Temperature Comparison of a Novel Thulium Fiber Laser vs Conventional Thulium Fiber Laser

Authors: Katya Hanessian, Kallan Richards, Gabriel Martin, Daniel Jhang, Joshua Ghoulian, Zhamshid Okhunov, D. Duane Baldwin
Loma Linda University Health, Department of Urology

Introduction:
While laser fragmentation during ureteroscopy (URS) and percutaneous nephrolithotomy (PCNL) has traditionally utilized a holmium laser, the thulium fiber laser (TFL) has recently emerged as a promising new laser system[1]. While the holmium laser emits pulsatile energy, TFL generates continuous energy[2]. This laser has a higher absorption of energy and ablation capacity than the holmium laser, increasing its efficiency in breaking up stones[1]. However, despite its ability to effectively break stones, the current TFL has the potential to generate damage to the urothelial tissue due to its high heat and energy transfer[1,3]. It is known that thermal heat beyond 43°C causes thermal tissue damage and above 60°C causes irreversible cell damage, protein denaturation, and initiation of cell death [5,6]. A new TFL has been developed that attempts to reduce heat generation by a proprietary modification of the laser activation duty cycle. There is no current literature, benchtop evaluation, or clinical trial comparing the novel TFL to the conventional TFL. The purpose of our study is to conduct a benchtop study comparing the thermal safety of this novel TFL with a modified duty cycle to the conventional platform.

Methodology:
The thermal temperatures generated by the conventional Soltive SuperPulsed laser (Olympus, Center Valley, PA) was compared to the novel OPTICA XT laser (Convergent, Oakland, CA) in a benchtop model. A 3D kidney and ureter model were constructed based on a patient's computer tomography (CT) imaging. Identical 10 mm BegoStones (Bego GmbH, Germany) were created with a calcium oxalate monohydrate consistency to simulate ureteral stones. These stones were then submerged in a saline bath for 24 hours before each trial and positioned 2 cm distal to the ureteropelvic junction of the kidney to simulate an impacted proximal ureteral stone. The kidney model was placed in a 35.5°C saline bath to mimic core temperature during endoscopic surgery. To monitor ureteral fluid temperatures, a type T needle thermocouple (ThermoWorks, American Fork, UT) was placed in the ureter wall 2 mm from the 200 μm laser fiber tip. A digital data acquisition system, including a MAX31855 T-Type Thermocouple Sensor breakout board (ThermoWorks, American Fork, UT), recorded temperature data with readings every 6.0 seconds. Continuous saline irrigation was maintained at 15 mL/minute at room temperature (22°C) using the Thermedx FluidSmart System (Thermedx LLC, Solon, OH).

Intraluminal temperatures were recorded during 60 seconds of continuous laser activation for each of the specified power settings: 3 W (0.3 J/10 Hz), 10 W (1 J/10 Hz), 20 W (1 J/20 Hz) and 30 W (0.6 J/50 Hz). The order of the lasers and power settings were randomized, with five trials performed for each power setting. The analysis included a comparison of average and maximum temperatures of ureteral fluid between the two laser systems at each power output. Statistical analyses, including Kruskal-Wallis and Mann–Whitney U tests, were conducted with a significance level set at $p<0.05$.

Results:

Both the conventional TFL and the novel TFL reached extremely low temperatures at 3 W, with the novel TFL reaching a maximum of 27.7°C at 30 seconds and the conventional TFL reaching a maximum of 27.3°C at 30 seconds ($p<0.05$, Figure 1). The highest temperature achieved at 10 W was lower in the novel TFL reaching 36.9°C at 48 seconds compared to the conventional TFL reaching 42.1°C at 54 seconds ($p<0.01$, Figure 2). Neither laser at the 3 W or 10 W setting went above 43°C. At the 20 W setting, the novel TFL reached a maximum temperature of 38.1°C at 54 seconds, whereas the conventional TFL laser reached a maximum temperature of 44.6°C at 48 seconds ($p<0.01$, Figure 3). The CEM_{43} of the conventional TFL reached 0.9 equivalent minutes, whereas the novel TFL did not exceed 43°C at the 20 W setting. At the 30 W setting, the thermal heat of the novel TFL laser reached a maximum of 52.5°C at 12 seconds whereas the conventional TFL reached a maximum of 63.6°C at 42 seconds ($p<0.05$, Figure 4). The CEM_{43} of the novel TFL laser reached 425 equivalent minutes and 275,919 equivalent minutes for the conventional TFL at 30 W. At 30 W, the novel TFL did not reach above 60°C, but the conventional TFL laser exceeded 60°C for at least 13 seconds.

Discussion:

Our study was the first to compare the thermal dose between the novel TFL laser with modified duty cycle to the conventional TFL laser. Prior studies have compared the Holmium to the standard TFL, concluding that the TFL generated higher temperatures during ureteral lithotripsy although the Thulium had lower rates of residual stone fragmentation and less heat dissipation[7, 8.] However, there have been no studies comparing the thermal safety of the conventional TFL to the novel TFL with modified duty cycle. Our results were consistent with the study by Belle et al. demonstrating that the temperatures did not rise above 30°C at 3 W and 43°C at 3 W, 10 W, and 20 W, but that both lasers exceeded 43°C at the 30 W settings [1].

Our study demonstrated that the novel duty cycle modification generated less thermal heat compared to the conventional TFL system. Because the Convergent laser produces lower thermal heat at the same setting as the conventional TFL, there is less potential to damage the tissue of the ureter. The Convergent laser spent significantly less cumulative equivalent minutes above 43°C compared to the conventional TFL, and did not exceed 60°C. These results suggest that the Convergent laser is less likely to damage tissue and incite cell death in the ureter compared to the conventional TFL. Our study results suggest the Convergent laser may be a safer alternative to standard conventional TFL in the ureter. Next steps in comparing the lasers include investigating comparisons in ablation rates as well as stone fragmentation performance.

Conclusion:

The novel TFL was superior to the conventional TFL in minimizing thermal heat emission, thus minimizing the potential of tissue damage and cell death. Urologists may benefit from using the novel TFL as a safer alternative to the conventional TFL to prevent ureteral damage in patients due to its lower thermal heat emission.

Figures:

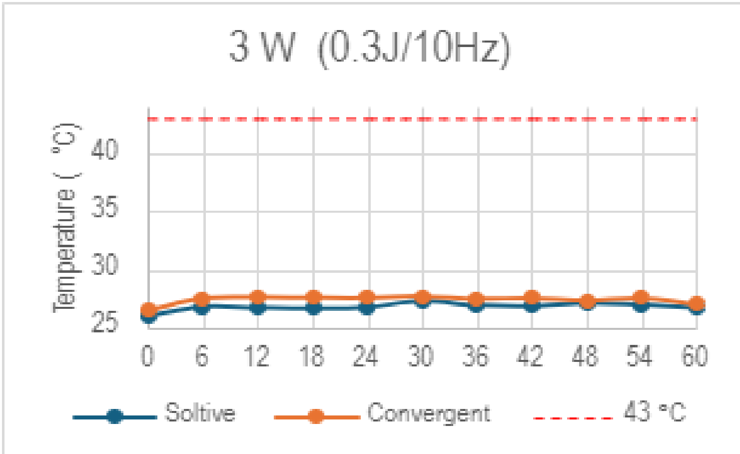

Figure 1

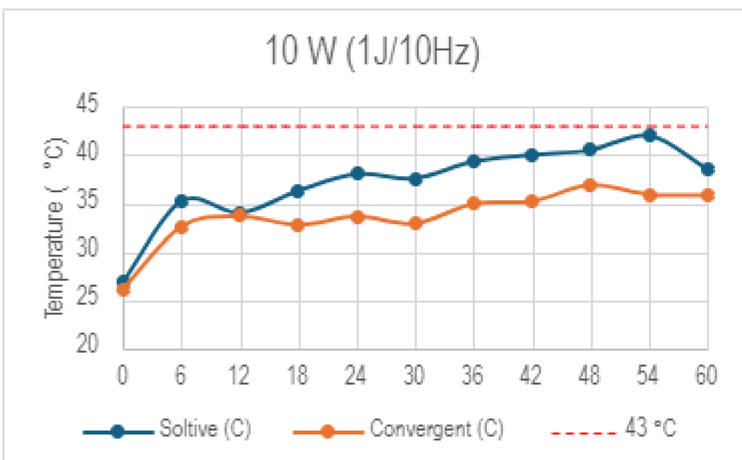

Figure 2

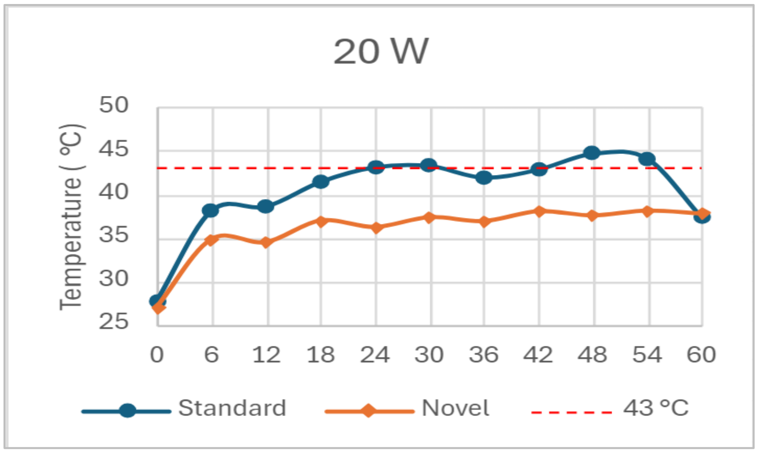

Figure 3

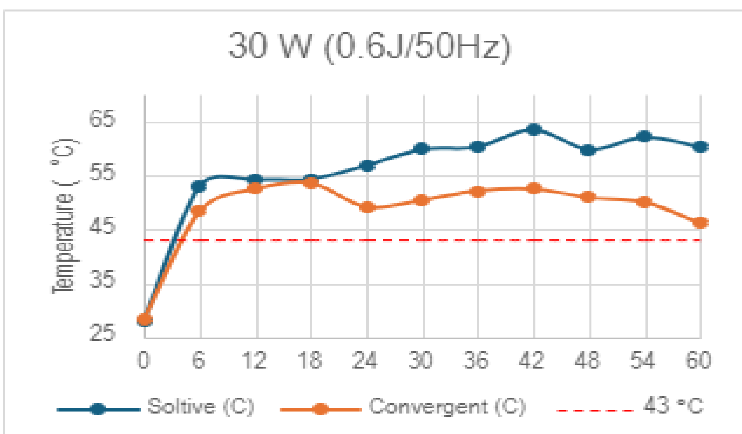

Figure 4

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