World Journal of Nephrology

Submit a Manuscript: http://www.wjgnet.com/esps/
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
DOI: 10.5527/wjn.v3.i4.282

*World J Nephrol* 2014 November 6; 3(4): 282-286
ISSN 2220-6124 (online)


MINIREVIEWS

# Usefulness of hounsfield unit and density in the assessment and treatment of urinary stones

Adnan Gücük, Uğur Üyetürk

Adnan Gücük, Uğur Üyetürk, Department of Urology, Faculty of Medicine, Abant Izzet Baysal University, 14280 Bolu, Turkey
Author contributions: Gücük A performed majority of experiments and designed, wrote the manuscript; Üyetürk U provided vital reagent and analytical tools.
Correspondence to: Dr. Adnan Gücük, Associate Professor, Department of Urology, Faculty of Medicine, Abant Izzet Baysal University, Gölköy Kampüsü, 14280 Bolu, Turkey. gucukadnan@hotmail.com
Telephone: +90-505-6748193 Fax: +90-374-2534615
Received: June 22, 2014 Revised: July 24, 2014
Accepted: September 6, 2014
Published online: November 6, 2014

## Abstract

Computed tomography (CT) is widely used to examine stones in the urinary system. In addition to the size and location of the stone and the overall health of the kidney, CT can also assess the density of the stone in Hounsfield units (HU). The HU, or Hounsfield density, measured by CT, is related to the density of the tissue or stone. A number of studies have assessed the use of HU in urology. HUs have been used to predict the type and opacity of stones during diagnosis, and the efficacy has been assessed using methods including extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), ureterorenoscopic ureterolithotripsy (URSL), and medical expulsive treatment (MET). Previous studies have focused on the success rate of HU for predicting the type of stone and of ESWL treatment. Understanding the composition of the stone plays a key role in determining the most appropriate treatment modality. The most recent reports have suggested that the HU value and its variants facilitate prediction of stone composition. However, the inclusion of data regarding urine, such as pH and presence of crystals, increases the predictive accuracy. HUs, which now form part of the clinical guidelines, allow us to predict the success of ESWL; therefore, they should be taken into account when ESWL is considered as a treatment option. However, there are currently insufficient data available regarding the value of HU for assessing the efficacy of PCNL, URSL, and MET. Studies performed to date suggest that these values would make a significant contribution to the diagnosis and treatment of urinary system stones. However, more data are required to assess this further.



**Key words:** Hounsfield unit; Urinary stones

**Core tip:** Hounsfield units provide information not only for the diagnosis of urinary system tumors but also regarding a number of properties of urinary stones. Computed tomography is currently used most commonly to predict the type of stone and assess the potential efficacy of extracorporeal shock wave lithotripsy treatment. However, it might also assist urologists to decide which of percutaneous nephrolithotomy, ureterorenoscopic ureterolithotripsy, and medical expulsive treatment should be used to treat a patient.

Gücük A,Üyetürk U. Usefulness of hounsfield unit and density in the assessment and treatment of urinary stones. *World J Nephrol* 2014; 3(4): 282-286 Available from: URL: http://www.wjgnet.com/2220-6124/full/v3/i4/282.htm DOI: http://dx.doi.org/10.5527/wjn.v3.i4.282

## INTRODUCTION

In recent years, the use of helical non-contrast computed tomography (CT) in patients with urinary system stones has increased. Hounsfield units (HU), a parameter generated from standard CT, are related to the density of the stone or structure of interest.

Sir Godfrey Newbold Hounsfield first introduced

**Table 1 Some critical hounsfield unit values in recent literature**

| | Ref. | Year | Hounsfield units | Affected parameters |
|---|---|---|---|---|
| Prediction of stones | Motley *et al*[4] | 2001 | Density < 76 /mm | Non-calcium stone |
| | Patel *et al*[5] | 2009 | Mean, 879 ± 230 | Calcium oxalate monohydrate stone |
| | | | Mean, 844 ± 346 | Apatite stone |
| | | | Mean, 550 ± 74 | Cystine stone |
| | Spettel *et al*[7] | 2013 | < 500 | Uric acid stone |
| Prediction of Radio-opacity | Chua *et al*[9] | 2012 | > 498.5 | Radio-opaque stone |
| | Huang *et al*[10] | 2009 | > 800 (ureteral stones) | Radio-opaque |
| | | | < 200 | Radiolucent |
| Predicting the success of ESWL | Hameed *et al*[15] | 2013 | > 1350 | Low ESWL success |
| | El-Assmy *et al*[16] | 2011 | > 1000 | Low ESWL success |
| | El-Assmy *et al*[17] | 2013 | ≤ 600 and stone length ≤ 12 mm (in children) | High ESWL success |
| | Ouzaid *et al*[18] | 2012 | > 970 | Low ESWL success |
| | Foda *et al*[19] | 2013 | > 934 | Low ESWL success |
| Use in PNL | Gücük *et al*[20] | 2012 | < 677.5 | Low PNL success |
| | Gücük *et al*[21] | 2013 | < 677.5 | Increases success with flexible nephroscope use |
| Use in URS | Kim *et al*[22] | 2014 | Any | No effect |
| Medical expulsive treatment | Erturan *et al*[24] | 2013 | Any | No effect |

ESWL: Extracorporeal shock wave lithotripsy.

the principle to quantify the amount of X-rays that pass through or are absorbed by tissues, and developed the resulting radiodensity scale. CT images are made up of pixels, each of which has a gray scale value from 1 (black) to 256 (white). This value corresponds to the amount of X-rays that pass through the structure, and can be measured and expressed in Hounsfield units (HU). HU have since been used to evaluate and quantify tissues and fluids. When the radiodensity of water is defined as 0, fat has a negative HU, and blood and other tissues have a positive HU. Using this method it is possible to differentiate 256 shades of gray that are indistinguishable to the naked eye[1].

HU can also be used to assess the CT density of urinary system stones. In recent years, this has become an important diagnostic tool, not only for predicting the type of stone but also for determining the appropriate mode of treatment. The aim of this review is to assess the various areas in which HU is used to diagnose and treat urinary system stones (Table 1).

## THE ROLE OF HU IN PREDICTING THE TYPE OF STONE

Understanding the composition of urinary system stones is critical for determining the optimal mode of treatment. Urine pH, the presence of crystals, urease-positive bacteria in urine, plain radiographs, and a history of urinary stones have long been used to predict the composition of stones; recently, HU also was used for this purpose[2]. Mostafavi *et al*[3] performed an *in vitro* study and reported that stone composition could be predicted with high accuracy using HU. Motley *et al*[4] attempted to determine stone composition using HU density, calculated by dividing HU by the greatest transverse diameter of the stone (in mm), and suggested that HU density was more effective than HU alone. However, the authors also reported that neither HU value nor density was sufficient for determining stone composition *in vivo*[4].

Patel *et al*[5] investigated whether HU values could be used for differentiating among subtypes of calcium stones, and reported they were particularly useful for diagnosing calcium oxalate monohydrate and dihydrate stones. In a similar study, the authors reported that calcium stones could be identified with high accuracy using HU values, but that there was an overlap between the HU values of cystine and uric acid stones, making it difficult to differentiate these types of stones[6].

Spettel *et al*[7] designed an *in vivo* study to predict uric acid stones using urine pH and HU, and argued that using the two parameters together were more effective for predicting uric acid stones than either one alone. Specifically, for a stone > 4 mm a HU ≤ 500 and pH ≤ 5.5 had a positive predictive value of 90% for uric acid composition[7]. To elucidate whether the composition of struvite stones could be predicted using HU values, Marchini *et al*[8] reported that the HU values of pure and mixed struvite stones overlapped, and concluded that struvite stone composition could not be accurately predicted by HU.

Recent studies suggested that HU and their variants are useful for predicting the composition of stones. However, they were insufficient for certain types of stone; the use of urinary parameters improved the accuracy in such cases.

## THE ROLE OF HU IN PREDICTING RADIO-OPACITY

Knowing the radio-opacity of urinary system stones affords significant information to urologists for selecting the appropriate treatment and imaging modality to use during follow-up. Nevertheless, the relationship between the range/threshold of the HU values of stones measured using CT and radio-opacity is poorly understood.

Identifying radiolucent stones using CT has the advantage of preventing unnecessary radiographies during follow-up, preventing exposure to radiation, lowering anxiety, and reducing costs. Chua *et al*[9] also assessed the predictive potential of the radio-opacity of stones identified using plain radiographs and HU values. They examined 184 cases, and calculated that 498.5 HU was the appropriate cut-off value for determining if a stone > 4 mm was radio-opaque or radiolucent, with 89.3% sensitivity and 87.3% specificity[9]. Huang *et al*[10] performed a study that also included ureteral stones, and reported that stones of HU > 800 were visible on plain radiographic images, whereas those with a density < 200 HU were not. Taken together, data assessing the relationship between HU values and radio-opacity suggested that the follow-up of certain groups of patients could be performed adequately using plain radiographs rather than repeated CT examinations, reducing the time, cost, and exposure to ionizing radiation.

## THE ROLE OF HU IN PREDICTING THE SUCCESS OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY TREATMENT

Extracorporeal shock wave lithotripsy (ESWL) can successfully eliminate approximately 90% of renal stones in adults[11]. Successful ESWL depends on the type of lithotripter, and the localization, size, and hardness of the stone[12]. Many previous studies have investigated the relationship between CT parameters and successful ESWL. Data revealed that the energy of the shock wave needed for fragmentation was related to stone density, and that the higher the stone density, the stronger the shock wave energy needed to achieve fragmentation[13,14].

Hameed *et al*[15] reported that successful fragmentation using ESWL was decreased in stones with HU > 1350, which required application of more shock waves. El-Assmy *et al*[16] used the Hounsfield value of the stones to predict stone composition and density, and the fragmentation success using ESWL, and selected HU > 1000 as their cut off value. Another study of pediatric patients by the same group revealed that stones ≤ 600 HU and ≤ 12 mm in length were significant independent predictors of SWL success in children[17].

Ouzaid *et al*[18] performed a prospective study on 50 patients, and reported that a HU threshold of 970 was predictive of successful ESWL. Specifically, the stone-free rate was 96% and 38% with HU < 970 and > 970, respectively[18]. Foda *et al*[19] demonstrated that stone disintegration failed if the stone density was > 934 HU; therefore, they did not recommend ESWL in this group of patients.

Taken together, the available data suggest that the HU value, a parameter that is incorporated into clinical guidelines and enables prediction of successful ESWL, should be considered when making decisions regarding the use of ESWL.

## THE ROLE OF HU IN PERCUTANEOUS NEPHROLITHOTOMY

Fluoroscopic imaging has been widely used during percutaneous nephrolithotomy (PCNL) operations to facilitate access to the collector system and renal anatomy, determine the placement of surgical tools, and identify and extract residual stones. The accurate assessment of post-operative residual stones significantly reduces morbidity. However, identifying residual stones using fluoroscopy depends largely on the size and opacity of the stone. In contrast, CT is an effective imaging tool for identifying all but indinavir stones. In addition, it allows the opacity of the stones to be quantified using HU. The HU value of stones affects the outcome of PCNL operations. Gücük *et al*[20] investigated the effects of certain parameters, including HU, on the outcome of 179 PCNL patients, and concluded that the HU value was an independent factor that affected the success of PCNL. Specifically, an HU value < 677.5 reduced the success of PCNL by 2.65-fold. The authors also reported a positive relationship between HU value and hemorrhage, and explained that this was associated with an increased frequency of endoscopic manipulation to extract residual stones. The identification of residual stones became easier with increasing HU value, and a higher HU value was also associated with increased renal trauma as a result of the higher energy required to breakdown stones[20]. The same group assessed the efficacy of routine flexible nephroscopic examination for identification and treatment of residual stones during PCNL operations, and reported that flexible nephroscopy was more effective in stones with low compared with high HU values. They suggested that this might be because flexible nephroscopy is used more commonly than fluoroscopy because stones with a low HU cannot be identified using fluoroscopy[21].

Although limited data are available regarding the association between HU and percutaneous nephrolithotomy, we conclude that consideration of HU values in patients scheduled for PCNL might assist selection of the appropriate treatment procedures and improve success rates.

## THE ROLE OF HU IN URETEROSCOPIC LITHOTRIPSY

Ureteroscopic lithotripsy (URSL) is an important treatment modality for ureteral stones that is currently used for stones of all sizes present in any location within the ureter. The size and location of the stone are the prime factors that determine the success of URSL. However, it remains unclear whether HU is a determinant of URSL success. The only previous study of the relationship between HU value and URSL success was performed by Kim *et al*[22]. They examined the size, location, impaction, and HU value of stones using CT, as well as the effect of these parameters on the success of URSL. Their results revealed that the HU value did not affect the success of treatment using URSL[22]. However, this study failed to assess several important parameters, such as the duration of the operation and of lithotripsy. As with ESWL, more energy might be needed and/or the procedure might be prolonged to fragment stones with a high HU using URSL. Therefore, further studies are required to elucidate whether higher energy and/or prolonged treatment are needed to successfully fragment stones with high HU values, and to identify any associated complications.

## THE ROLE OF HU IN MEDICAL EXPULSIVE TREATMENT

Medical expulsive treatment (MET) is commonly used to facilitate the passage of ureteral stones in the absence of severe renal colic, infection, and obstruction. The spontaneous passage ratio can be as high as 98%, particularly in stones smaller than 5 mm. The most important factors that affect spontaneous passage are the size and location of the stone[23]. Erturhan *et al*[24] assessed the effect of HU value on the success of MET. This study, the only current report assessing this relationship, demonstrated that stones with a high HU would pass through the ureter slowly and with difficulty because of their compact structure. They compared two groups of stones with mean HU values of 625 and 507, and concluded that HU could not be used to predict the likelihood of success for MET[24]. However, that study included two groups in which the HU values were similar. As such, additional studies including stones with a wider range of HU values would make a significant contribution to current knowledge. Nevertheless, the available data suggest that HU values do not provide any additional benefit to MET.

## CONCLUSION

Previous studies have revealed the benefit of HU values, parameters obtained from CT scans, on ESWL treatment and predicting the composition of urinary system stones. HU measurements now form part of the clinical guidelines because of the lower success rate of ESWL treatment of high HU stones[11]. Although HU is currently used most commonly during ESWL treatment and for prediction of stone composition, current data suggest that it could be used in other treatment modalities as our knowledge increases.

## REFERENCES


1 CT Teaching Manual. Edited by Hoffer M. Verlog, Berlin: Springer; 2007

2 **Ramakumar S**, Patterson DE, LeRoy AJ, Bender CE, Erickson SB, Wilson DM, Segura JW. Prediction of stone composition from plain radiographs: a prospective study. *J Endourol* 1999; **13**: 397-401 [PMID: 10479003 DOI: 10.1089/end.1999.13.397]

3 **Mostafavi MR**, Ernst RD, Saltzman B. Accurate determination of chemical composition of urinary calculi by spiral computerized tomography. *J Urol* 1998; **159**: 673-675 [PMID: 9474123 DOI: 10.1016/S0022-5347(01)63698-X]

4 **Motley G**, Dalrymple N, Keesling C, Fischer J, Harmon W. Hounsfield unit density in the determination of urinary stone composition. *Urology* 2001; **58**: 170-173 [PMID: 11489691 DOI: 10.1016/S0090-4295(01)01115-3]

5 **Patel SR**, Haleblian G, Zabbo A, Pareek G. Hounsfield units on computed tomography predict calcium stone subtype composition. *Urol Int* 2009; **83**: 175-180 [PMID: 19752613 DOI: 10.1159/000230020]

6 **Torricelli FC**, Marchini GS, De S, Yamaçake KG, Mazzucchi E, Monga M. Predicting urinary stone composition based on single-energy noncontrast computed tomography: the challenge of cystine. *Urology* 2014; **83**: 1258-1263 [PMID: 24726314 DOI: 10.1016/j.urology.2013.12.066]

7 **Spettel S**, Shah P, Sekhar K, Herr A, White MD. Using Hounsfield unit measurement and urine parameters to predict uric acid stones. *Urology* 2013; **82**: 22-26 [PMID: 23688376 DOI: 10.1016/j.urology.2013.01.015]

8 **Marchini GS**, Gebreselassie S, Liu X, Pynadath C, Snyder G, Monga M. Absolute Hounsfield unit measurement on noncontrast computed tomography cannot accurately predict struvite stone composition. *J Endourol* 2013; **27**: 162-167 [PMID: 22974047 DOI: 10.1089/end.2012.0470]

9 **Chua ME**, Gatchalian GT, Corsino MV, Reyes BB. Diagnostic utility of attenuation measurement (Hounsfield units) in computed tomography stonogram in predicting the radio-opacity of urinary calculi in plain abdominal radiographs. *Int Urol Nephrol* 2012; **44**: 1349-1355 [PMID: 22581423 DOI: 10.1007/s11255-012-0189-x]

10 **Huang CC**, Chuang CK, Wong YC, Wang LJ, Wu CH. Useful prediction of ureteral calculi visibility on abdominal radiographs based on calculi characteristics on unenhanced helical CT and CT scout radiographs. *Int J Clin Pract* 2009; **63**: 292-298 [PMID: 19196367 DOI: 10.1111/j.1742-1241.2008.01861.x]

11 **Miller NL**, Lingeman JE. Management of kidney stones. *BMJ* 2007; **334**: 468-472 [PMID: 17332586 DOI: 10.1136/bmj.39113.480185.80]

12 **Türk C**, Knoll T, Petrik A, Sarica K, Skolarikos A, Straub M, Seitz C. Guidelines on urolithiasis: European Association of Urology Guidelines, 2014

13 **Gupta NP**, Ansari MS, Kesarvani P, Kapoor A, Mukhopadhyay S. Role of computed tomography with no contrast medium enhancement in predicting the outcome of extracorporeal shock wave lithotripsy for urinary calculi. *BJU Int* 2005; **95**: 1285-1288 [PMID: 15892818 DOI: 10.1111/j.1464-410X.2005.05520.x]

14 **Pareek G**, Hedican SP, Lee FT, Nakada SY. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. *Urology* 2005; **66**: 941-944 [PMID: 16286099 DOI: 10.1016/j.urology.2005.05.011]

15 **Hameed DA**, Elgammal MA, ElGanainy EO, Hageb A, Mohammed K, El-Taher AM, Mostafa MM, Ahmed AI. Comparing non contrast computerized tomography criteria versus dual X-ray absorptiometry as predictors of radio-opaque upper urinary tract stone fragmentation after electromagnetic shockwave lithotripsy. *Urolithiasis* 2013; **41**: 511-515 [PMID: 23907170 DOI: 10.1007/s00240-013-0596-1]

16 **el-Assmy A**, Abou-el-Ghar ME, el-Nahas AR, Refaie HF, Sheir KZ. Multidetector computed tomography: role in determination of urinary stones composition and disintegration with extracorporeal shock wave lithotripsy--an in vitro study. *Urology* 2011; **77**: 286-290 [PMID: 20719366 DOI: 10.1016/j.urology.2010.05.021]

17 **El-Assmy A**, El-Nahas AR, Abou-El-Ghar ME, Awad BA, Sheir KZ. Kidney stone size and hounsfield units predict successful shockwave lithotripsy in children.

*Urology* 2013; **81**: 880-884 [PMID: 23395121 DOI: 10.1016/j.urology.2012.12.012]
18 **Ouzaid I**, Al-qahtani S, Dominique S, Hupertan V, Fernandez P, Hermieu JF, Delmas V, Ravery V. A 970 Hounsfield units (HU) threshold of kidney stone density on non-contrast computed tomography (NCCT) improves patients' selection for extracorporeal shockwave lithotripsy (ESWL): evidence from a prospective study. *BJU Int* 2012; **110**: E438-E442 [PMID: 22372937 DOI: 10.1111/j.1464-410X.2012.10964.x]
19 **Foda K**, Abdeldaeim H, Youssif M, Assem A. Calculating the number of shock waves, expulsion time, and optimum stone parameters based on noncontrast computerized tomography characteristics. *Urology* 2013; **82**: 1026-1031 [PMID: 24044913 DOI: 10.1016/j.urology.2013.06.061]
20 **Gücük A**, Uyetürk U, Oztürk U, Kemahli E, Yildiz M, Metin A. Does the Hounsfield unit value determined by computed tomography predict the outcome of percutaneous nephrolithotomy? *J Endourol* 2012; **26**: 792-796 [PMID: 22201298 DOI: 10.1089/end.2011.0518]
21 **Gücük A**, Kemahlı E, Üyetürk U, Tuygun C, Yıldız M, Metin A. Routine flexible nephroscopy for percutaneous nephrolithotomy for renal stones with low density: a prospective, randomized study. *J Urol* 2013; **190**: 144-148 [PMID: 23313202 DOI: 10.1016/j.juro.2013.01.009]
22 **Kim JW**, Chae JY, Kim JW, Oh MM, Park HS, Moon du G, Yoon CY. Computed tomography-based novel prediction model for the stone-free rate of ureteroscopic lithotripsy. *Urolithiasis* 2014; **42**: 75-79 [PMID: 24162952 DOI: 10.1007/s00240-013-0609-0]
23 **Preminger GM**, Tiselius HG, Assimos DG, Alken P, Buck AC, Gallucci M, Knoll T, Lingeman JE, Nakada SY, Pearle MS, Sarica K, Türk C, Wolf JS. 2007 Guideline for the management of ureteral calculi. *Eur Urol* 2007; **52**: 1610-1631 [PMID: 18074433 DOI: 10.1016/j.eururo.2007.09.039]
24 **Erturhan S**, Bayrak O, Mete A, Seckiner I, Urgun G, Sarica K. Can the Hounsfield unit predict the success of medically expulsive therapy? *Can Urol Assoc J* 2013; **7**: E677-E680 [PMID: 24282456]

**P- Reviewer**: Foda K, Olowu WA, Nowicki S
**S- Editor**: Song XX **L- Editor**: A **E- Editor**: Lu YJ

Published by **Baishideng Publishing Group Inc**
8226 Regency Drive, Pleasanton, CA 94588, USA
Telephone: +1-925-223-8242
Fax: +1-925-223-8243
E-mail: bpgoffice@wjgnet.com
Help Desk: http://www.wjgnet.com/esps/helpdesk.aspx
http://www.wjgnet.com