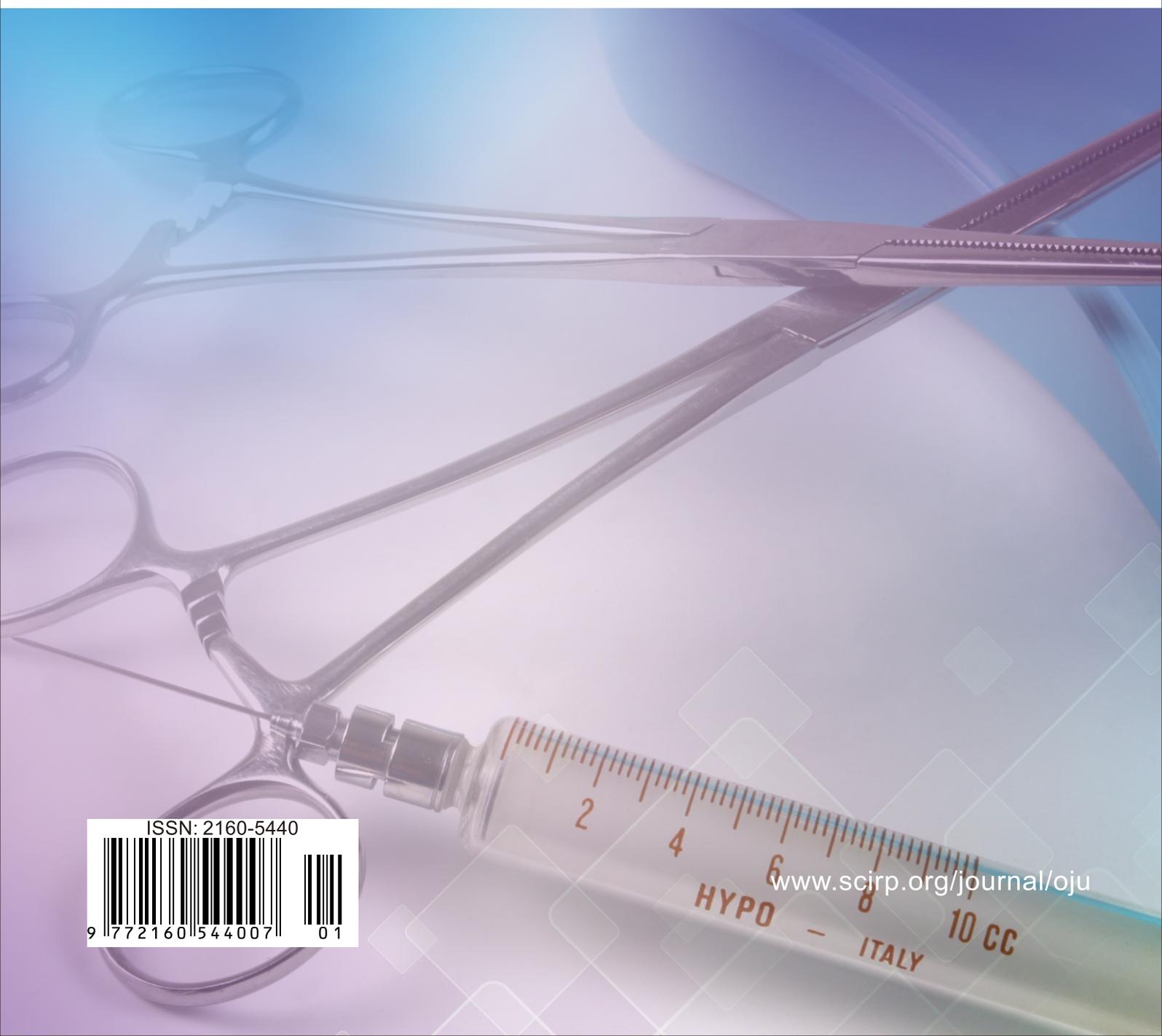


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First Intraluminal Temperature Measurement during Ho:YAG-Laser Exposure at an *In-Vitro* URS

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Abstract

Introduction: The laser is a high energy instrument which can melt metals like nitinol. So it is very important to know under which conditions it is dangerous to perform an endourologic lithotripsy. We measure the temperature increase during laser exposure in an underwater *in-vitro* ureter model. For comparison, temperatures with and without irrigation and with different distances from the laser fiber to the thermometer are measured. **Materials and Methods:** We used the Ho:YAG-laser (Vera Pulse™, Coherent) with a 365 μm laser fiber. The settings of the laser were 0.6 J with a frequency of 5 Hz which is the minimum setting for that type of laser. The experimental setup was closely aligned with the clinical situation. A metal container was filled with 0.9% sodium chloride (NaCl) solution (Temp. 36.8°) and a catheter with an inner diameter of 4 mm was attached to the rim of the container. The tip of the thermometer was attached inside the catheter through a water-proof hole. The laser fiber was guided by means of a rigid URS video device (11.5 F). We had four different settings during the measurement: 1) Distance of 0.5 cm between the laser and the thermometer; without irrigation, 2) Distance of 0.5 cm between the laser and the thermometer; with irrigation, 3) Distance of 1 cm between the laser and the thermometer; without irrigation, 4) Distance of 1 cm between the laser and the thermometer; with irrigation. **Results:** The maximum overall temperature was recorded in the 1) and 3) setting, both featuring no irrigation. The maximum temperature was ~50°C in both settings, with the 1) setting reaching the maximum temperature after 50 seconds and hence approximately twice as fast as the 3) setting. During measurements with a NaCl solution flow we couldn't detect any noticeable increase in temperature, neither at short nor at long distance between the laser fiber and the thermometer. **Conclusion:** There is a relevant heating in the ureter beside an endourologic lithotripsy. In our model we could reproduce a maximum heating until ~50°C without irrigation and no heating with irrigation. Without ir-

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rigation there is a relevant bubble formation which should be an indicator for the surgeon to stop lithotripsy due to a temperature increase which could harm surrounding tissue.

Keywords

YAG-Laser, Exposure, Intraluminal, Irrigation, Laser Fiber

1. Introduction

The Ho:YAG-Laser is named as the gold standard lithotripsy modality for endoscopic lithotripsy [1]. In a global study of the endourological society with 11,885 patients, 49% (5820) of the physicians used the laser as a fragmentation device beside the ureteroscopy [2].

Acute complication like a perforation of the ureter by the laser is mainly caused by the photonic and acoustic energy the laser emits. The Ho:YAG-Laser is categorized as a potentially dangerous lithotripsy device for perforation [3]. Long time complications like ureteral strictures seem to be directed by thermal and mechanical injury. So it is important to know the temperature profiles in the ureter with different conditions. The laser is a high energy instrument which can melt a metal like nitinol [4]. So it is very important to know under which conditions it is dangerous to perform an endourologic lithotripsy.

We measure how the temperature increases during laser exposure in an underwater *in-vitro* ureter model. For comparison we measure temperatures with and without irrigation and with different distances from the laser fiber to the thermometer.

2. Material and Methods

We used the Ho:YAG-laser (Vera Pulse™, Coherent) with a 365 μm laser fiber. The setting of the laser was 0.6 J with a frequency of 5 Hz which is the minimum setting for that type of laser. The experimental setup was closely aligned with the clinical situation (Figure 1).

A metal container was filled with 0.9% sodium chloride (NaCl) solution (Temp. 36.8°) and a catheter with an inner diameter of 4 mm was attached to the rim of the container. The tip of the thermometer was attached inside the catheter through a waterproof hole. The Laser Fiber was guided by means of a rigid URS video device (11.5 F) (Figure 2).

The above mentioned instruments were now inserted into the artificial ureter with a distance between the tip of the thermometer and the laser fiber of both 0.5 cm and 1 cm (Figure 3).

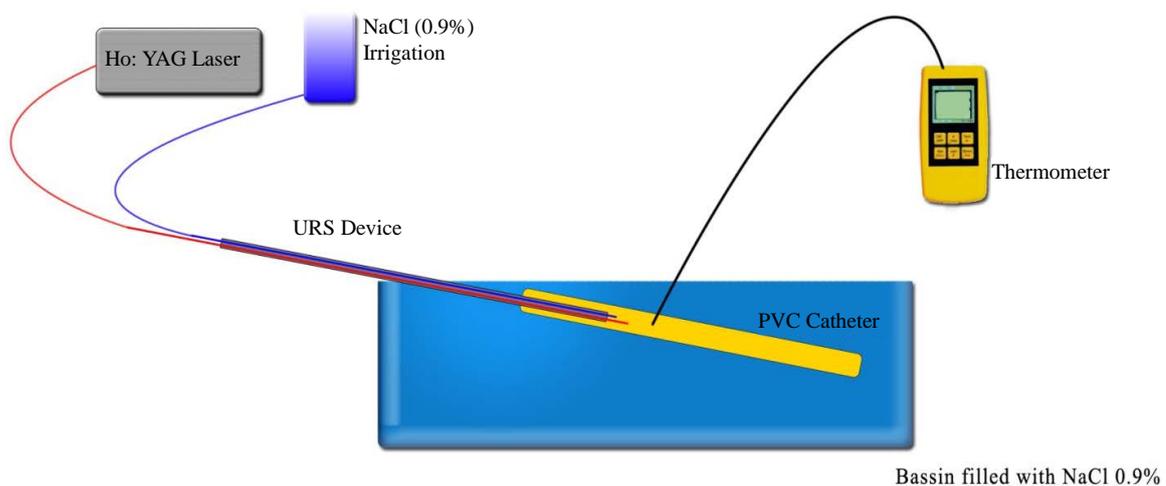


Figure 1. The schematic drawing of the experimental setup shows the URS device with the laser fiber and the intraluminal tip of the thermometer inside a catheter surrounded by NaCl solution.

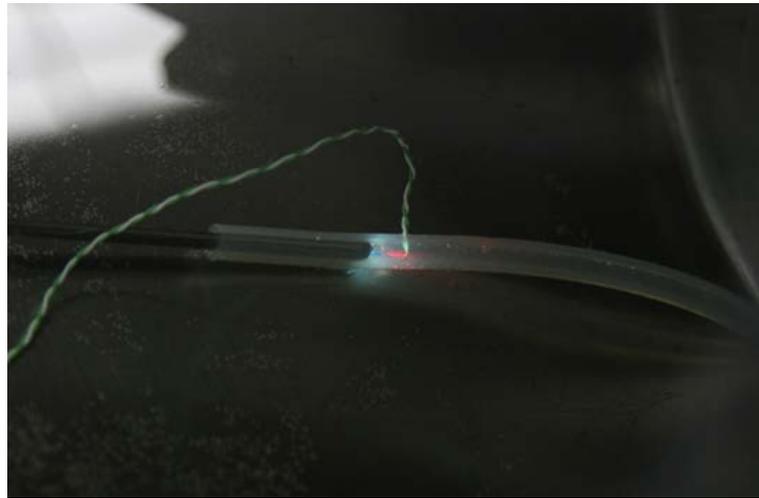


Figure 2. Artificial ureter with the probe of the thermometer (green cable) and the tip of the semirigid renoscope with the attached laser fiber.

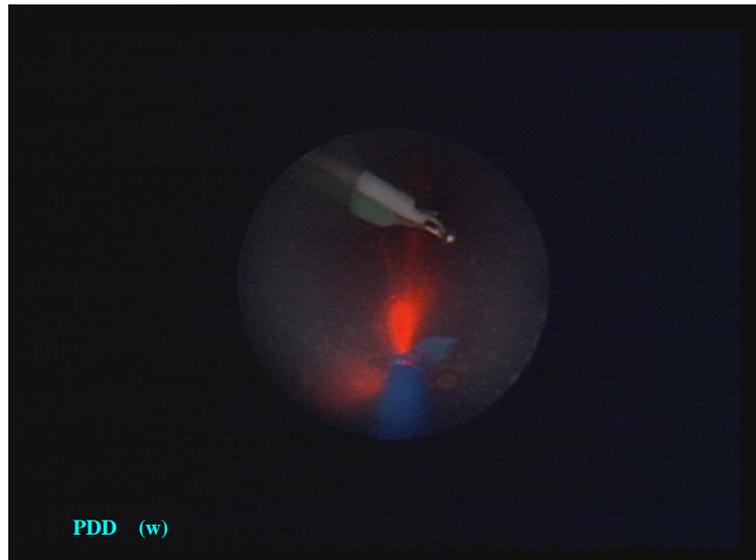


Figure 3. View from inside the catheter through the renoscope. Both the tip of the thermometer and the laser fiber are visible.

During the measurements with irrigation, a NaCl solution was piped through the URS-device. The irrigation has the same height as it is commonly used in our theater. The irrigation fluid came out of our warming facility with 37°C (**Figure 4**).

We had four different settings during the measurement.

- 1) Distance of **0.5 cm** between laser and thermometer; **without** irrigation;
- 2) Distance of **0.5 cm** between laser and thermometer; **with** irrigation;
- 3) Distance of **1 cm** between laser and thermometer; **without** irrigation;
- 4) Distance of **1 cm** between laser and thermometer; **with** irrigation.

3. Results

The maximum overall temperature was recorded in the 1) and 3) setting, both featuring no irrigation. The maximum temperature was 50°C in both settings, with the 1) setting reaching the maximum temperature after 50 seconds and hence approximately twice as fast as the 3) setting (**Figure 5**). During measurements with a NaCl



Figure 4. Photo of the experimental setup with the basin and the irrigation fluid.

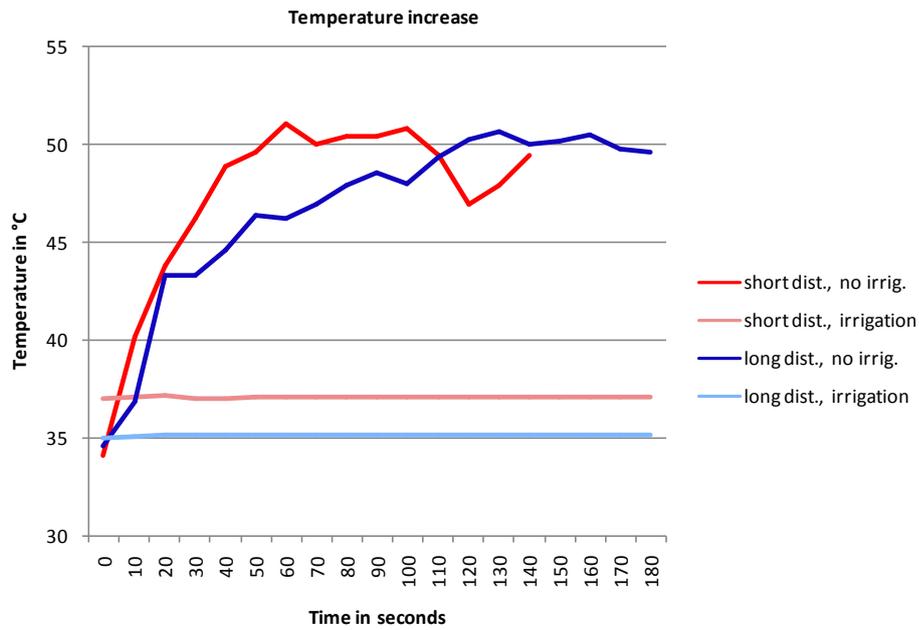


Figure 5. Four different settings: Short means 0.5 cm and long means 1 cm.

solution flow we couldn't detect any noticeable increase in temperature, neither at short nor at long distance between the laser fiber and the thermometer.

Without continuous flow as in setting 1) and 3) we saw steady bubble emergence. With continuous irrigation no bubbles were detected. The starting temperature was 35°C in the 1), 34.6°C in the 2), 37.0°C in 3) and 34.1°C in the 4) setting. The starting temperatures differ 2.9°C at maximum.

4. Discussion

This is the first intraluminal temperature measurement of an activated Ho:YAG-Laser beside an *in vitro* URS. Molina *et al.* [5] already measured the Temperature Profile of Laser Lithotripsy Activation with a thermal camera. They measured outside a ureter model and with an open ureter model with a thermal camera. They used a higher energy setting with 1 J/Pulse and 10 Hz. With our model we can reproduce the external measurement with irrigation of 37.4°C and without irrigation of 49.5°C. In the open model they had higher temperature levels at 49.7°C with irrigation and 112.4°C without irrigation. Maybe the distance of 0.5 cm to the thermometer is an explanation for this difference. Also the open ureter in our setting could be a reason.

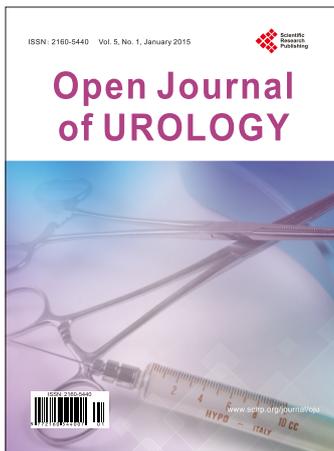
Limitation of this *in vitro* study is the open ureter. In the normal clinical setting maximal irrigation is only possible when the upper tract of the ureter is not full (of NaCl solution, for example) or the operating surgeon uses an irrigation set. The artificial ureter is thicker than a normal ureter. The measurement only covers one setting for the energy-level and one laser fiber of 365 µm. Important for the physician is the bubble-emergence right in front of the laser fiber. The surgeon should be aware that steady bubble appearance could indicate a temperature increase.

5. Conclusion

There is a relevant heating in the ureter beside an endourologic lithotripsy. In our model we could reproduce a maximum heating until ~50°C without irrigation and no heating with irrigation. Without irrigation there is a relevant bubble formation which should be an indicator for a physician to stop lithotripsy. There should be more studies to evaluate the temperature profile.

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