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HEAD AND NECK

Comparison of fiber delivered CO_2 laser and electrocautery in transoral robot assisted tongue base surgery

Murat Karaman[1] · Taylan Gün[2] · Burak Temelkuran[3,4] · Engin Aynacı[5] · Cem Kaya[6] · Ahmet Mahmut Tekin[1]

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Abstract To compare intra-operative and post-operative effectiveness of fiber delivered CO_2 laser to monopolar electrocautery in robot assisted tongue base surgery. Prospective non-randomized clinical study. Twenty moderate to severe obstructive sleep apnea (OSA) patients, non-compliant with Continuous Positive Airway Pressure (CPAP), underwent Transoral Robotic Surgery (TORS) using the Da Vinci surgical robot in our University Hospital. OSA was treated with monopolar electrocautery in 10 patients, and with flexible CO_2 laser fiber in another 10 patients. The following parameters in the two sets are analyzed: Intraoperative bleeding that required cauterization, robot operating time, need for tracheotomy, postoperative self-limiting bleeding, length of hospitalization, duration until start of oral intake, pre-operative and post-operative minimum arterial oxygen saturation, pre-operative and post-operative Epworth Sleepiness Scale score, postoperative airway complication and postoperative pain. Mean follow-up was 12 months. None of the patients required tracheotomy and there were no intraoperative complications related to the use of the robot or the CO_2 laser. The use of CO_2 laser in TORS-assisted tongue base surgery resulted in less intraoperative bleeding that required cauterization, shorter robot operating time, shorter length of hospitalization, shorter duration until start of oral intake and less postoperative pain, when compared to electrocautery. Postoperative apnea–hypopnea index scores showed better efficacy of CO_2 laser than electrocautery. Comparison of postoperative airway complication rates and Epworth sleepiness scale scores were found to be statistically insignificant between the two groups. The use of CO_2 laser in robot assisted tongue base surgery has various intraoperative and post-operative advantages when compared to monopolar electrocautery.

Keywords Obstructive sleep apnea · Fiber delivered CO_2 laser · Monopolar electrocautery · Robot assisted surgery · Tongue base surgery

✉ Murat Karaman
karaman1398@yahoo.com

Taylan Gün
taylangun@gmail.com

Burak Temelkuran
burak@hupomone.co

Engin Aynacı
enginaynaci@gmail.com

Cem Kaya
cemkaya06@mynet.com

Ahmet Mahmut Tekin
drtekinahmet@gmail.com

1 Department of otorhinolaryngology, Istanbul Medipol University, Istanbul, Turkey

2 Department of otorhinolaryngology, Bahçeşehir University, Istanbul, Turkey

3 OmniGuide Surgical, London, UK

4 OmniGuide Surgical, Lexington, MA, USA

5 Department of pulmonology, Istanbul Medipol University, Istanbul, Turkey

6 Department of anesthesiology, Istanbul Medipol University, Istanbul, Turkey

Introduction

Transoral robotic surgery (TORS) has become popular among surgeons in the treatment of tumors of the larynx and pharynx. TORS possesses many advantages compared to other techniques such as Transoral Laser

Microsurgery, providing better access, exposure and visualization [1, 2]. The Da Vinci surgical robot system (Intuitive Surgical Inc., Sunnyvale, CA, USA) has been mainly used for the treatment of malignant and benign disease of the upper aerodigestive tract [1, 2], where majority of the applications are focused around oropharyngeal surgery and published results confirm this approach as a safe, feasible, and efficacious surgical modality for the treatment of oropharyngeal neoplasms [3–6]. This system utilizes an electrocautery monopolar or bipolar as energy source that is manipulated by one of the robotic arms.

Monopolar cautery is the most commonly used surgical cutting and hemostatic tool for TORS [3] and is extremely effective. However, many studies have shown that the use of cautery causes a significant amount of collateral tissue damage [7–9]. Such thermal damage may have undesired effects on wound healing, safety of critical structures around the site where the energy is applied, and clinical outcomes; as a result, alternative technologies such as the harmonic scalpel and carbon dioxide (CO_2) laser are becoming popular due to their lesser degree of collateral thermal damage while still offering similar effectiveness in cutting and coagulation [10–12].

The use of CO_2 lasers in head and neck surgery has been well established in the literature since its introduction in the early 1970s [13]. Moreover, current technology has also made it available as a cost-effective technique, increasing its prevalence in operating rooms [14]. A cadaveric study has shown that the flexible CO_2 laser fiber causes less depth of thermal damage when compared to the harmonic scalpel [10]. The studies showed the feasibility of adding the advantages of CO_2 laser to those of TORS, allowing easier resection of pharyngolaryngeal tumors while limiting the thermal effect [1, 2].

Upper airway collapse often involves obstruction at the level of the tongue base. A number of surgical procedures have been introduced in recent years for the tongue base reduction (TBR). Among these techniques, TORS has been successfully used for the treatment of OSA patients and the authors found the results encouraging and worthy of further evaluation [15]. However, the thermal damage of electrocautery, which causes edema and crusting, has been a major drawback for TORS. In this study, we proposed the use of the new Flexible CO_2 Laser Fiber (OmniGuide Surgical, Lexington, MA, USA) in TORS to minimize the thermal effect during TBR. To our knowledge, this is the first study comparing the efficacy of CO_2 laser and electrocautery during robot assisted tongue base surgery.

Materials and methods

Patient selection

This prospective study consisted of 20 moderate to severe OSA patients, non-compliant with continuous positive airway pressure (CPAP), who underwent TORS using the Da Vinci surgical robot, with the flexible CO_2 Laser Fiber or electrocautery, in our University Hospital. Surgery with the CO_2 laser fiber introduced an additional cost to the patient as per the rules of our hospital, and this additional cost set the selection criteria of the energy source for this study. The first 10 patients who accepted the additional cost of the fiber formed the CO_2 laser group, and the first 10 patients who rejected the additional cost of the fiber formed the electrocautery group. The pre-operative work included a polysomnographic evaluation, assessment of general medical health, thorough sleep history and a comprehensive upper airway examination with fiber-optic endoscopy. In addition to the general ENT examination, we calculated body mass indexes, neck circumferences, tonsil sizes (grade 0–IV), modified Mallampati–Friedman Scoring (I–IV), and drug induced sleep endoscopy of all the patients. Epworth Sleepiness Scale score was assessed for all the patients. The patients had significant obstruction at the tongue base and TORS for TBR was offered as a primary procedure to each patient. All the patients had polysomnographic evidence of moderate to severe OSA (AHI >30) and excessive daytime somnolence (Epworth Sleepiness Scale score 17–23). Exclusion criteria were: history of a cerebrovascular disease, progressive neuromuscular disease, significant or unstable cardiovascular disease, significant psychological instability, use of anticoagulatives, signs of potentially difficult exposure including significant retrognathia, an inability to hyperextend the neck, an interincisive distance over 2.5 cm, or trismus.

Surgical procedure

All the procedures were performed in the same operating room by the same surgical team and under general anesthesia. The surgeon did not have any experience with CO_2 laser prior to this study, and had extensive experience with monopolar cautery. The surgical robotic cart which is equipped with a robotic router and four arms was positioned 30° from the surgical bed on the left side of the patient. For the surgeries performed with the laser, mounted arms were holding a 30° endoscope, Maryland atraumatic forceps, an 8-mm EndoWrist Needle Driver (IntuitiveSurgical Inc.) which grasps a flexible metal carrier with the CO_2 laser fiber. The fiber that is used to perform the TBR is a hollow waveguide with an effective spot size at the tip of the fiber of 320 µm (BeamPath® Robotic Fiber, OmniGuide, Lexington, MA, USA). A 3-mm metal carrier containing the flexible laser-delivery fiber was guided into the surgical site with the robotic needle driver. A spatula tip at the end of the metal carrier allowed blunt dissection, as well as operating the laser in contact mode. Laser energy out of fiber is divergent and allows operation in non-contact mode up to a distance of 15 mm. The CO_2 laser power was set to 14 W for dissection and 7 W for coagulation. The optical power on tissue is approximately 50% of the power set on the screen, due to the transmission properties of these fibers. The surgeon's control panel was on the left side, positioned away from the patient. At the control panel, the surgeon controls the instrument arms and camera by maneuvering the master robot manipulators. A second surgeon was seated at the head of the patient. The video tower was on the right side of the patient. One cautery unit was used, and it was connected to a coagulating suction tube handled by the second surgeon at the head of the patient. For the patients treated by monopolar electrocautery the needle driver arm was replaced by the monopolar cautery arm of the robot, and the rest of the set-up remained the same. The monopolar cautery was used at a fixed power setting of 30 W in both cutting and coagulation modes. The FK-WO TORS Laryngo-Pharyngoscope retractor was used in all the surgeries. It was suspended anteriorly with a laryngoscope hold (Fig. 1).

The tongue base was then exposed with the FK retractor. The tongue was pulled anteriorly with stay sutures and using the retractor. During the exposure of epiglottic vallecula, we aimed to limit the tissue resection to the superficial layer of lingual lymphoid tissue; however, most cases required extension of the dissection into the lingual musculature to achieve this exposure. Special attention is needed for the lingual artery and its dorsal branches, the lingual nerve, and the hypoglossal nerve. In our experience, the volume of excised tissue is not effective if it is less than 7 ml; and excising more than 50 ml tissue may cause complications, presents risks such as neurovascular injury, and will not improve outcomes of surgery further. The volume of excised tissue in this study was measured to be in the 14–20 ml range. Due to this tight distribution, we do not expect this parameter to have any effect on the results reported in this study. Lingual tonsillectomy was performed afterwards using TORS with the same energy source used prior to tonsillectomy. The wound was inspected carefully to verify adequate hemostasis. Suction cautery was used as needed for persistent bleeding (Fig. 2).

Postoperatively, the tongue and airway were closely inspected for edema. None of the patients required tracheostomy. The patients received a nasogastric (NG) feeding tube in the immediate postoperative period, which was removed when the patient could swallow liquid or soft food without aspiration. Postoperative observation was undertaken in the appropriate monitored setting.

Polysomnographic evaluation, assessment of general medical health, thorough sleep history and a comprehensive upper airway examination with fiber-optic endoscopy, Epworth Sleepiness Scale score and visual analogue scale for postoperative pain were repeated 6 months after the surgery for all patients.

Minitab version 16 was used for statistical analysis (Minitab, Inc., State College, PA, USA). Parametric continuous variables were compared using a two-sample *t* test, assuming normal distributions of the variables. Categorical data were presented as frequencies and compared with two-proportion test, using Fisher's exact test to obtain the *p* value.

Fig. 1 View of mounted arms holding a 30° endoscope, Maryland atraumatic forceps, an 8-mm EndoWrist Needle Driver (Intuitive-Surgical Inc.) which grasp a flexible metal conduit carrying the CO_2 laser fiber during transoral robot assisted TBR

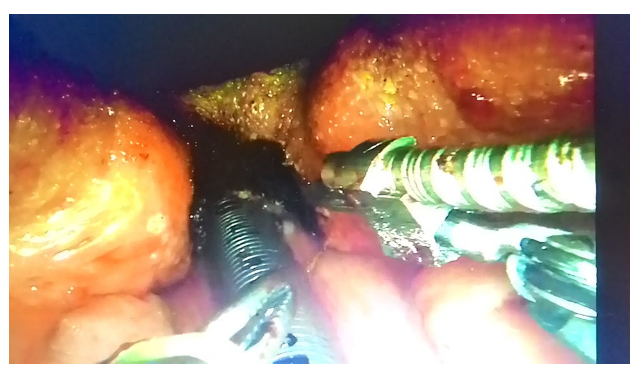

Fig. 2 View of tongue base reduction at the end of TORS with fiber delivered CO_2 laser

Results

Twenty patients (16 males, 4 females) were included in this study. The mean age was 45.1 ± 7.2 years (range 30–56 years). Ten patients were in CO_2 laser group and ten patients were in electrocautery group. The mean follow-up time was 12 months. None of the patients required tracheotomy and there were no intraoperative complications related to the use of the robot or the CO_2 laser. Only one laser fiber was used per operation, there was no need to replace a fiber due to defect or breakage.

The average duration of the excision for the CO_2 laser group was 8.6 min; significantly shorter than the duration of excision for the electrocautery group which was 17.3 min (Fig. 3).

The mean hospital stay for CO_2 laser group patients was 2.0 days, and was 3.2 days for electrocautery group (Fig. 4). Oral feeding was started at 6 h for CO_2 laser group and 10.3 h for electrocautery group. All these differences were statistically significant with $p < 0.001$ (two-sample t test) (Fig. 4). Pre-operative apnea–hypopnea indices were similar in both groups: 36.2 for CO_2 laser group and 36.6 for electrocautery group. However, post-operative apnea–hypopnea index was 8.8 for CO_2 laser group and 11.1 for electrocautery group (Fig. 4). The post-operative difference was statistically significant ($p = 0.003$, two-sample t test). The postoperative pain score was 3.9 for the CO_2 laser group, and 8.1 for the electrocautery group ($p < 0.001$, two-sample t test) (Fig. 4).

Intraoperative bleeding that required cauterization was 10% for the CO_2 laser group, and was 90% for the electrocautery group. This difference was statistically significant ($p = 0.001$, two-proportions test) (Fig. 5). Postoperative airway complication rates, postoperative self-limiting bleeding and Epworth sleepiness scale scores were statistically insignificant between the two groups [$p = 0.21$ (two-proportions test), $p = 0.21$ (two-proportions test), $p = 0.87$ (two-sample t test), respectively] (Fig. 5).

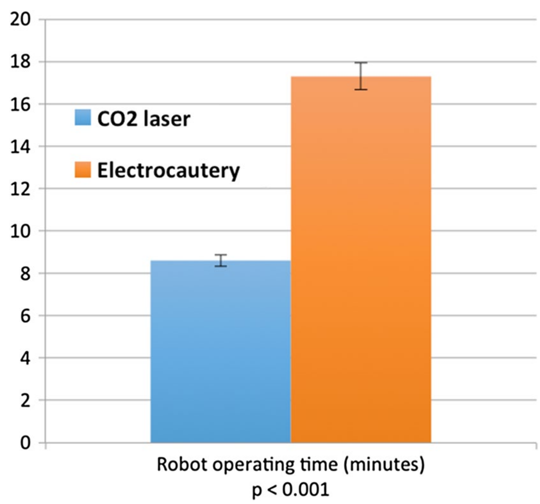

Fig. 3 Comparison of the duration of the operation between CO_2 laser and electrocautery in transoral robot assisted tongue base surgery

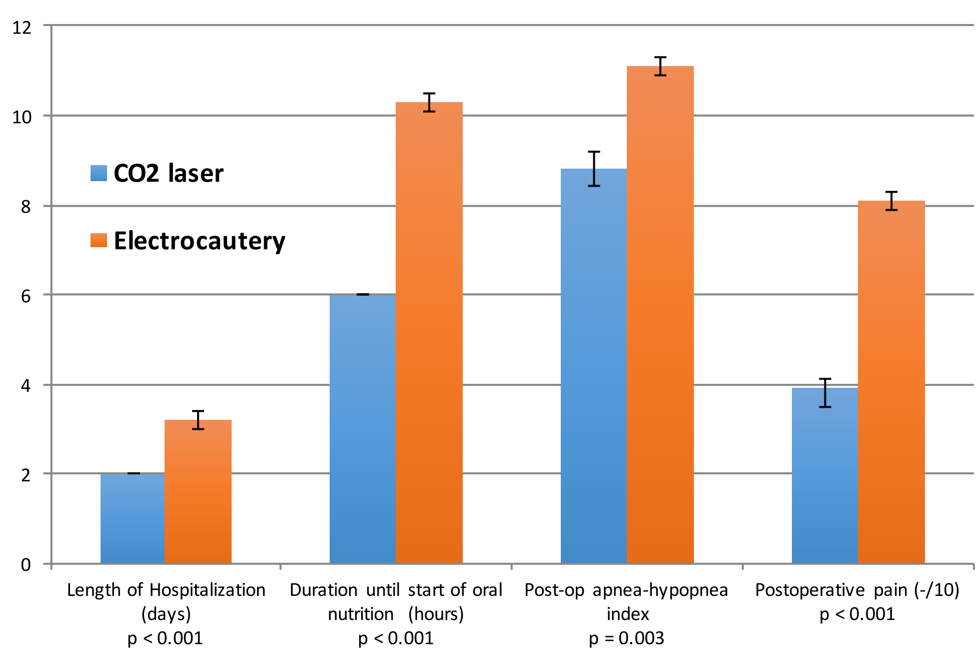

Fig. 4 Comparison of length of hospitalization, duration until start of oral nutrition, postoperative AHI and pain scale between CO_2 laser and electrocautery in transoral robot assisted tongue base surgery

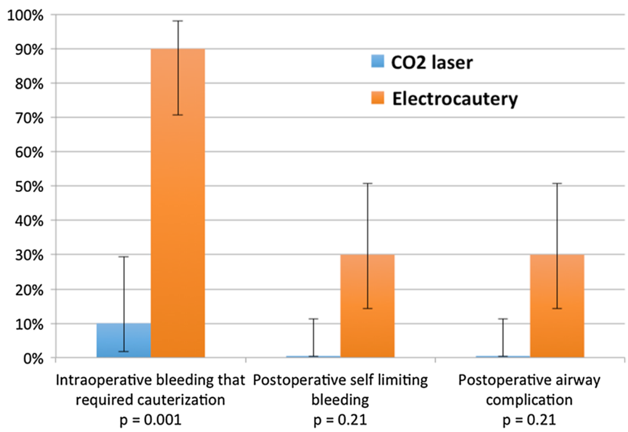

Fig. 5 Comparison of intraoperative bleeding that required cauterization, postoperative airway complication rates and the postoperative self-limiting bleeding between CO_2 laser and electrocautery in transoral robot assisted tongue base surgery

Discussion

The Da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) is mostly used in the oropharynx, supraglottis and piriform sinus for the treatment of malignant and benign disease since its approval by the US Food and Drug Administration in December 2009. Performing TBR with the TORS approach allows removal of a part of the base of the tongue from the foramen cecum to the vallecula [16]. Lee et al. studied the use of transoral robot-assisted lingual tonsillectomy and uvulopalatopharyngoplasty for the surgical management of tongue base obstruction in patients with obstructive sleep apnea, and completed the study having 20 patients with encouraging results [15]. Chiffer et al. successfully combined OSA-TORS with MRI to demonstrate the dependence of greater decreases in postoperative AHI to larger decreases in the total and retro-palatal lateral pharyngeal wall volumes [17] We report 100% surgical success in both of our study groups where surgical success is defined as AHI reduction by at least 50% and final AHI <20. Average robot operating times, hospitalization times, time to soft diet start, post-operative AHI and ESS scores we report for the electrocautery group are comparable to reported values by Vicini et al. [18].

The advantages of TORS over traditional endoscopic surgery are numerous. Among these advantages, we can emphasize the adjustments of large hand movements of the operator to small movements of instruments in the airway enhancing dexterity, the three-dimensional visualization of the surgical field provided to the surgeon for true depth perception, and the filtering out natural hand tremor [19, 20], Additional studies, including comparison with other techniques, are anticipated to assess the proper role of TORS in sleep surgery.

TORS depended on monopolar electrocautery until recently, and the thermal effects of the cautery were a major drawback for TORS. The CO_2 laser was first introduced into Otolaryngology by Jako and Strong in 1972, and it has been used in Otolaryngology practice extensively since then [13]. Liboon et al., in their study, showed that the acute width of injury for the incisions is greater with monopolar electrocautery than with CO_2 laser [21]. Minimal thermal spread to the surrounding tissue makes the CO_2 laser well suited for TORS especially for use near critical anatomical structures [20]. However, before the introduction of hollow wave guides, CO_2 laser could not be used in TORS as the delivery system required attachment to a microscope.

The new technology made it possible for the development of flexible, biocompatible, low loss fibers for CO2 lasers that can safely and reliably deliver high powers suitable for laser surgery applications [22, 23]. These fibers were commercially introduced by OmniGuide Surgical (Lexington, MA, USA) [24, 25], and have been used in many different laser surgery including endoscopic skull base and pituitary surgery, endoscopic sinus and nasal procedures, surgery for glottic and subglottic respiratory papillomatosis and transoral laryngeal malignancy surgeries [26].

Solares et al. reported the first use of CO_2 laser fiber with transoral robotic surgery in 2007, studied the feasibility on three patients with malignant laryngeal tumors and concluded that the use of surgical robotics coupled with CO_2 laser will likely enhance our ability to treat laryngeal cancer patients [1]. Remacle et al. performed a similar study more recently on four patients and concluded that adding the advantages of CO_2 laser to those of TORS will allow easier resection of pharyngo-laryngeal tumors while limiting the thermal effect [2].

To our knowledge, there is no study that compares the clinical efficacy of CO_2 laser and electrocautery in TORS for TBR in the literature. Hoffmann et al. reported intraoperative performance evaluation of 4 different energy sources including CO_2 laser energy and monopolar cautery based on surgeon ratings [9]. In this study, we have quantitatively demonstrated various intra-operative, as well as clinical advantages of CO_2 laser over electrocautery.

We showed that the duration of the operation was shorter in CO_2 laser group than the electrocautery group. The spatula tip of the electrocautery had to be cleaned almost every 3–4 cuts due to tissue sticking to the tip, which slowed down the operation in the electrocautery group significantly. These findings are also supported by Hoffmann et al.

The mean hospital stay and oral feeding time were shorter, and postoperative pain scores were better for the CO_2 laser group. We relate these outcomes to minimal thermal damage to the remaining healthy tissue after the resection with the CO_2 laser. Intraoperative bleeding that required cauterization was lower in the CO_2 laser group, which increases the surgeon's comfort during the surgery. Surgeon ratings reported by Hoffmann et al. also agrees with our results. The electrocautery unit had poor depth control and precision, and the evaporated tissue as well as the damage inflicted to surrounding tissue were much larger when compared to the precise cuts achieved by the CO_2 laser. Fiber-delivered CO_2 laser energy allows a smooth transition from cutting to coagulation by defocusing the beam simply by retracting the fiber from the target tissue, providing a smooth surgery without any major bleeding. Patients' comfort levels, as well as functional outcomes were also better in the CO_2 laser group. Postoperative apnea–hypopnea index scores have shown that the efficacy of the CO_2 laser was better than that of the electrocautery.

We also would like to report a financial expense comparison for the two groups of our study. The additional cost due to the disposable fibre (including the rental cost of the laser system) for the CO_2 laser group was approximately equivalent to the cost associated with the average additional one night stay for the electrocautery group. Although the use of monopolar cautery as opposed to CO_2 laser approximately doubled the robot operating time, we expect this difference to play a more significant role in surgeries where the actual robot operating time is much longer. Overall, the financial expenses for both groups were found to be similar.

This study had several limitations we would like to discuss. This was a non-randomized study, but the patients chose the energy source they will be treated with, which took the assignment of the treatment out of the control of the authors. The surgeon had significant experience in robotic surgery with monopolar cautery. The lack of previous experience with CO_2 laser, resulting in a learning curve, was a limitation in this study, and additional experience with the laser could result in further improvements on the reported benefits of CO_2 laser. The small number of patients in each group was also a limitation, but was sufficient to show statistically significant differences in several parameters that we analyzed.

Conclusion

The use of fiber delivered CO_2 laser in TORS-assisted tongue base surgery resulted in less intraoperative bleeding that required cauterization, shorter robot operating time, shorter lengths of hospitalization, shorter durations before the start of oral intake and less postoperative pain, when compared to electrocautery.

The study results are also in favor of fiber delivered CO_2 laser when compared for postoperative self-limiting bleeding and postoperative airway complication, but a larger sample size is proposed to understand if these results have clinical significance.

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