原著

ORIGINAL ARTICLE

経皮的腎結石破砕術におけるレーザー補助超音波走査法を用いた新しい腎杯針穿刺

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**A Novel Needle Puncture Technique to the Renal Calyx using
Laser-Assisted Ultrasound Scanning (LAUS) Method just
before Percutaneous Nephrolithotomy: Preliminary Report**

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要 旨

正しい経皮的針穿刺は、経皮的腎結石破砕術 (PNL) 成功の鍵を握っている。腎杯円蓋部への針穿刺が安全に施行されれば、その後の操作は比較的容易である。超音波ガイド下穿刺法は、水腎症患者においては、容易に施行可能であるが、水腎症がない症例においては、技術的に困難である。今回、水腎を有しない珊瑚状結石患者において、PNL 直前にレーザー補助超音波走査法を用いた腎杯針穿刺の有用性を検討したので報告する。軟性尿管鏡先端を目的の腎杯に到達させるために、珊瑚状結石に対し軟性尿管鏡により Ho:YAG レーザー結石破砕を行い、結石内に通路を作成した。腎杯内の結石を砂状にレーザー破砕しつつ、超音波ガイド下に経皮的針穿刺を行った。超音波画像上、レーザー破砕により碎片化した結石は腎杯内において粉雪状で高エコーに描出され、針穿刺における良い指標になった。針穿刺後 PNL を行ったが、周術期合併症は認められなかった。PNL 直前におけるレーザー補助超音波走査法を用いた腎杯針穿刺は、特殊な器具を要さないため、水腎症がない症例において安全で安価と考えられた。今後症例を重ねて本法の有用性を検討する予定である。

キーワード：珊瑚状結石、経皮的腎結石破砕術、Ho: YAG レーザー結石破砕術、針穿刺、レーザー補助超音波走査法

Abstract

Percutaneous entry is the initial and most important part of percutaneous nephrolithotomy (PNL). Needle puncture directly into the fornix of a calyx is the safest route of percutaneous entry into the renal collecting system. When the pelvicalyceal system is not dilated, localization and puncture of the specific calyx may require special expertise. Ho:YAG laser lithotripsy was performed

to carve a channel to allow the ureterscope to be passed into the desired calyx occupied with stone. At this point, percutaneous antegrade access to the calyx of interest was obtained using a 21-gauge nephrostomy needle under ultrasonic guidance with a biopsy attachment. Vapor bubbles and fragmented calculi were visualized as hyperechoic moving particles like powder snow in the aimed calyx on the B-mode gray-scale ultrasound monitor during laser firing. The needle was safely inserted into the desired calyx. This novel technique of needle puncture to the renal calyx using laser-assisted ultrasound scanning (LAUS) method is safe and effective, even when the pelvicalyceal system is not dilated. Greater experience and comparison to standard technique are required to determine if this method will be a useful technique in the future.

Key words : staghorn calculus, percutaneous nephrolithotomy, Ho:YAG laser lithotripsy, needle puncture, laser-assisted ultrasound scanning (LAUS) method

1. Introduction

Percutaneous entry is the initial and most important part of percutaneous nephrolithotomy (PNL). Needle puncture directly into the fornix of a calyx is the safest route of percutaneous entry into the renal collecting system. The ultrasonographic approach has the advantages of minimizing radiation exposure and allowing imaging of intervening structures between skin and kidney. The ultrasonic depiction of the dilated calyces is easily obtained. However, when the pelvicalyceal system is not dilated, localization and puncture of the specific calyx may require special expertise¹⁾. Improper site selection can lead to difficulty performing the procedure at best and devastating hemorrhagic complication at worst. The present study investigated the usefulness and safety of laser-assisted ultrasound scanning (LAUS) method in the needle puncture to the renal calyx.

2. Materials and Methods

The patient profile is as follows. BMI is 22.2. Comorbidity is hypertension, diabetes mellitus, hyperlipemia, fatty liver, and artificial anus formation due to ulcerative colitis. No bacteriuria was found. For this 66-year-old man with a radiolucent branched staghorn calculus that involves all calices and no hydronephrosis, we would favor a combined antegrade-retrograde approach with percutaneous access obtained under direct, endoscopic vision to obtain precise placement of a single, middle-pole nephrostomy tract in the modified Valdivia position²⁾. This study used HI VISION AscendusTM ultrasonic diagnostic equipment (HITACHI, Japan) with a 3.5-MHz convex transducer (ECP-B514TM with the biopsy channel in the center of the field of view). This machine sets out dual vision with real-time monitor mode (corresponding virtual CT imaging mode, B-mode) simultaneously.

General anesthesia was administered with monitoring by blood pressure, heart rate and saturation pulse oximetry. The URF-P5TM flexible ureterscope (Olympus, Japan) was advanced into the renal pelvis through the ureteral access sheath. Ho:YAG laser lithotripsy was then performed to carve a channel to allow the ureterscope to be passed into the desired calyx occupied with stone under fluoroscopic vision. The stone in the desired calyx was irradiated and fragmented with 80 W

Fig.1 Schematic drawing of needle puncture technique to the renal calyx using laser-assisted ultrasound scanning (LAUS) method.

Ho:YAG energy (VersaPulse SelectTM, Boston Scientific, USA) using a 200 μ m optical fiber (SlimLineTM, LUMENIS, Israel) at 1.0 J/pulse and 10Hz. At this point, percutaneous antegrade access to the calyx of interest was obtained using a 21-gauge nephrostomy needle under ultrasonic guidance with a biopsy attachment (Fig.1).

3. Results

The hyperechoic moving particles over the tip of the ureterscope provided an excellent ultrasonic target on the B-mode ultrasound monitor during laser firing (Fig.2). The needle was safely punctured into the aimed calyx. The puncture of the nephrostomy needle into the collecting system was monitored under direct ureteroscopic vision (Fig.3). There were no perioperative complications (fever, perforation, neighbor organ injury and blood loss necessitating blood transfusion) of calyceal needle puncture following PNL. The stone was removed completely and composed of uric acid.

Fig.2 Dual vision with real-time monitor mode (virtual CT imaging (left), ultrasound B-mode (right)) simultaneously.

Fig.3 Endoscopic findings of needle penetration into the aimed calyx during Ho:YAG laser lithotripsy.

4. Discussion

The American Urological Association Nephrolithiasis Guideline Panel, in their report on staghorn renal calculi, analyzed all relevant literature from 1992 to 2003 and concluded that PNL should be used as first-line treatment because of an overall stone-free rate of 78%, which was superior to all other methods and had similar rates of complications³⁾. Recently, the utilization of both PNL and ureteroscopy in patients with staghorn stones has been reported to be successful^{4,5)}.

Achieving complete clearance of staghorn calculi in a timely manner, through one percutaneous tract, may be difficult because of caliceal anatomy; often, several tracts have been needed to reach branched stones occupying several calices. Flexible ureteroscopy with lithotripsy just before PNL may obviate the need for multiple access tracts and therefore reduce blood loss. While overall operative time may be similar or even slightly increased with this procedure, the amount of time needed for stone fragmentation after the tract has

been dilated may be reduced⁶⁾. We successfully performed simultaneous PNL and ureteroscopy using Ho: YAG laser lithotripsy in this patient with complete staghorn calculus through one percutaneous tract.

Clinical Ho:YAG laser lithotripsy has become very popular since 1995⁷⁾. Laser parameters have been optimized to a pulse duration of 250 μ sec, with pulse energies ranging from 200 mJ to 2 J and with repetition rate ranging from 5 Hz to 20 Hz. A range of clinical delivery fiber selections is available from 200 μ m to 1000 μ m in core diameter. We chose a standard power setting of 10W in the present study with the use of 200 μ m fiber, which was similar to a common ureteroscopic procedure.

Detailed studies showed that the fragmentation process in Ho:YAG laser lithotripsy was predominantly photothermal secondary to a long pulse duration that significantly reduced the strength of acoustic emission. The vapor bubble produced an open channel that facilitated laser delivery to the calculus surface. Rapid vaporization creates vapor pressure that expands to form a bubble if the laser light is highly absorbed in water. This vapor bubble usually has minimal mechanical effect on hard tissues but rather parts the water (the "Moses effect") for direct deposition of the remaining portion of the laser light on the calculus surface⁸⁾. Vapor bubbles produced at the holmium's fiber tip have been identified with photographs. The size of the vapor bubbles in water depends not only on the energy levels, pulse frequency, and fiber size but also on pulse duration. Dushinski & Lingeman measured that vapor bubble size at 1 J/pulse produced with 200 μ m fiber was about 5 mm in diameter⁹⁾.

Simultaneous puncture and scanning can be performed, enabling needle entry to be monitored from skin into the collecting system in percutaneous nephrostomy using real-time sonographic guidance¹⁰⁾. Using a hand-held 3.5-MHz ultrasound transducer, one inspects the kidney and selects a calyx for percutaneous entry. Needle guides can be placed on the transducer to direct the needle in the plane of visualization of the probe. Some prefer to place the needle freehand instead, moving the transducer around to gain different views of the kidney and needle, and observe the needle as it is advanced until it appears that the tip is within the calyx. In order to ensure an accurate puncture, the needle tip should be seen along the electronic dotted line through its course. The puncture guide helps in directing the needle in the desired plane and depth. The ultrasound probe should be aligned in such a way that the tract provides the shortest access from the skin through the cup of the calyx¹¹⁾. In the present study, vapor bubbles and fragmented calculi were visualized as hyperechoic moving particles like powder snow in the aimed calyx on the B-mode gray-scale ultrasound monitor during laser firing. The needle was safely punctured into the aimed calyx with the hyperechoic moving particles over the tip of the ureteroscope even when the pelvicalyceal system was not dilated. No investigator has reported the ultrasonic depiction during Ho:YAG laser lithotripsy. We named this phenomenon

“the laser-assisted ultrasound scanning (LAUS)”. We believe the elements that shattered sand-like stones and vapor bubbles at the tip of the fiber are the presence of hyperechoic appearance produced during the Ho:YAG laser lithotripsy.

For a complete staghorn stone, the middle calyx is preferable, because it is convenient for an ureteroscope to access the ureter and avoid important renal blood vessels during puncture¹²⁾. When there is no hydronephrosis, the balloon dilator is usually used to occlude the ureter, and the pyelocaliceal system is distended using saline injection. Our method is cost-effective because of eliminating the need for an occlusion balloon dilator and requires no patient repositioning prior to PNL in the same session.

5. Conclusions

A novel needle puncture technique to the renal calyx using LAUS method just before PNL is a feasible technique that has promise even when the pelvicalyceal system is not dilated in case with complete staghorn calculus. Greater experience and comparison to standard technique are required to determine if this method will be a useful technique in the future.

References

- 1) N. Ishito, T. Sako, T. Nakada, Y. Shiotsuka, Y. Yamamoto, H. Takamoto: A new needle puncture technique to the renal calyx using contrast-enhanced ultrasonography with intracalyceal and intravenous injection of Sonazoid. *Videourology*, Vol.25, Issue 2, 2011.
- 2) G. Ibarluzea, CM. Scoffone, CM. Cracco, M. Poggio, F. Porpiglia, C. Terrone, A. Astobeta, I. Camargo, M. Gamarra, A. Tempia, JG. Valdivia Uria, RM. Scarpa: Supine Valdivia and modified lithotomy position for simultaneous antegrade and retrograde endourological access. *BJU Int.*, 100:233-236, 2007.
- 3) GM. Preminger, DG. Assimos, JE. Lingeman, SY. Nakada, MS. Pearle, JS. Wolf Jr: AUA Nephrolithiasis Guideline Panel. Chapter 1: AUA guideline on management of staghorn calculi: Diagnosis and treatment recommendations. *J. Urol.*, 173:1991-2000, 2005.
- 4) J. Landman, R. Venkatesh, DI. Lee, J. Rehman, M. Ragab, M. Darcy, CP. Sundaram: Combined percutaneous and retrograde approach to staghorn calculi with application of the ureteral access sheath to facilitate percutaneous nephrolithotomy. *J. Urol.*, 169: 64-67, 2003.
- 5) N. Ishito, R. Kishimoto, K. Nozaki, Y. Yamamoto, H. Takamoto: Flank position transurethral lithotripsy-assisted percutaneous nephrolithotomy (dual H: YAG laser lithotripsy) for complete staghorn renal calculus. *Jpn.J. Laser. Surg. Med.*, 28: 383-387, 2008.
- 6) CG. Marguet, P. Springhart, YH. Tan, A. Patel, S. Undre, DM. Albala, GM. Preminger: Simultaneous combined use of flexible ureteroscopy and percutaneous nephrolithotomy to reduce the number of access tracts in the management of complex renal calculi. *BJU Int.*, 96: 1097-1100, 2005.
- 7) K. Matsuoka, S. Iida, M. Nakanami, H. Koga, A. Shimada, T. Mihara, S. Noda: Holmium:yttrium-aluminium-garnet laser for endoscopic lithotripsy. *Urology*, 45: 947-952, 1995.
- 8) KF. Chan, TJ. Pfefer, JMH. Teichman, AJ. Welch: A perspective on laser lithotripsy: fragmentation processes. *J. Endourol.*, 15: 257-273, 2001.
- 9) JW. Dushinski, JE. Lingeman: High-speed photographic evaluation of holmium laser. *J Endourol* 12:177-181, 1998
- 10) RL. Baron, JKT. Lee, BL. McClennan, GL. Melson: Percutaneous nephrostomy using real-time sonographic guidance. *AJR*. 136: 1018-1019, 1981.
- 11) MR. Desai, AP. Ganpule: Percutaneous renal access under ultrasound control, AD. Smith, GH Badlani, GM. Preminger, LR. Kavoussi(eds), *Smith Textbook of Endourology*, third edition, 173-179, 2012, Blackwell Publishing.
- 12) MH. Lu, XY. Pu, X. Gao, XF. Zhou, JG. Qui, J. Si-Tu: A comparative study of clinical value of single B-mode ultrasound guidance and B-mode combined with color doppler ultrasound guidance in mini-invasive percutaneous nephrolithotomy to decrease hemorrhagic complications. *Urology*. 76: 815-820, 2010.

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