TEMPERATURE GENERATION OF KTP AND ND:YAG LASERS WHILE APPLIED ON RAT LIVER

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Abstract

As the laser produces its biological effects on tissue converting the light energy into heat energy, we experimented the effectiveness of KTP laser in cutting liver tissue in comparison to Nd:YAG by recording and evaluating the generated heat during application on rat liver. Eleven -week old male Wistar rats were used in the experiment. Comparisons were made at different energy levels (5-14 watts) at different time limits (1-8 sec). Only noncontact (working distance 5 mm) application was used. The KTP/YAG Surgical Laser System (Laserscope®, California), was used with a 0.4 mm diameter bare fiber for both KTP and Nd:YAG laser delivery. The temperature generation during the application was recorded by a Thermotracer® (TH1000, Nippon Denki Sanei, Tokyo), which had a recordable temperature range from 100 to 600°C. Temperatures at the center of lesions as well as 0.25, 0.50, 0.75, 1.00 and 1.25 mm from the center for every seconds through 1st to 8th were recorded. In case of KTP, temp. at the beginning was much higher than at the 8th sec. As for example the temp at the center of the lesions at 2nd sec. for 5 watt of KTP was 287.53±22.56 whereas for YAG was 129.16±26.02 (P value is <0.001). But the temp at the center at 8th sec for 5 watt of KTP was 327.52±37.12 and that for YAG was 271.28±28 (P values are <0.05). Analysis of the result showed that the KTP had always a rapid and faster rise of temperature at the center than YAG. At the other 5 points of recording, KTP and YAG showed little differences in radiation of temperature laterally. KTP shows a sharper lateral fall of temperature despite a greater temperature at the center than those of YAG. To justify the above results we have experimented the absorption of both lasers light in bile juice, blood, the two major liquid components of liver and blood contents such as plasma and serum. We also studied the absorption and transmission of light in the same materials of different wavelengths by a spectrophotometer. All the results showed a greater and remarkable absorption of KTP laser in blood and bile juice, which causes a greater heat production and less scatter. The above results justified the faster and sharper cutting effects of KTP laser on rat liver in comparison to that of YAG laser.

Introduction

The application of laser in liver surgery has long been studied after the introduction of this energy delivery system as a surgical tool. The cutting, coagulating and vaporizing capabilities of surgical laser give a number of advantages over scalpel and electrosurgical instruments in the practice of general surgery. Although the basic nature of surgical lasers is identical every laser has its own characteristics, cutting-coagulating capacities. That is the reason why surgeons are still in search of the best suitable laser in general surgical procedure. Potassium Titanyl Phosphate Laser (KTP), the latest surgical laser having a wavelength of 532 nm which produces a visible green light. Very scanty data have been published concerning the efficacy of use of KTP laser in general
surgery and as yet, no data is seen on the effects of the application of this laser on liver tissue. So in this study we experimented the mode of temperature generation of KTP and YAG laser in a comparative fashion while applied on rat liver. At the same time we experimented the absorption of the both lasers in the major liquid components of liver to correlate the thermal effect of them on liver tissue.

Material and Methods

Eleven-week-old male Wistar rats, weighing between 330 to 350 gm were used in the experiment. On the day of the experiment the rats, having fasted overnight, were transported to the experiment room. The rats were anesthetised by intraperitoneal injection of pentobarbital sodium (30 mg/kg). Inhalation anesthesia by ether was avoided for any probable combustion accident due to the presence of inflammable ether gas. After anesthesia each animal was placed in a supine position on a wooden block and the whole anterior abdominal wall was shaved with blades. With a long incision in the anterior abdominal wall the liver was exposed. A small gauze bolster was placed under the thorax causing the liver to fall slightly forward away from the diaphragm. The median lobe, the left lateral lobe and the right lateral lobe of the liver were selected for laser application.

The KTP/YAG Surgical Laser System (Laserscope, San Jose, California), which has the option for accessing either the KTP or the Nd:YAG energy independently within few seconds, was used. For laser delivery 0.4 mm diameter bare fibre was used and a perfect beam was maintained by cutting the end of the fibre when seemed necessary.

The temperature generation during the application was recorded by a Thermotracer® (TH1000, Nippon Denki Sanei, Tokyo), which had a recordable temperature range from 100 to 600°C. A highly sensitive camera displays the temperature of the center of the wound and its surrounding by different colors in a monitor. Both KTP and Nd:YAG lasers were applied with different power settings of 5, 7, 10 and 14 watts. The time limit of the application for recording of generated temperature was 8 sec with a continuous non-contact (working distance 5 mm) mode. Temperatures at the center of lesions as well as 0.25, 0.50, 0.75, 1.00 and 1.25 mm from the center for every seconds through 1st to 8th were recorded. This allowed us to understand the rate and mode of the rise of temperature in case of both KTP and YAG laser. Since only surface temperature was recorded, contact application was not included for temperature study. Five rats were used in this experiment and each type of application was repeated for 5 times (n=5) and the average temperature of each second for each type of application was calculated and compared.

The absorptions of both KTP and YAG lasers in human bile juice, diluted total blood, total human blood plasma and total human blood serum were studied. We also studied the wavelength-dependent absorption of light in the same materials. The absorption and transmissivity were studied in this phase of experiment, to get a relative impression of the thermal effects of both lasers as well as the lights of different wavelengths. In the first experiment we used a powermeter (Coherent, Fieldmaster) to detect the laser light after passing through the respective materials. A power detector (Coherent, LM45) has received the remaining amount of laser light after passing through a glass cell (which is used in Hitachi Spectrophotometer) containing bile juice, blood etc. and the powermeter displayed the amount in watts after absorption in the material. The same KTP/YAG Surgical Laser System was used for both lasers, delivered through bare fiber. The glass cell is measured 12.5X12.5X45.1 mm³ in size and the thickness of the glass is 1.3 mm. The power meter was calibrated by delivering 5 watts of KTP and YAG lasers directly on the detector. Distilled water was taken as the control material for the study and placed in front of the detector after pouring into the cell. The transmissivity through the glass cell containing distilled water was regarded as 100%. The fiber tip was placed 15 mm apart from the detector. The transmissivity of laser light was checked for each material for 3 times and the average reading was taken for calculation.
Results

Of temperature recording:

The recorded temperature showed that, for KTP application the temp. is much higher at the beginning in comparison to YAG whereas the temp on the 8th sec. showed close approximation for both lasers. As for example the temp at the center of the lesions at 2nd sec. for 5, 7, 10, and 14 watts of KTP were 287.53±22.56, 318.78±17.10, 337.52±21.18 and 292.52±27.72 respectively, whereas for YAG were 129.16±26.02, 171.22±12.94, 212.50±64.22 and 217.52±30.77 respectively (P values are <0.001, <0.001, <0.01 and <0.05 respectively). But the temp at the center at 8th sec for 5, 7, 10, and 14 watts of KTP were 327.52±37.12, 363.78±10.27, 367.52±29.1 and 327.52±36.6 respectively and those for YAG were 271.28±28, 300.02±13.28, 332.52±13.54 and 361.28±14.93 respectively (P values are <0.05, <0.01, >0.05 and >0.05 respectively).

Analysis of the result showed that the both lasers generated a temperature of about 300 to 400°C in the 8th second and caused variable amount of vaporization. KTP had always a rapid and faster onset of temperature than YAG (shown in tables and graphs). The peak temperature was always found in the center in case of both lasers and greater temperature generation was found by the KTP laser (photographs). At the other 5 points of recording, KTP and YAG showed little differences in radiation of temperature laterally. KTP shows a sharper lateral fall of temperature despite a greater temperature at the center than those of YAG. Since the Thermotracer we used could only record the temperature of a range from 100°C to 600°C, the most lateral point of temperature recording was also at the state of water steaming and vaporization.

Of the study of the absorption of the laser light

In the first experiment, the absorption of KTP laser light was higher in all four specimen viz. blood, bile, plasma and serum. Among those blood showed the highest absorption of KTP, followed by bile, plasma and serum. YAG showed a very poor absorption in all of the above mentioned specimens. In diluted blood and CBD bile juice the transmissivity of KTP laser was 1.6% and 15.9% whereas that of YAG was 90.9% and 97.4% respectively. In plasma and serum the figures were 66.8% and 71.6% in case of KTP, on the other hand 99.3% and 99.1% in case of YAG.

Again in the spectrophotometer study, tracings showed a greater absorption in lights of lower wavelengths, specially below 600 nm. Transmissivity tracings also showed a similar findings.

Since all the results showed a greater and remarkable absorption of KTP laser in blood and bile juice, which causes a greater heat production hence deep vaporization and less scattering in the liver tissue unlike YAG laser. On the other hand due to poor absorption in blood, blood contents and bile juice Nd:YAG laser produces more scattering hence gives wider coagulation and lateral thermal damage.

Absorption of Laser Light in Different Specimen
Discussion

In case of electrosurgery, heat is produced by the spark which is created when the current is passed from the instrument to the tissue. On the other hand laser uses photons, the light energy to produce its effects on tissue. By conversion of these photons from light energy into heat and using this heat on target tissue, laser gives the ultimate biologic effect. Delivering a stream of photons of single color, in a single direction laser helps us to get a unique accuracy and a high doses of energy to the tissue in a very precise way. The bouncing of photons in a tissue site, which is termed as scatter continues until all the photons are converted into heat being absorbed by the tissue or being reflected leave the tissue. As the temperature of the tissue is raised it passes through some stages which are denaturation, coagulation, necrosis and carbonization and vaporization or the loss of tissue. Extent of these changes certainly depends on the character of temperature generation. Where vaporization gives the the ultimate cutting effect of laser, it is always associated with coagulation which causes hemostasis. In fact hemostasis can not be achieved unless lateral thermal damage is created.

In this study we have compared the rate and mode of temperature generation by KTP and YAG lasers and their effects regarding the vaporization as well as lateral thermal damage while applied on rat liver. The character of temperature generation is always responsible for the type of cutting and coagulating capabilities.

The most important optical parameter is the wavelength-dependent absorption of biologic molecules. Any light that hits the tissue will produce a combination of 4 effects, reflection, absorption, scatter and transmission. Of all these effects, scatter is the most important. The light scatters around the tissue until it is eventually absorbed. So, to consider the thermal effect on liver tissue we must think about the absorption in liver tissue as well as its major components such as blood, bile juice etc. In the second stage of our experiments we could find a supportive result of higher absorption of KTP laser in blood and bile juice, two most important liquid contents of liver than that of YAG. High absorption leads to very efficient energy transfer and heating of the tissue during irradiation. Scattering effect becomes more when the absorption is poor. So the less absorption of YAG laser in the contents of liver, produces more scatters of light in the surrounding tissue which gives larger lateral thermal damage. But KTP produces deep and sharp cutting wound because of its high absorption into the contents of liver but sometimes limited in its coagulation abilities.

Conclusion

In our experiment a number of conclusions can be drawn that KTP laser has the capability of producing a greater heat in a faster way than that of Nd:YAG laser in rat liver. This confirms that KTP can give a greater vaporization effect, hence deeper cutting capability. Also the difference in absorption of the two types of laser light in the important tissue components of liver, hence capacity of scatter production also confirms the unique differences of the basic characters of the two surgical lasers. While KTP cuts well, YAG provides a good hemostasis and that is why a combination of both effects might be helpful in liver surgery.

References