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Conceptual Paper

Laser and Radiofrequency Energy Applications in the Percutaneous Endoscopic Surgical Treatment of Degenerative Disc Disease: Should be abandoned?

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The word LASER stands for Light Amplification by Stimulated Emission of Radiation. According to this abbreviation that summarizes the energy generation; it is the light that occurs when the crystal between two full and semi reflective mirrors is exposed to intensified energy amplification the type of laser is named with the substance in the liquid crystal [1, 2]. Laser was first applied in the musculoskeletal system w by Whipple in 1984 using C02 laser. Classification according to the laser optic parameters (wavelength, power and dose) was developed in clinical trials after that date [1, 3]. Laser is known to change cell proliferation, motility and secretion at different doses. Tissue interaction can occur in the form of destruction, liquification, heating and evaporation depending on dose. The type of laser commonly used for the musculoskeletal system is resonance type which can be classified as follows [2];

1. UV Laser (Excimer).
2. Visible Laser (Argon).
3. IR Laser (Ionization Resonance).

C02
YAG: (Yttrium-Aluminum Garnet) o Neodmium o KTP Doubled Neodmium (Potassium-titanyI-Phosphate) o Holmium, Erbium.

Argon laser is absorbed well by hemoglobin and creates effect by exerting heat in the tissue. This effect results in the apoptosis after oxygen is activated in cell nucleus. This is the basis of photodynamic treatment. Excimer does not create heat, breaks molecular connections; that's why it is called cold laser. With C02, high power is generated at low frequencies, it is absorbed by water. Superficial effect occurs without penetration. Nd YAG has the highest penetration and coagulation effect.

The effect of laser energy is categorized into three stages [2].

1. Photo-thermal: Coagulation, necrosis and evaporation.
2. Photo-chemical (Argon, Excimer): Connective structures change as a result of the molecular absorption of the energy. It is advantageous in the treatment of metabolic active tissues (like tumors).
3. Photo-mechanical effect is the combination of ultraviolet and infrared effect at short waves and low frequencies. Tissue reacts to rapid ionization and "Acoustic shock wave" effect occurs. De-

struction-cutting power is created with this mode even on bones.

Radiofrequency energy is a shortwave sound energy. Like in the light energy, physical state changes in proportion to the tendency of the object focused by the energy reaching the amplified shortwave length gets into unstable state. Explained with the conversion to thermal energy, this energy is the basis of cooking mode of microwave ovens [4, 5].

The thermal effect of radiofrequency energy is frictional. There two different effects: ohmic and dielectric. Ohmic effect develops at frequencies below 500 mHz. Dielectiric effect occurs above 500 mHz, where microwave destructive effect develops. 1300 mHz ohmic effect of radiofrequency energy is used for musculoskeletal system [4].

Covalent bonds of tissues can be broken in a dose dependent manner with radiofrequency (RF) energy (relaxing-cutting), can be evaporated completely or new bonds (corrugation-shrinking) can be created. The ohmic effect created in medical practices by increasing and decreasing the frequency allows clinicians to intervene with less complicated options compared to laser. However, its destructive effect is limited in soft tissues.

To know which energy should be used how and at which frequencies in the musculoskeletal system, one should know the chemical and physical outcomes of these energy modes on tissues and choose the mode accordingly. Penetration is the most important limiting factor in both energy types. The reason why Holmium YAG is preferred for laser applications in orthopedic surgery is because it provides mechanical advantages despite low penetration [5, 6, 7, 8].

With Holmium YAG laser, thermal penetration and thus necrosis decrease, but it can be used due to the other advantages of this type of energy. In addition to acoustic shock effect, thermal coagulation, evaporation, corrugation and bleeding control can be achieved by extremely decreasing tissue penetration. Especially during minimally invasive endoscopic procedures, its effect on areas that cannot be reached with mechanical devices is indispensable in arthroscopy, tenoscopy and foraminoscopy.

Thermal therapy used since Hippocrates revived with laser and radiofrequency applications. Thermal effect is created as protein denaturation at 40-70 degrees, coagulation at protein 70-85 degrees, vacuolization at 85-100 degrees, evaporation at 100 degrees and carbonization at 400 degrees. Living tissues starts dying at 45 degrees and 45 degrees is the temperature where the effect just starts for RF effect. For radiofrequency thermal effect to result in irreversible tissue contraction, energy to create heat at 60-75 degrees should be transferred. This effect occurs by 30% at 50 degrees for 5 minutes, 36% at 62 degrees and more than 50% after 65 degrees. With thermal effect, the helix structure converts to gel form through protein denaturation and decreases its volume, tissue shortens and gives morphological response. This effect is briefly called ‘’ablation’’ [3, 4].

Functional results of thermal effect are almost perfect in tissues with regeneration capability. It contributes to healing process in capsules, connective and tendinous structures while functional expectations are met in the are limited by RF during remodeling. However, cellular necrosis that occurs due to thermal effect is irreversible in structures such as cartilage and intervertebral discs. Therefore, mechanisms have been developed to generate energy that is created at high temperatures with monopolar electrocautery tips by using bipolar radiofrequency tips at low temperatures, which provides coagulation and ablation at the same time. For example, ablative effect occurs with a spark depending on the shape of the probe. The shape of the monopolar tip or energy transferred without spark with bipolar tips provides non-ablative RF energy application. Bipolar effect which provides coagulation and plasma generating ablative effect (non-ablative) is coagulation ablation: coblation. Coblation effect provides plasma conversion at low temperature, which is different from multipolar radiofrequency. This can be called cold ablation [3, 4, 9, 10, 11, 12].

Therefore, there two types of radiofrequency application:

1. Monopolare.
2. Bipolar: Coblation-plasma effect-cold ablation.

Coblation is groundbreaking in intradiscal pressure decreasing and nucleoplasty treatment while it has good outcomes in selected cases. Today, it is the first choice of clinicians in practice due to the effect created by intradiscal ring in cervical disc protrusion. With an average ten-minute application of cervical coblation wand at four directions, a 2mm cavity is created and volume is decreased by 10%.

In the lumbar region, coblation nucleoplasty effect is created by opening canals. With coblation, 6 canals are opened on average, which may be enough to decrease the disc pressure. Plasma debris cannot be removed in radiofrequency nucleoplasty, which should be considered as a disadvantage compared to mechanical nucleoplasty, thus intradiscal cefazolin should be added to discography performed prior to that. Residual debris may lead to discitis.

Intradiscal therapies

Laser therapy for protruded discs that was launched by Choy and Asher in 1986 by decreasing disc pressure through vaporization in nucleus pulposus was then named as "percutaneous laser disc decompression" (PLDD) [2, 12]. Multi-Centre trials including hundred thousand cases so far show that complications of laser probe such as endplate thermal necrosis, root injury and discitis are statistically insignificant. In properly performed applications at doses and frequencies in parallel to the endplate and in accurately selected cases, complications are very few. However, tetraplegia cases after cervical application reported by authors such as Martin Knight raised questions about thermal penetration in spinal cord and radiation safety [1, 11].

PLDD is the procedure in which 400-1000 joule Nd YAG laser energy is transfered into the disc for 10-30 minutes. This last for 1-2 minutes in KTP laser. Richley used Holmium and transferred a total energy of 1200-2000 joule and reported success rate of 88%. Neodymium has twice higher ablation depth and thermal effect compared to Holmium. Higher water absorption and removal of water from the area increase thermal effect, leading to carbonization. Thermal effect can be decreased by right frequency selection and relapse time. Varying depending on wavelength, this is 1200 joule in total at 10-15 watt, 10 hertz relapse time in Holmium YAG laser. Casper recommends total energy of 1200 j at 13 Watt, 10 Hertz for 5 minutes of relapse time. Table 1 shows the acceptable doses proposed after multi-center trials [3, 11, 12, 13, 14, 15, 16, 17].

Another concern associated with residual debris caused by thermal effect in intradiscal therapy was eliminated with the use of Laser Assisted Spine Endoscopy (LASE) in practice [14] (Figure 5). Annuloplasty was achieved with percutaneous intervention that also provides image and irrigation in addition to laser, and debris could be removed. In the lumbar region, distance of laser energy to the annular region does not cause any problem during sub annular decompression and annuloplasty, whereas 10 mm distance to the posterior longutinal origin is the operational limit during cervical application. Sang-Ho Lee et al. suggests max energy of 10-watt max, 10-15 hertz in the cervical region. The same safe range should be preferred for the lumbar region as well. Non-ablative limit is the energy transfer not exceeding 500 joule at one shot at a frequency of 10 hz and relapse time of 5 seconds [15, 16]. Chiu recommends gradual energy transfer during thoracic disc laser application. He recommends that it should start at 10 watts at non-ablative degrees, be reduced to 5 watt and the transferred energy should be decreased to 300 joule (12 hz). Vaporization is the target at the first phase, while at the second phase only shrinkage and hardening are targeted. Sino vertebral neurolysis and denervation are proven by decreased pain at the second stage reported by patients. Chiu recommends mechanical removal of debris and endoscopic control [10].

Intradiscal applications of radiofrequency energy are available in the market in a range from monopolar RF IDET energy to coblation probes. In IDET therapy, sub annular heating up to 85 degrees achieves annuloplasty and nucleoplasty while the thermal effect transmitted to the tissue was measured at 55 degrees. This temperature reaches 30 degrees in the epidural distance. Pain of patients during application should be taken into consideration even if it is sclerotomal and energy should be stopped (Figure AD) [12, 14, 15, 18].

Coblation provides safer nonthermal effect. Especially its cervical application tips are advantageous. While coblation running on mechanical-coblative principles by opening canals in the lumbar region, its radiation effect in the cervical region is more in the forefront. Both radiofrequency effects decrease pressure [12].

Percutaneous endoscopic applications

As a result of the endoscopic laser applications that started in parallel to the description of percutaneous endoscopic surgery by Hijikata and Kombin and continued with Yeung and Knight, the concept of foraminoplasty was described.

Brutal surgical results of lateral spinal stenosis can be negligible given the endoscopic detection or removal of foraminal stenosis. The problem of excision of structures such as bones-osteophytes during foraminoplasty was eliminated with the shock wave effect of the laser. The destructive effect created through the constant application of 30-40 w 10 Hz energy directly on bone not only is sufficient to achieve decompression but also eliminates situations that prevent imaging such as bleeding-debris formation [13, 19, 20].

The use of radiofrequency energy in endoscopy facilitates excision of annular fibrils, relaxation of nucleus fragment and stopping epidural bleeding. Therefore, both energy types are preferred in endoscopic discectomy [20].

One should be selective in choosing laser or radiofrequency energy in spinal endoscopic surgery.

The same application where coblation method is safe and effective in cervical protrusions during intradiscal applications can be performed on condition that it is limited to protrusion in especially asymmetrical localized foraminal lumbar herniation. In extensive central and diffuse protrusions, monopolar IDET application can be preferred. On the other hand, laser nucleoplasty can be combined in painful discography. Successful clinical outcomes have been reported with this application which can remove annular relaxation and decrease pressure in nucleus with laser plasma effect.

Mechanical nucleoplasty is recommended especially for cases with protrusion and minimal extrusion in addition to annular tear in the lumbar region. Lee et al. reported that they also relieved the compression secondary to plastic annular deformation by performing sub annular LASE annuloplasty after mechanical nucleoplasty. Shortly in Turkey, it will be possible to relieve posterior compression with selective annuloplasty through LASE. In endoscopic spinal surgery, bipolar RF probe is very helpful in the excision of tissues holding the extruded disc in addition to bleeding control. It is not preferred to excise these tissues with mechanical devices as bleeding will distort the field of vision. On the other hand, after the disc is excised, treatment is reinforced with sub annular RF application.

Contralateral protrusion can be intervened during sub annular application of laser while also annuloplasty is possible but LASE should be preferred for safety. Moreover, LASE may be a robust alternative to mechanical nucleoplasty as it also allows removal of debris. Thanks to excision of osteophytes during foraminoplasty and decompression through the resection of foraminal ligament, superiority of laser is disputable [14]. Given that foraminoscopic shaver applications provide limited options and cause bleeding, it is clear that laser application will continue to be an integral part of foraminoplasty.

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