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Minerva Ginecologica 2018 February;70(1):53-7
DOI: 10.23736/S0026-4784.17.04101-6

ORIGINAL ARTICLE

Flexible CO_2 laser fiber: first look at the learning curve required in gynecological laparoscopy training

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ABSTRACT

BACKGROUND: The advent of flexible CO_2 laser fiber to gynecology arena might represent a turning point in the use of laser energy on a large-scale basis in gynecological surgery. However, there might be some concerns regarding the degree of surgical skills required to use the flexible system. The purpose of our study is to evaluate whether flexible CO_2 laser fiber is technically accessible.

METHODS: Fourteen residents in Obstetrics and Gynecology without surgical experience attending laparoscopic box training with both flexible CO_2 laser fiber and traditional line-of-sight CO_2 laser using Lumenis AcuPulse Duo CO_2 laser (Lumenis, Yokne'am Illit, Israel) were prospectively enrolled. Participants were tested at sequential time points on specific surgical tasks and results obtained with the flexible CO_2 laser fiber and the traditional line-of-sight CO_2 laser were compared. Results were compared by means of paired *t*-test and a two-tailed P value <0.05 was considered significant.

RESULTS: Mean grading at the beginning of training were similar between flexible fiber and line-of-sight CO_2 laser. At the end of training, significant improvement in surgical skills was obtained for both techniques, with a statistically significant higher grading for flexible fiber CO_2 laser compared to line-of-sight CO_2 laser.

CONCLUSIONS: Our study found that residents without surgical experience show better skills with the flexible CO_2 laser fiber delivery system compared to the standard line-of-sight CO_2 laser system after a two-month training period with gynecological laparoscopic box. According to our results, flexible CO_2 laser fiber delivery system is technically accessible and holds a potential in gynecological surgery.

(*Cite this article as:* Vanni VS, Ottolina J, Candotti G, Castellano LM, Tandoi I, De Stefano F, *et al*. Flexible CO_2 laser fiber: first look at the learning curve required in gynecological laparoscopy training. Minerva Ginecol 2018;70:53-7. DOI: 10.23736/S0026-4784.17.04101-6)

Key words: Laparoscopy - Laser - Fiber optic technology - Learning curve.

The narrow emission of power that characterizes laser surgery allows minimization of damage inflicted to surrounding structures, holding a great potential in ovarian fertility-sparing surgery where damage to the ovarian cortex can result in a significant impairment of a patients' ability to conceive.[1-4] As a matter of fact, laser energy has already been shown to have a better safety profile in terms of surrounding tissue damage compared to electrocoagulation, in both animal and human models.[3, 5, 6] However, a widespread application of laser energy in gynecological surgery has so far been cumbered by the relatively limited maneuverability and long learning process of the traditional line-of-sight laser systems.[4] The precision of laser energy has thus been hindered by the relatively higher difficulty to

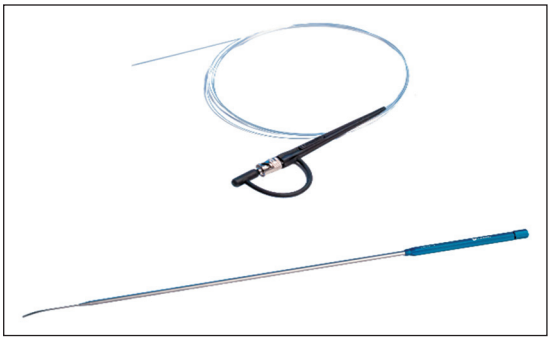

Figure 1.—Flexible CO_2 laser fiber delivery system. The flexible CO_2 laser fiber is maneuvered through a carrier which is a rigid handpiece that leaves only the tip of the fiber uncovered.

access constrained anatomical spaces.[3] For this reason, flexible CO_2 laser fiber delivery systems have been designed with the intent to allow a higher degree of movement and thus a more versatile, precise and easy to use technique compared to line-of-sight laser systems (Figure 1). Intuitively, a flexible CO_2 delivery system grants a higher anatomical access compared to traditional line-of-sight laser systems, and some preliminary experiences have been published on the use of flexible fiber laser in gynecological robotic surgery, with encouraging results.[4-7] Thus, the recent advent of flexible CO_2 laser fiber to the gynecology arena might represent a turning point in the use of laser energy on a large-scale basis in gynecological fertility-sparing surgery, as already occurred in other surgical settings (*i.e.* neurosurgery, otolaryngology).[8-10] However, the introduction of a flexible laser-delivery system might itself rise some obstacles in the adoption of this technology — the first being the degree of surgical skills required from a novel surgeon to safely and efficiently use the flexible system. On this basis, we sought to establish whether flexible CO_2 laser fiber is indeed technically accessible enough to be a candidate for a large-scale adoption by novel users in gynecological surgery.[11, 12] For this reason we designed a prospective study including residents without laparoscopic surgical experience (*i.e.* residents starting their gynecological laparoscopy practice) who were trained with a gynecological laparoscopic simulator over a two-month period with both flexible CO_2 laser fiber and traditional line-of-sight CO_2 laser. Surgical skills, improvement and confidence of the residents were evaluated throughout and at the end of the training period with both flexible CO_2 laser fiber and traditional line-of-sight laser, and gradings obtained with the two techniques were compared.

Materials and methods

Fourteen residents of Obstetrics and Gynecology at San Raffaele Scientific Institute for Reesarch and Care (Milan, Italy) without surgical experience (*i.e.* residents aged 26-27 starting their gynecological laparoscopic surgery practice) attended repeated laparoscopic box training sessions, twice weekly over a two-month period, using both free-beam line-of-sight CO_2 laser and flexible CO_2 laser fiber (using Lumenis AcuPulse Duo laser, Lumenis, Yokne'am Illit, Israel). Each session consisted in 7 hours of training (*i.e.*, 30 minutes of training per participant, 15 minutes approximately with each device) on incision/ablation skills on a bull testicle in a gynecological simulator. Sequential evaluations - approximately one every ten days, *i.e.* after two consecutive training sessions - were carried out as follows (Evaluation 1 through 6, with Evaluation 1 being the first and Evaluation 6 being the last): at each assessment, participants were tested by a single evaluator (*i.e.*, an experienced senior gynecological laparoscopy surgeon) on five different incision/ablation surgical tasks on a 3×3-cm area on the bull testicle (accuracy on edges of shape, accuracy within the shape, eye-hand coordination, homogeneity in speed, homogeneity in tissue depth). Each task was graded in a scale of 1 to 5 (1 representing the minimum grade and 5 representing the maximum grade) and at each assessment residents were graded on all tasks with both free-beam line-of-sight CO_2 laser and flexible CO_2 laser fiber (Lumenis AcuPulse Duo laser, Lumenis). Mean grading per each technique was calculated as the mean grading obtained on the five different tasks. Number of errors performed during the test (such as protruding

the boundaries of the shape, missing eye-hand coordination, accidentally accelerating/stopping the movement or reaching too deep) and error severity were also measured on the scale of 1 to 5 (1 representing the minimum severity and 5 representing the maximum severity) and recorded per each technique.

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. Formal ethical approval was not required due to the nature of the study. Informed consent was obtained from all individual residents who participated in the study.

Statistical analysis

Results were compared by means of Paired *T*-test and a two-tailed P value <0.05 was considered significant.

Results

Table I shows participants' baseline skills as graded by the evaluator at Evaluation 1.—As shown, mean basal grading (3.1±0.7 for fiber laser *vs.* 3.0±0.8 for line-of-sight CO_2 laser, P=0.8) as well as all single baseline grading (accuracy on edges of shape, accuracy within the shape, eye-hand coordination, homogeneity in speed, homogeneity in tissue depth, Table I) were similar between flexible fiber and line-of-sight CO_2 laser. Similarly, both the mean number (1.2±0.4 *vs.* 1.6±1.0) and mean severity of errors (1.8±1.0 *vs.* 2.1±1.4) were similar between flexible fiber and line-of-sight CO_2 laser respectively at baseline. Figure 2 shows the learning curve of both flexible CO_2 fiber and line-of-sight CO_2 laser from baseline (Evaluation 1) to the last evaluation (Evaluation 6) as expressed by mean grading. Compared to baseline (Evaluation 1), residents achieved a significant improvement in the mean grading at Evaluation 2 for line-of-sight CO_2 laser (3.7±0.6 *vs.* 3.0±0.8, respectively; P<0.01), and at Evaluation 4 for the flexible fiber CO_2 laser (3.9±1.0 *vs.* 3.1±0.7, respectively; P=0.01). At the end of the two-month-period of training, the significant improvement in surgical skills was maintained for both flexible fiber (mean grading 3.1±0.7 *vs.* 4.5±0.5 at Evaluation 1 and 6, respectively; P<0.01) and line-of-sight CO_2 laser (mean grading 3.0±0.8 *vs.* 4.2±0.6 at Evaluation 1 and 6, respectively; P<0.01) (Figure 2). Concordantly, both the mean number (0.1±0.3 *vs.* 1.2±0.4; P<0.001 for fiber laser and 0.3±0.5 *vs.* 1.6±1.0; P<0.001 for line-of-sight) and mean severity of errors (1.1±0.3 *vs.* 1.8±1.0; P<0.001 for fiber laser and 0.9±0.3 *vs.* 2.1±1.4; P<0.001) were decreased for both

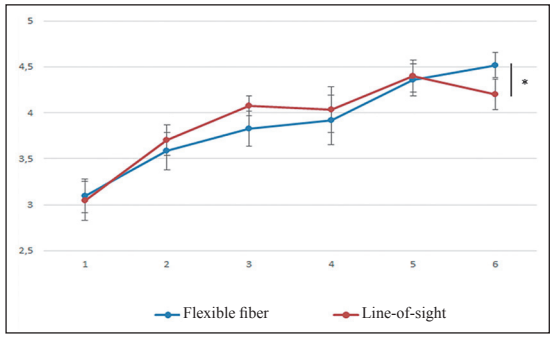

Figure 2.—Learning curve of flexible CO_2 fiber and line-of-sight CO_2 laser. Learning curve of both flexible CO_2 fiber and line-of-sight CO_2 laser from baseline (Evaluation 1) to the last evaluation (Evaluation 6) as expressed by mean grading. When comparing the two techniques at the end of the two-month-period of training, a statistically significant higher mean grading was observed for flexible fiber CO_2 laser *vs.* line-of-sight CO_2 laser.

TABLE I.—*Beginning of training (evaluation 1).*

Surgical skills grading	Fiber laser	Line-of-sight laser	P value
Mean grading	3.1±0.7	3.0±0.8	0.8
Accuracy on edges	2.6±1.0	2.7±1.1	0.8
Accuracy within the shape	3.6±0.5	3.4±0.7	0.3
Eye-hand coordination	3.2±0.9	2.9±0.7	0.3
Homogeneity in speed	2.9±0.9	3.1±0.9	0.5
Homogeneity in depth	3.1±0.9	3.0±0.9	0.8

Data is presented as mean±SD.

TABLE II.—*End of training (evaluation 6).*

Surgical skills grading	Fiber laser	Line-of-sight laser	P value
Mean grading	4.5±0.5	4.2±0.6	0.03*
Accuracy on edges	4.3±0.5	4.1±0.7	0.3
Accuracy within the shape	4.6±0.7	4.3±0.8	0.3
Eye-hand coordination	4.3±0.7	4.1±0.6	0.2
Homogeneity in speed	4.7±0.7	4.3±0.8	0.1
Homogeneity in depth	4.7±0.5	4.2±0.8	0.05

Data is presented as mean±SD.

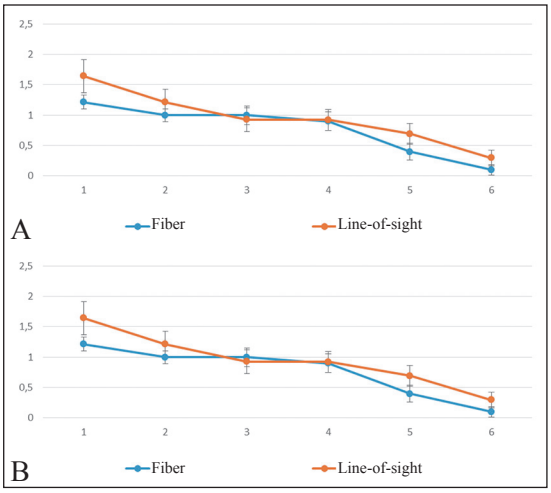

Figure 3.—Mean number (A) and mean severity (B) of errors throughout training with both flexible CO_2 fiber and line-of-sight CO_2 laser. No significant differences were noted when comparing the two techniques at the end of the two-month-period of training.

techniques at evaluation 6 compared to baseline. Table II shows the comparison between the two techniques at the end of the surgical training: all single skill gradings at evaluation 6 resulted higher with flexible fiber CO_2 laser than with line-of-sight CO_2 laser, resulting in a statistically significant higher mean grading at the end of the two-month-period of training (4.5±0.5 for flexible fiber CO_2 laser *vs.* 4.2±0.6 for line-of-sight CO_2 laser, respectively; P=0.03) (Table II, Figure 2). In contrast, no differences were noted between the two techniques in terms of number and severity of errors at Evaluation 6 (Figure 3A, B).

Discussion

Our study — the first to describe the learning curve of a flexible fiber CO_2 laser delivery system — found that Obstetrics and Gynecology residents without surgical experience showed better skills using the fiber device compared to the traditional line-of-sight CO_2 laser system after a two-month period of pelvic box training. Based on our results, flexible fiber CO_2 laser in pelvic surgery might therefore allow increased maneuverability compared to standard line-of-sight laser. Our study was aimed at investigating whether flexible CO_2 laser fiber delivery system should be considered technically challenging, and the findings thus reassure the adoption of the flexible CO_2 laser fiber delivery system in gynecological laparoscopy from the perspective of its technical accessibility. As one would assume such a flexible device to require a relatively higher surgical ability compared to the standard line-of-sight system, our results are somewhat unexpected. However, the flexible fiber CO_2 laser is maneuvered through a carrier which is a rigid handpiece that leaves only the tip of the fiber uncovered (Figure 1), making this flexibility well controlled. The small dimensions of the rigid handpiece also likely contribute to the ease-of-use of the flexible CO_2 laser fiber compared to the standard line-of-sight CO_2 laser system. Nonetheless, it should not be disregarded that a longer time was needed to achieve a significant improvement with the fiber CO_2 laser compared to the standard line-of-sight system. In fact, residents in our study achieved a statistically significant improvement in their surgical skills already at Evaluation 2 using the line-of-sight laser (*i.e.* after two training sessions) and at Evaluation 4 using the flexible fiber system (*i.e.* after six training sessions). This observation likely indicates that the flexible fiber does indeed require some more dexterity but that this is successfully obtained over a limited period of training. Thus, our findings suggest that even if a slightly longer learning curve might be expected for the implementation of flexible fiber CO_2 laser system compared to standard line-of-sight CO_2 laser systems, better surgical skills can be achieved using the fiber device compared to the traditional line-of-sight laser system. Even if laparoscopic box model training is recognized to be an effective tool for the assessment and improvement of technical skills in trainees with no previous laparoscopic experience,[13, 14] studies focused on the learning curve and safety of flexible fiber CO_2 laser implementation in the clinical setting are warranted and might allow to enhance the somewhat limited current use of laser energy in gynecological laparoscopy.[12, 15, 16] Also confirmation of our results in larger studies would be of interest, as the relatively small number

of participants included represents a limitation. However, the fact that we used one single evaluator eliminates inter-operator biases and reinforces our results.

Conclusions

In conclusion, based on our data, residents without surgical experience show better skills with the flexible CO_2 laser fiber delivery system compared to the standard line-of-sight CO_2 laser system after a two-month pelvic box training period. Our study shows that flexible CO_2 laser fiber in gynecologic laparoscopy training is more technically accessible than traditional line-of-sight CO_2 laser to unexperienced residents. Hence, flexible CO_2 laser fiber delivery system might hold a clinical potential in gynecological laparoscopy.

References

1. Somigliana E, Benaglia L, Paffoni A, Busnelli A, Vigano P, Vercellini P. Risks of conservative management in women with ovarian endometriomas undergoing IVF. Hum Reprod Update 2015;21:486-99.
2. Wyns C, Donnez J. Laser vaporization of ovarian endometriomas: the impact on the response to gonadotropin stimulation. Gynecol Obstet Fertil 2003;31:337-42.
3. Bailey AP, Lancerotto L, Gridley C, Orgill DP, Nguyen H, Pescarini E, *et al.* Greater surgical precision of a flexible carbon dioxide laser fiber compared to monopolar electrosurgery in porcine myometrium. J Minim Invasive Gynecol 2014;21:1103-9.
4. Choussein S, Srouji SS, Farland LV, Gargiulo AR. Flexible Carbon Dioxide Laser Fiber Versus Ultrasonic Scalpel in Robot-Assisted Laparoscopic Myomectomy. J Minim Invasive Gynecol 2015;22:1183-90.
5. Hendriks ML, van der Valk P, Lambalk CB, Broeckaert MA, Homburg R, Hompes PG. Extensive tissue damage of bovine ovaries after bipolar ovarian drilling compared to monopolar electrocoagulation or carbon dioxide laser. Fertil Steril 2010;93:969-75.
6. Tulikangas PK, Smith T, Falcone T, Boparai N, Walters MD. Gross and histologic characteristics of laparoscopic injuries with four different energy sources. Fertil Steril 2001;75:806-10.
7. Barton SE, Gargiulo AR. Robot-assisted laparoscopic myomectomy and adenomyomectomy with a flexible CO2 laser device. J Robot Surg 2013;7:157-62.
8. Rich JT, Milov S, Lewis JS Jr, Thorstad WL, Adkins DR, Haughey BH. Transoral Laser Microsurgery (TLM)±Adjuvant Therapy for Advanced Stage Oropharyngeal Cancer: Outcomes and Prognostic Factors. Laryngoscope 2009;119:1709-19.
9. Agarwal G, Kupferman ME, Holsinger FC, Hanna EY. Sinonasal and Nasopharyngeal Applications of the Hand-Held CO2 Laser Fiber. Int Forum Allergy Rhinol 2011;1:109-12.
10. Mastronardi L, Cacciotti G, Scipio ED, Parziale G, Roperto R, Tonelli MP, *et al.* Safety and usefulness of flexible hand-held laser fibers in microsurgical removal of acoustic neuromas (vestibular schwannomas). Clin Neurol Neurosurg 2016;145:35-40.
11. Schimizu Y, Takaschima A, Takahashi K, Noboyuki K, Fujiwara M, Murakami T. Long-term outcome, including pregnancy rate, recurrence rate and ovarian reserve, after laparoscopic laser ablation surgery in infertile women with endometrioma. J Obstet Gynaecol Res 2010;36:115-8.
12. Posadzka E, Jach R, Pityński K, Marcin Jacek Jablonski MJ. Treatment efficacy for pain complaints in women with endometriosis of the lesser pelvis after laparoscopic electroablation vs. CO2 laser ablation. Lasers Med Sci 2015;30:147-52.
13. Nagendran M, Toon CD, Davidson BR, Gurusamy KS. Laparoscopic surgical box model training for surgical trainees with no prior laparoscopic experience. Cochrane Database Syst Rev 2014;17:CD010479.
14. Dubuisson J, Vilmin F, Boulvain M, Combescure C, Petignat P, Brossard P. Do laparoscopic pelvic trainer exercises improve residents' surgical skills? A randomized controlled trial. Eur J Obstet Gynecol Reprod Biol 2016;206:177-80.
15. Nezhat C, Crowgey SR, Garrison CP. Surgical treatment of endometriosis via laser laparoscopy. Fertil Steril 1986;45:778-83.
16. Dan H, Limin F. Laparoscopic ovarian cystectomy versus fenestration/coagulation or laser vaporization for the treatment of endometriomas: a meta-analysis of randomized controlled trials. Gynecol Obstet Invest 2013;76:75-82.

Authors' contributions.—Jessica Ottolina, Massimo Candiani, and Stefano Ferrari conceived the idea for the study. Valeria S. Vanni, Giorgio Candotti, Laura M. Castellano, Iacopo Tandoi, Francesca De Stefano, Giorgia Poppi, and Jessica Ottolina participated in data collection and manuscript drafting. All authors read and approved the final manuscript.

Conflicts of interest.—This study was supported through an unrestricted grant from Lumenis Corporate, Yokne'am Illit, Israel, to the San Raffaele Scientific Institute for Research and Care (Milan, Italy).

Article first published online: October 9, 2017. - Manuscript accepted: October 5, 2017. - Manuscript received: June 6, 2017.