ($p < 0.001$).
- Low dose CT has high specificity and sensitivity, without differences from the standard CT, and can be repeated without the harmful effects of cumulative doses.
- Low-dose CT was performed using 30mA and has a sensitivity and specificity similar with standard-dose CT performed using 120 or 180 mA being of high value in the correct identification of calculi and for alternative diagnoses.
- We recommend using low-dose CT scans as standard method for the diagnosis of patients with suspected urolithiasis.

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