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Applications of Co_2 laser in endoscopic surgery for sinonasal neoplasms

Francesco Giombi *, Davide Di Santo, Giuseppe Spriano, Giuseppe Mercante, Fabio Ferreli, Giovanni Colombo

Department of Biomedical Sciences, Humanitas University, Via Rita Levi Montalcini 4, 20090 Pieve Emanuele, Milan, Italy
Otorhinolaryngology Unit, IRCCS Humanitas Research Hospital, Via Manzoni 56, 20089 Rozzano, Milan, Italy

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ABSTRACT

Objective: The aim of the study is to assess safety, effectiveness, and potential advantages of CO_2 fiber laser during endoscopic endonasal surgery for the resection of sinonasal neoplasms.
We present text, images, and videos to show our experience with this new device recently introduced in endoscopic endonasal surgery and as a potential tool for educational purpose.
Methods: Six patients affected by benign or malignant sinonasal tumors who underwent endoscopic resection between January and May 2021 were enrolled in the study.
Surgical approach was conducted via standardized centripetal endonasal technique.
During the surgery we evaluated instrument ergonomics, quality in section on both healthy tissue and tumor, coagulation, and bleeding control from major vessels.
Results: In our experience, CO_2 fiber laser has proved to have good ergonomics, as well as to be a safe and effective tool for the resection of both neoplastic and healthy tissues. Cauterization was efficient only in vessels with average diameter lower than 1 cm.
Prolonged procedural time, costs, and necessity of learning-curve and expertise are possible drawbacks.
Conclusion: Co2-fiber laser is an effective tool which can aid the surgeon during endoscopic endonasal approach to sinonasal neoplasms.

1. Background (0:03–0:23)

Endoscopic endonasal surgery revolutionized the classical external approach to sinonasal and skull base disease. Recently, new surgical devices have improved this technique. The introduction of lasers, due to their minimal invasiveness and high precision, opened new possible frontiers in this surgical technique. CO_2 and diode lasers are two of the most promising tools for both oncologic or functional sinonasal and skull base disease.

2. Objective (0:23–0:33)

The aim of the present study is to assess safety, effectiveness, and potential advantages of CO_2 laser during endoscopic endonasal surgery for the resection of sinonasal neoplasms.

3. Material and methods (0:33–3:17)

The surgical procedures have been performed with SmartXide, which can generate either Diode laser (980 nm wavelength) or CO_2 laser (10.600 nm wavelength). Different characteristics of lasers depend on their different absorption coefficient in each kind of biological tissue. Diode laser is absorbed from both hemoglobin and water and has a continuous emission mode. In tissues, this generates a high lateral thermal damage thus producing an effective coagulation but less precise cut. CO_2 laser has a higher absorption coefficient mainly in water. Emission can be either continuous or pulsed. These characteristics generate poor lateral thermal damage in tissues thus producing a precise cut but a generally less effective coagulation. Diode laser is delivered by a hollow fiber system with a wide range of diameters (from 200 to 600 μm). CO_2 laser can by emitted from a similar hollow-fiber tool, driven by rigid or malleable tip cannulas, or from endoscopic endonasal handpiece. This system consists of a laser focusing handpiece to be attached

* Corresponding author at: Humanitas University, Via Rita Levi Montalcini, 4, 20090 Pieve Emanuele, MI, Italy.
E-mail addresses: francesco.giombi@humanitas.it (F. Giombi), davide.disanto@humanitas.it (D. Di Santo), giuseppe.spriano@hunimed.eu (G. Spriano), giuseppe.mercante@hunimed.eu (G. Mercante), fabio.ferreli@hunimed.eu (F. Ferreli), giovanni.colombo@humanitas.it (G. Colombo).

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posteriorly to the Smartxide articulated arm and anteriorly to an internal hollow waveguide and an external rigid probe. Laser emission can be either straight with 0° rigid probe or angulated with 90° probe. In contrast with diode laser which emission can be only continuous, CO_2 emission mode can be either continuous or pulsed. Emission mode is related to a different temperature increment in tissues. In detail continuous wave emission mode exponentially increases tissues temperature thus producing more lateral thermal damage. This characteristic guarantees good blood coagulation but a less precise cut. On the contrary, pulsed wave emission limits temperature increment and lateral thermal damage and guarantees a more precise and surgical cut with a worse coagulation. According to the frequency, pulsed emission mode can be Ultra-pulsed or High-pulsed. The lower lateral thermal damage is provided by the lower frequencies.

Patients affected by benign or malignant sinonasal tumors eligible for endoscopic resection were enrolled between January and May 2021.

Surgical approach was conducted via centripetal endonasal technique, described by Castelnuovo et al. for the treatment of malignant tumors of the paranasal sinuses and anterior skull base [1]. First step is the "Debulking phase", to reduce neoplasm's volume, increase surgical space and locate the base of implant of the lesion. Second step is the centripetal subperiosteal removal of macroscopically health ethmoidal-nasal mucosa, to allow safe-margins surgery. Third step is the removal of bone underlying the tumor. Finally, fourth step is the removal of the dura, olfactory bulbs, periorbita and eventual skull base duraplasty in case of high staged malignant tumors.

During the surgery we evaluated: Instrument ergonomics, quality in section on both health tissue and tumor, and coagulation and bleeding control from major vessels.

4. Results (3:17–3:35)

From January to May 2021, six patients who underwent endoscopic endonasal surgery were eligible for the study. Three of them had a benign inverted papilloma and three had a malignant neoplasm which on histopathologic report revealed to be intestinal-type adenocarcinoma in two cases and sinonasal melanoma in one case.

4.1. Instrument ergonomics (3:35–4:08)

Patient positioning follows surgical routine, and the machine can be placed behind the surgeon. The cable exits from the machine and easily enters the operating field. The fiber is light and slim so that each anatomical site of nasal cavities resulted easily accessible. CO_2 laser demonstrated good ergonomics. The surgical field has been easily set up. Endoscopic handpieces are thin and slim. Due to the good handling, the first operator adequately performed complete endoscopic exploration of sinonasal cavities in each intervention.

4.2. Quality in section (4:08–7:08)

High-pulsed emission mode provided the higher quality in section. This modality delivers a controlled train of low frequency high-power pulses, minimizing thermal damage to surrounding tissues. This characteristic produces the best quality cut but a worse cauterization and is ideal for health mucosa or poorly vascularized lesions resection.

Health tissue dissection is a necessary step to guarantee free surgical margins. We present our results in the mucosa of the nasal floor, septum, and lateral wall. Approach to health tissue was conducted through 90° angulated probes with 50 Hz pulsed frequency emission mode. Perpendicular dissections guaranteed by 90° angulated probes produced a precise cut, a natural section of mucosa and avoided tissue carbonization often caused by straight probes (Fig. 1).

We tested CO_2 laser with the same low frequency settings even for the removal of poorly vascularized lesions. We present the case of a relapsed Inverted Papilloma of the right nasal fossa. Radiological characteristics

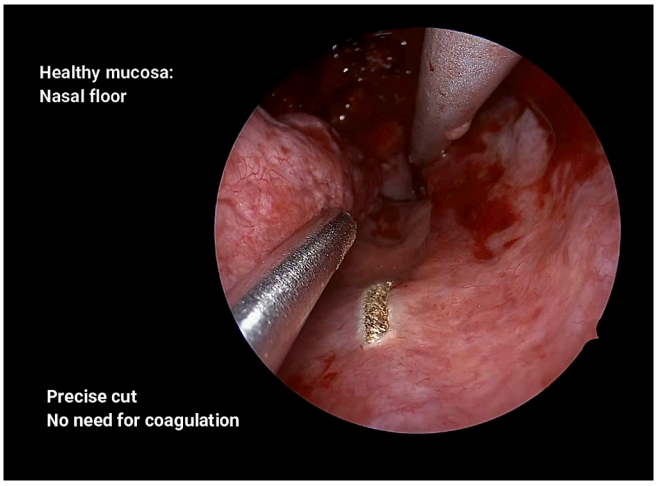

Fig. 1. Right nasal cavity ITAC vaporization.

in T1 weighted with contrast show its poor vascularization and STIR sequencies, or fat-suppressed, reveal its main water content. Due to its high absorption coefficient in water, CO_2 laser is an ideal tool for the removal of this kind of lesion. In this case we show the hollow fiber with flexible handpiece. High pulsed emission mode was used because no high coagulation was needed due to the scarce vascularization of the lesion. With these settings we performed a precise cut, and no bleeding was observed during the procedure (Fig. 2).

Ultra-pulsed mode emits CO_2 laser with fixed higher frequencies producing slightly more thermal effect in lateral tissues. This sill guarantees a precise cut but a better coagulation. This modality is ideal for the removal of vascularized lesions. We present the case of a highly aggressive Intestinal-type Adenocarcinoma of the right nasal fossa, which invaded the lamina papyracea dislocating the endo-orbital content but without orbital or anterior cranial fossa invasion. From T1 weighted with contrast sequencies we can observe a major blood content than the relapsed inverted papilloma of the previous clinical case. The endonasal vegetating portion was approached with a straight probe by ultra-pulsed emission mode at 300 Hz frequency (Fig. 3). This modality proved to offer a better coagulation, necessary in such a highly vascularized disease. First steps of the debulking phase were conducted by vaporization of the mass. Subsequently, removal of the vegetating endonasal portion of the neoplasm was completed by cutting its base of implant, aided by gentle traction. Even though the high aggressive behavior and vascularization of this disease, no significant bleeding was

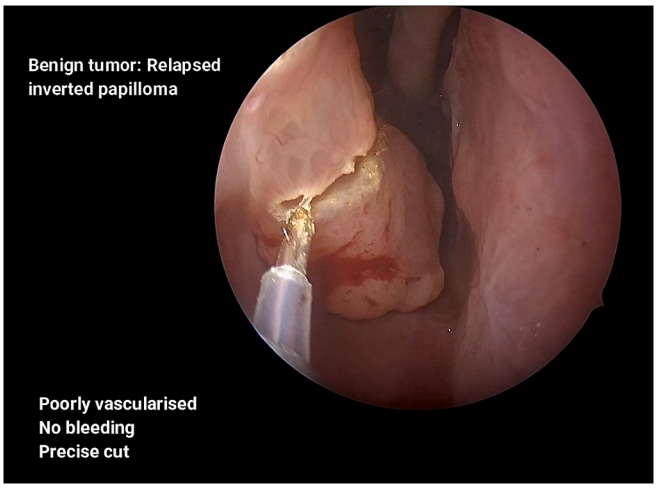

Fig. 2. Right nasal cavity relapsed inverted papilloma resection.

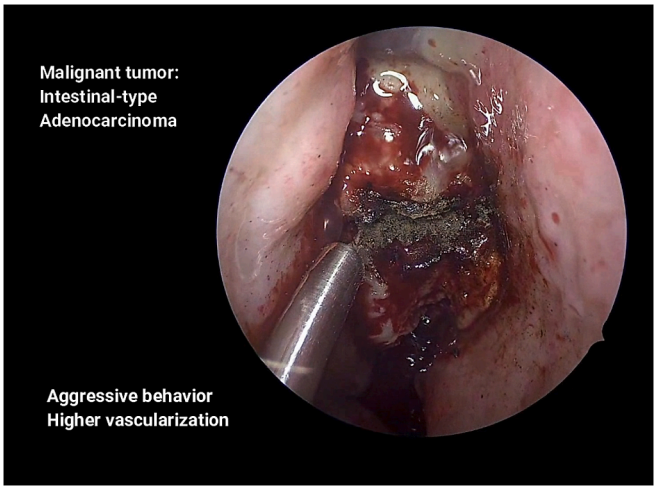

Fig. 3. Nasal floor mucosa section with 90° probe.

observed during this phase.

4.3. Coagulation and bleeding control from major vessels (7:08–8:20)

To test coagulation and bleeding control from major vessels we used continuous-wave emission mode. This modality emits a continuous wavelength that maximizes thermal damage to lateral tissues, thus producing a worse quality cut but optimizing cauterization and is ideal for bleeding control.

In this first clinical case, we show a minor mucosal bleeding, approached with CO_2 laser with rigid straight endoscopic probe delivery system and continuous wave emission mode. Blood coagulation was successfully achieved.

We tested CO_2 in major vessels. This is the anterior ethmoidal artery (0,56 to 1,04 mm) average diameter according to Yang et al. [2]. Even though CO_2 wavelength absorption is scarce by hemoglobin, this size of vessel showed to optimally be cauterized by our tool in continuous wave emission mode (Fig. 4).

Secondarily, we tested CO_2 laser in Sphenopalatine artery (1.5–2.4 mm average diameter according to Lee et al. [3]). Due to the larger dimensions of this vessel, cauterization was yet possible, but results were suboptimal. Lots of steam was observed in this phase and this increased the duration of the procedure. Further aid with electrosurgical forceps was needed to obtain a complete result.

5. Discussion (8:20–9:21)

In our test, ergonomics resulted good and positioning easy to perform. Sections were high quality in both healthy and neoplastic tissue. Coagulation and vessels cauterization resulted effective until an average diameter of approximately 1 cm. CO_2 laser resulted a helpful tool to obtain a bloodless surgical field during the debulking phase of both benign and malignant tumors. We observed that 90 degrees angulated probes gave the possibility to obtain perpendicular dissections of the healthy mucosa, which guarantees more precise and natural sections and avoids tissue carbonization rather than classical tangential tools. Finally, CO_2 laser enables cut and cauterization of small and major blood vessels with the same instrument.

Possible drawbacks of CO_2 laser are its cost and time-consuming

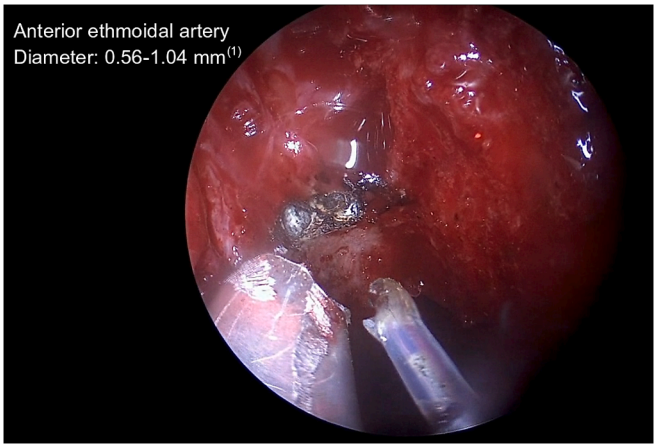

Fig. 4. Anterior ethmoidal artery cauterization.

characteristics, mainly due to the necessity of expertise and learning curve. We observed that the first procedures conducted with CO_2 laser have been those who generally lasted more. It is possible that, with repeated usage of the tool, time-dependability will decrease.

6. Conclusion (9:21–9:45)

CO_2 laser demonstrates good ergonomic, significant advantages in tumor debulking and health mucosa sectioning, and the possibility to obtain an effective cauterization of nasal vessels smaller than 1 cm in diameter. Despite these advantages, this tool is potentially more-time consuming and more expensive. Further studies are needed to directly compare effectiveness of CO_2 laser over other lasers and cold instruments.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjoto.2021.103281.

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