The Journal of Laryngology and Otology
October 1996, Vol. **110,** pp. 942–946

Pulsed dye laser lithotripsy of submandibular gland salivary calculus

HIROTAKA ITO, M.D., SHUNKICHI BABA, M.D.

Abstract

An *in vivo* study was performed to evaluate the use of pulsed-dye laser beam for the fragmentation of salivary calculus. In accordance with the absorption and reflection spectra of sections of salivary stones, optimal fragmentation was achieved with a pulsed-dye laser with a pulse width of 1.4 μm and tuned to a wavelength of 504 nm. Further studies on particle size were conducted, and a new "sialoendoscope" technique was developed. Fifteen patients with sialolithiasis of the submandibular gland were treated. Under continuous endoscopic monitoring laser-induced shock wave lithotripsy was performed. In six patients complete fragmentation and removal of the salivary stones was achieved and in another patient 50 per cent fragmentation was sufficient to restore salivary flow. Laser lithotripsy of salivary stones with endoscopic monitoring permits treatment on an outpatient basis with little inconvenience to the patient, and this is a breakthrough in otolaryngology.

Key words: Salivary gland calculi; Laser, pulsed-dye; Submandibular salivary gland

Introduction

Salivary gland calculus (salivary stone) when present, most frequently develops in the submandibular gland. In patients with this problem, the stones develop because: 1) The outward flow of saliva through the duct is hindered because it has to go against the direction of gravity; 2) the saliva is at its most alkaline state in this area; 3) There is a higher concentration of calcium and phosphate in the duct (due to food particles and such debris); 4) Saliva in the duct has a higher mucus content. These four conditions interact thus leading to the formation of salivary calculus (Rice, 1993).

The patients chosen for the study have a history of recurrent swelling and pain in the submandibular glands, and this is often associated with the chewing of food. They suffer from repeated episodes of obstruction and swelling that may, or may not be, accompanied by an infection.

The therapy for distal salivary calculi is surgical sialolithotomy for the removal of the stone. Other cases of surgically inaccessible calculi require the removal of the whole gland with the risk of severe blood vessel damage and nerve lesions (Rice, 1993). To avoid these side-effects, shock wave lithotripsy seemed to be a suitable method for salivary calculi removal. There are two methods of shock wave application; Extra corporeal percutaneous shock wave lithotripsy (ESWL) and endoscopically controlled shock wave lithotripsy using an eximer laser (Gundlach *et al.*, 1990, Iro *et al.*, 1990). In 1993 endoscopically controlled electrohydraulic intra-corporeal shock wave lithotripsy (EISL) was applied to salivary calculi, but damage to the submandibular duct was reported for dosages exceeding 450 mj distributed over 100 shockwaves (Königsberger *et al.*, 1993). For this study, we performed salivary gland calculus disintegration using pulsed-dye laser irradiation, while continuously monitoring/confirming contact with the salivary stone through endoscopic control, and obtained favourable results. This is the first time that this type of lithotripsy (pulsed-dye laser) has been attempted in otolaryngology. In the urology field, there have been many successful reports on the use of pulsed-dye laser for stone fragmentation without the tissue injuries associated with continuous wave laser because the pulsed-dye laser has a more controllable, tunable beam and thus can be used with greater precision and control (Dretler *et al.*, 1987; Watson and Wickham, 1989).

Materials and methods

A total of 15 patients, nine women and six men with ages ranging from 23 to 53 years old, and with a mean age of 35, were treated by pulsed-dye laser lithotripsy from September, 1993 to January, 1994. All of the patients were diagnosed as suffering from recurrent acute inflammation, and swelling in association with eating over a period of several years (Table I). The calculi diameters ranged from 5 mm

From the Department of Otorhinolaryngology, Nagoya City University, Medical School, Nagoya, Japan.
Accepted for publication: 27 July 1996.

TABLE I
PATIENT DATA

Cases/sex	15/M6; F9
Calculus side	right 11 left 4
Stone size	5–17 mm
History of suppuration	2
History of recurrent swelling with eating	13

to 17 mm, having an average size of 13.46 mm as determined by radiography. The calculi were present in the hilus of the submandibular gland (Figure 1) (Table II).

Endoscope

For this trial, a special flexible endoscope with a diameter of 1.5 mm and a length of 25 cm, with an attached lateral channel for a 200 μm laser quartz fibre was commissioned (Clinical Supply Co., Japan) (Figure 2). We used a 15" television as our monitor.

Pulsed-dye laser

A pulsed-dye laser lithotriptor device designed for urinary stone fragmentation was used (MDL 2000, Candela Co. Natrik, USA). Using data from urology, a test wavelength of 504 nm was decided upon, and obtained with the use of coumarin green in the dye chamber of the laser. The exposure parameters were set at 70 mj per pulse, at a duration of 1 μsecond, and at a frequency of five pulses per second. The number of pulses necessary to fragment the calculus, and total energy required for fragmentation were recorded for each calculus.

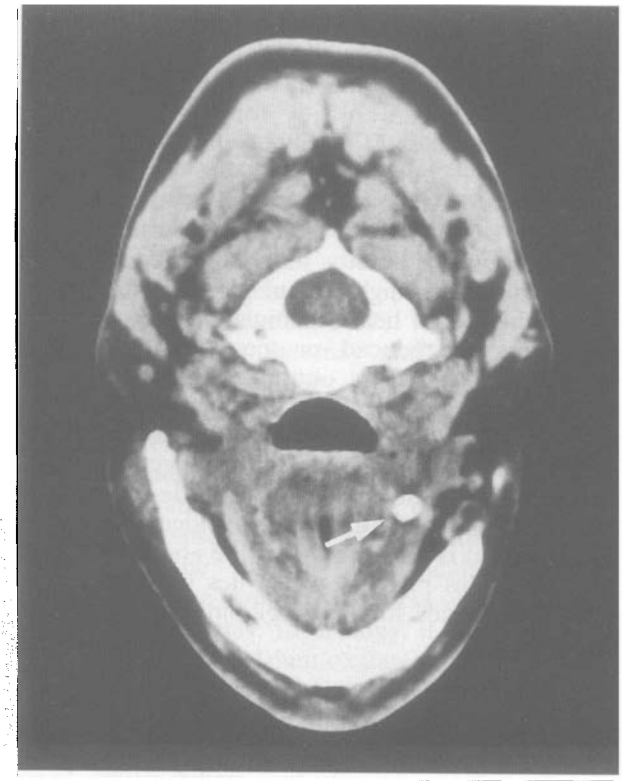

Fig. 1
C T scan showing the salivary stone.

TABLE II
TREATMENT DATA

Total no. patients	15
Diameter (mm) of calculus	
Mean	13.46 mm
No. pulses at 70 mj	
Mean (range)	840 (150–1350)
Standard deviation	408.44
Total energy	
Mean (range)	58.8 (10.5–94.5) joules
Standard deviation	28.6
Results	
Fragmentation	6
Disintegration	9
Failure	0

Method

The endoscope was introduced into the orifice of the submandibular duct without the use of anaesthesia and the presence of a calculus confirmed visually on the TV monitor. Then, the 200 μm silicon-coated quartz fibre was inserted through the lateral channel of the endoscope and the tip of the quartz fibre was allowed to protrude 1 mm. Using the TV monitor, the tip of the quartz fibre was positioned against the surface of the calculus and laser pulse delivery initiated at the predetermined exposure parameter until calculus fragmentation was achieved (Figure 3).

The fragmentation of the calculus was attempted with the maximum dosage set at about 150 pulses per day of treatment (@ 10.5 joules). If fragmentation could not be achieved in one session, the laser irradiation was repeated on other days until frag-

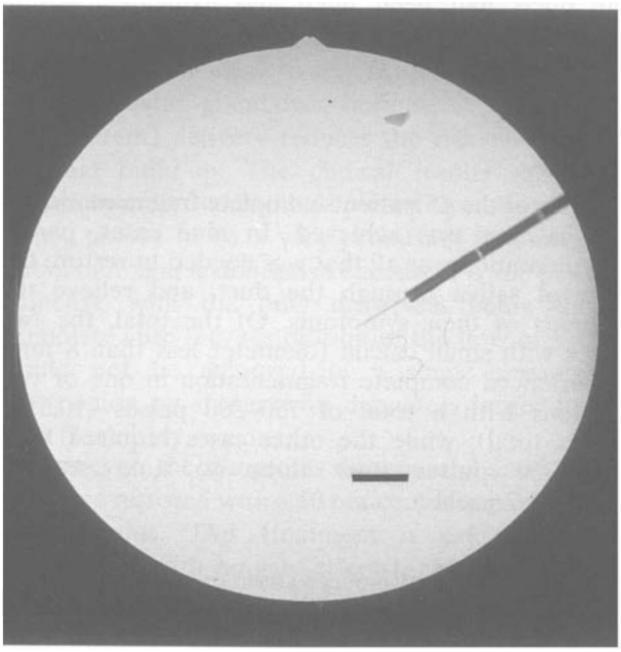

Fig. 2
Silicon-coated fibre extending from tip of endoscope (scale 1: 1 cm)

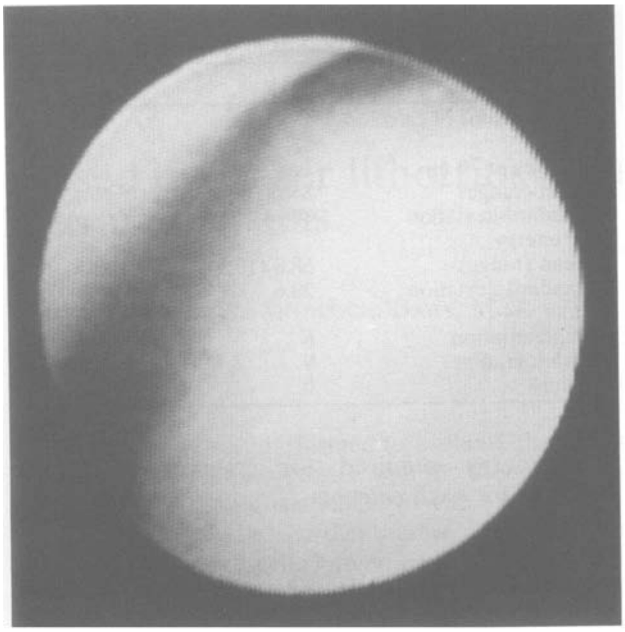

FIG. 3
Endoscopic view of salivary calculus in the submandibular duct before lithotripsy

mentation was achieved. Prior to initiation of therapy, the entire process was explained to all the patients, and informed consent obtained.

Before the clinical application of pulsed-dye laser lithotripsy, the pulsed-dye laser was used to fragment salivary calculi in five human Wharton's ducts which were extracted by surgery for the treatment of other diseases (e.g. sialolithiasis, benign tumour). In order to demonstrate the damage to Wharton's ducts the stone was impacted tightly (stored stone) into the hilus of the submandibular gland and we performed stone fragmentation using three settings from 50 mj to 80 mj per pulse. Shock waves were applied after the ducts had been filled and expanded with a sodium chloride solution. The results are show in Table III.

Results

In six of the 15 patients complete fragmentation of the calculus was achieved. In nine cases, partial fragmentation was all that was needed to restore the flow of saliva through the duct, and relieve the patients of their symptoms. Of the total, the two cases with small calculi (diameter less than 8 mm) experienced complete fragmentation in one or two sessions with a total of 150–200 pulses (10.5–14 joules total); while the other cases required from 450–1350 pulses over three to nine sessions (31.5–95.2 joules).

The restoration of salivary flow in the submandibular gland was confirmed by sialography after the treatment. The average number of pulses needed to achieve calculus fragmentation was 840 pulses (58.8 joules); and time to fragmentation was 30 minutes per one session (Table II). Figure 4 shows the progress of fragmentation in *Case 6*.

The lithotripsy was performed with no pain, no anaesthesia, and no noticeable side-effects.

Discussion

Salivary gland calculus (stone) is most frequently found in the submandibular gland. Treatment depends on the location of the calculus. When accessible (at or near the orifice of the duct), it may be removed trans-orally, however stones within the hilum of the gland often require complete excision of the gland itself (Rice, 1993).

To avoid surgical extirpation, trials of salivary calculus lithotripsy using ESWL, lithotripsy and endoscopically controlled shock wave lithotripsy using eximer lasers have been performed by otolaryngologists with positive results (Gundlach *et al.*, 1990; Iro *et al.*, 1990; Königsberger *et al.*, 1993). We performed an *in vivo* study to examine the efficacy of a pulsed-dye laser beam with a pulse width of 1.4 μm and a wave-length of 504 nm for fragmentation of salivary stones, and new sialoendoscope equipment was developed.

Unlike continuous wave lasers, the pulsed-dye laser has characteristics that allow effective stone ablation without tissue injury (Watson and Wickham, 1986; Dretler *et al.*, 1987; Vandeursen *et al.*, 1991). From our experimental irradiation using a pulsed-dye laser, we have confirmed this advantage.

The flash lamp-pumped pulsed-dye laser has several distinct advantages for use in delicate surgical procedures. It has a very high output level: for any given pulse energy, there is an inverse relationship between power density (watt per cm^2) and pulse duration such that as the pulse duration decreases power density increases proportionally. But because this high output is only emitted for 1 μsec, the risk of heat accumulation that results in tissue injury is reduced, or completely eliminated. The pulsed-dye laser's output wavelength can be adjusted by changing the dye contained in the reflector cavity reservoir so that the laser's output wavelength matches the absorption spectrum of the target material reducing the risks of side-effects from reflected light. Tissue damage is avoided because the laser's output is tuned to match the absorption band of the calculus pigment which lies in between the absorption bands for haemoglobin. On the whole,

TABLE III
DYE LASER IRRADIATION INDUCED EFFECT ON ISOLATED SUBMANDIBULAR DUCTS AFTER DIRECT LASER IRRADIATION OF THE STONE'S SURFACE WITH 150 PULSES

Discharge energy	7.5 joules (50mj/pulse)	10.5 joules (70mj/pulse)	12 joules (80mj/pulse)
Mechanical lesion	*	*	0

* no damage 0 minor damage to mucosa

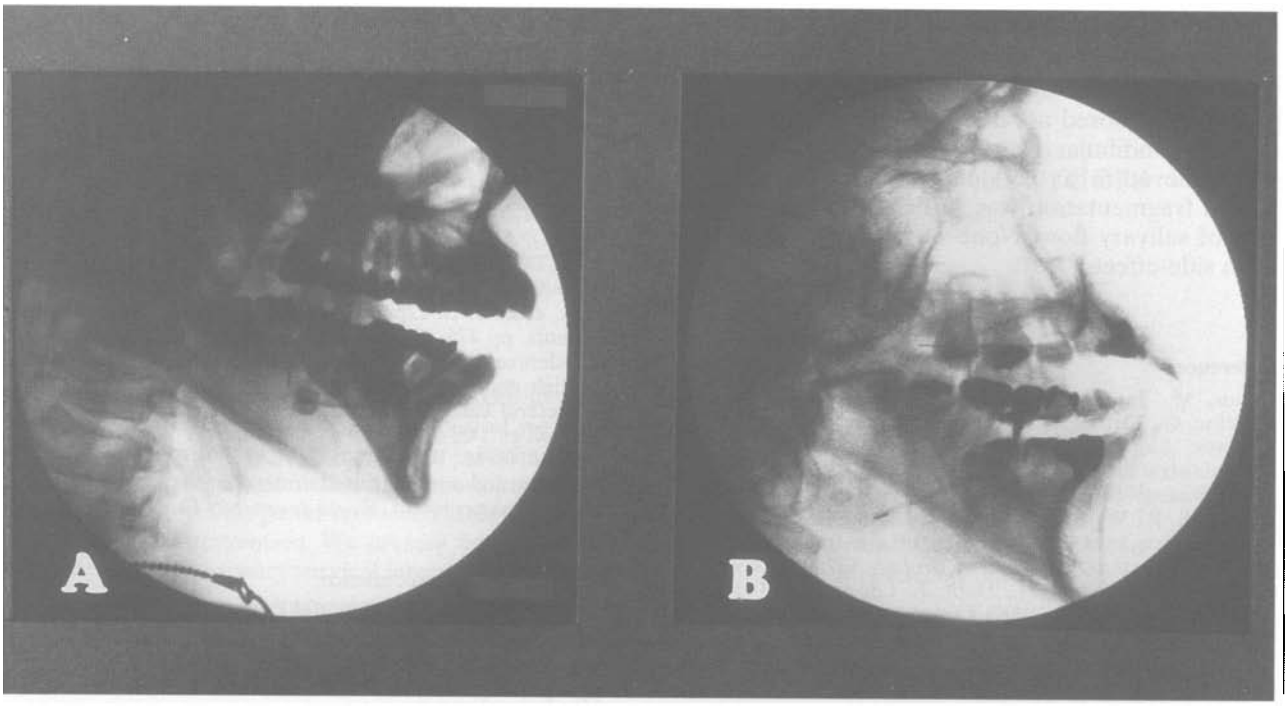

FIG. 4
Plane radiograph pre-treatment film(A) and post-treatment film(B)

higher energy levels may be used without causing tissue injury.

A further advantage may be found in our use of a 200 µm quartz optical fibre for transmitting the laser beam. This is because power density increases when the cross-sectional area of the optical fibre transmitting the laser energy decreases and the energy output remains constant.

It is postulated that the absorption of the laser pulse causes plasma to form on the surface of the calculus (plasma is a rapidly expanding cavity of ions and electrons which collapses rapidly after the laser pulse), and this action produces a mechanical shock wave. The saline solution used for irrigation confines the shock wave, thus concentrating its effect on the stone. The high pressure created by the shock wave then causes the fragmentation of the calculus (Pensel *et al.*, 1981; Dretler *et al.*, 1987).

Although each pulse may only remove a small fragment, the 5HZ per sec. (five pulses per second) transmission rate, and the multiple shock waves it produces results in the occurrence of laser fissures. This promotes the rapid crumbling of the calculus. The combination of wavelength, pulse duration and frequency, pulse energy, and the fibre diameter, determines the size of the calculus fragments produced by the laser, i.e. its effect on the composition of the calculus. In urology, it was found that calculi formed of calcium oxalate monohydrate had the highest tensile strength. But a high energy level is rarely needed for large and impacted calculi except to accelerate the lithotripsy procedure (Vandeursen *et al.*, 1991). Salivary calculi are normally composed of calcium phosphate (Rice, 1993). Even though the energy levels used in this study are lower than those used in urology, successful fragmentation was achieved without any complications.

The use of ESWL lasers in urology has been accompanied by reports of side-effects such as haemolysis and myolysis due to shock wave exposure and overheating (Kishimoto *et al.*, 1986; Delius *et al.*, 1989). This is because continuous wave lasers such as CO_2, argon or neodymium: YAG have a constant output and this results in excessive release of thermal energy at the levels necessary to fragment or vaporize a calculus.

This is the direct opposite of the pulsed-dye laser, which makes it ideal to use in the confines of the submandibular gland/duct because its pulsed (i.e. intermittent) delivery reduces the risk of excessive thermal build-up. The clinical results show that endoscopically controlled pulsed-dye laser lithotripsy proves to be a very promising treatment for submandibular sialolithiasis because it is 100 per cent effective with the only drawback being that a complete cure (i.e. restoration of the flow of saliva), could not be achieved in a single session for obstruction by stones with diameters larger than 8 mm (for safety reasons).

However, the symptoms disappeared and salivary flow was restored with a 50 per cent fragmentation of the calculus. This treatment is safe (i.e. non-destructive, with no side-effects), can be applied in an out-patient setting, and at most will necessitate local surface anaesthesia, and is thus very convenient. Based on this, we consider pulsed-dye laser lithotripsy to be the safest and most reliable method for the treatment of salivary calculus.

Conclusion

We performed salivary gland calculus disintegration using pulsed-dye laser irradiation on fifteen patients diagnosed as suffering from sialolithiasis of the submandibular gland. Complete fragmentation was achieved in six patients, while in nine patients, partial fragmentation was sufficient for the restoration of salivary flow. None of the patients suffered from side-effects.

References

Delius, M., Jordan, M., Eizenhofer, H., Marlinghaus, E., Heine, G., Liebich, H. G. (1989) Biological effects of shock waves: kidney hemorrhage by shock waves in dogs administration rate dependence. *Ultrasound in Medicine and Biology* **14:** 689–694.

Dretler, S. P., Watson, G., Parrish, J. A., Murray, S. (1987) Pulsed dye laser fragmentation of ureteral calculi initial clinical experience. *Journal of Urology* **137:** 386–389.

Gundlach, P., Scherer, H., Hopf, J., Leege, N., Müller, G., Hirst, L., Scholz, C. (1990) Die endoskopisch kontrollierte Laserlithotripsie von Speichelsteinen. *H.N.O.* **38:** 247–250.

Iro, H., Schneider, T., Nitshe, N., Waitz, G., Ell, C. (1990) Extrakorporale piezoelek trishe Lithotripsie von speichelsteinen. *H.N.O.* **38:** 251–255.

Königsberger, R., Feyh, J., Goetz, A., Kastenbauer, E. (1993) Endoscopically-controlled electrohydraulic intracorporeal shock wave lithotripsy (EISL) of salivary stones. *Journal of Otolaryngology* **22:** 12–13.

Kishimoto, T., Yamamoto, K., Sugisoto, T., Yoshihara, H., Maekawa, M. (1986) Side effect of extracorporeal shock wave exposure in patients treated by extracorporeal shock wave lithotripsy for upper urinary tract stone. *European Urology* **12:** 308–313.

Pensel, J., Frank, F., Rothenberger, K., Hofstetter, A., Unsold, E. (1981) Destruction of urinary calculi by neodymium-YAG laser irradiation. In *Proceedings of Fourth International Symposium on Laser Surgery.* Vol 10 (Kaplan, I. eds.), Academic, Jerussalem, pp 4–6.

Rice, D. H. (1993) Diseases of the salivary gland. In *Head and Neck Surgery—Otolaryngology.* (Byron, J. B., Harold, C. P., eds.). J. B. Lippincot Company, Philadelphia, Pennsylvania, pp 475–484.

Vandeursen, H., Pittomvils, G., Boving, R., Baert, L. (1991) High energy pulsed dye laser lithotripsy: Management of ureteral calcium oxalate monohydrate calculi. *Journal of Urology* **145:** 1146–1150.

Watson, G. M., Wickham, J. E. A. (1989) The development of a laser and a miniaturised ureteroscope system for ureteric stone management. *World Journal of Urology* **7:** 147–150.

Address for correspondence:
Department of Otorhinolaryngology,
Nagoya City University,
Medical School,
No. 1 Kawasumi, Mizuhocho,
Mizuhoku, Nagoya,
Japan 467

Fax: 52–851–5300