Diode Laser for Laryngeal Surgery: a Systematic Review

Helena Hotz Arroyo¹ Larissa Neri¹ Carina Yuri Fussuma¹ Rui Imamura¹

¹Department of Otorhinolaryngology, Hospital das Clinicas, School of Medicine, Universidade de São Paulo, São Paulo, Brazil

Address for correspondence Helena Hotz Arroyo, MD, Universidade de São Paulo, Avenida Doutor Eneas de Carvalho Aguiar 155, 6o andar sala 6167, Sao Paulo, Brazil (e-mail: helenaharrooy@hotmail.com).

Introduction

Lasers have been used in laryngeal surgeries since 1972, when Strong and Jako first reported the use of carbon dioxide laser (CO₂) in the human larynx.¹ Despite initial criticism, endoscopic laser treatments have achieved universal acceptance and been successfully used in endolaryngeal microsurgery (EMS).² Most of the laser procedures involve either excision or tissue vaporization, depending on the interaction between the wavelength (λ) and the chromophores of the tissue. For years, the CO₂ (λ = 10600 nm) seemed to be the preferred laser for transoral laser microsurgery due to its precise cut,³ given that it is better absorbed by water. However, there are some disadvantages of the CO₂ device, namely, its straight line beam delivery from surgical microscope, narrow penetration depth to tissue, difficult transportation, and increased cost. These drawbacks favored the study and application of other wavelengths in larynx, such as Thulium YAG (λ = 2000 nm), Nd:YAG (neodimium:yttrium-aluminum-garnet - λ = 1064 nm), diode (λ = 805 - 980 nm), PDL (pulsed dye laser - λ = 585 nm) and KTP (potassium titanyl phosphate - λ = 532 nm).³ ⁴

The diode laser has excellent hemostatic properties as a result of high absorption by hemoglobin and particularly by...
oxyhemoglobin. It is also absorbed by water, but less so than the CO₂ laser.³ Furthermore it is portable, small, relatively inexpensive, and simple to use. It also has stable power output, long lifetime, and low installation and maintenance costs.² Moreover, the diode laser is delivered down by a fine glass fiber that allows the surgeon to hold it in a pencil-like holder for accurate manipulation.² The fiber guidance system tip can be angled, which allows access to areas that are difficult to handle with the CO₂ laser.² As a result, the use of diode laser in laryngeal diseases and outcomes shown so far.

Methods

A systematic search was performed in PubMed, Cochrane Library, Ovid, Web of Science, and Scielo databases. Search terms and Boolean operators used were “larynx” OR “glottic” OR “airway” OR “laryngeal surgery” OR “vocal fold” AND “diode laser.” We only included publications in English or Spanish languages. The final search was performed on September 28th, 2015. We screened titles and abstracts for relevance and relevant articles for assessment. Reference lists were manually searched for further relevant articles.

We considered all studies relating to human laryngeal pathologies (from superior edge of epiglottis to inferior edge of cricoid cartilage). We only included studies that provided information on patient and lesion characteristics, treatment (diode laser’s parameters used in surgery – at least two items described among wavelength, fiber diameter, output power, frequency, wave radiation, and contact mode), and outcomes related to the laser surgery performed. Outcomes could be “cure of the initial pathology,” “need of complementary operation,” “recurrence of the lesion,” or even “complications or adverse/side effects.” Studies were excluded if they consisted of less than two subjects or case report. Patients with tracheal disease were not included. Finally, studies that described the use of diode laser with non-surgical intent were excluded.

We collated data from included studies using an Excel (Microsoft, Redmond, Washington) spreadsheet. Specifically, data on sample demographics and clinical characteristics, sample size, diode laser parameters used, duration of follow-up, main outcome findings, and complications were extracted from each study. Article authors were contacted directly to obtain further information in cases of incomplete reported data.

The internal validity of included studies was low overall. We identified no randomized clinical trial and only two experimental controlled studies (not randomized) were included.

Results

Our search strategy yielded a total of 284 articles (including duplicates). By screening the titles alone, 234 articles could be excluded, as they were either review articles, obviously not relating to the use of diode laser in larynx, or clearly not eligible for inclusion (for example, studies looking at diode laser in animals). This left 50 abstracts, of which 36 were duplicate. After reading the abstracts, one was removed due to its focus on endobronchial diseases. Then, the 13 eligible articles were full-text assessed, but two more were excluded due to failure to meet eligibility criteria (one that did not describe the laser parameters used at one single surgery and another that included patients with lesions outside the larynx). This left 11 articles appropriate for inclusion in the review. We manually searched reference lists for further relevant articles, but none was eligible (~Fig. 1).

The 11 studies selected for inclusion were published between 2003 and 2014 and originated from 5 different countries. Two studies were experimental controlled but not randomized⁶,⁹ and another one was a prospective experimental uncontrolled study.⁷ The other studies comprised of 8 retrospective reviews.²,³,⁵,⁶,¹⁰–¹³ We found no randomized controlled trial or multicenter trials.

A total of 357 subjects made up the study population from the 11 included studies. The average number of participants per study was 32.45 (range: 8–72). ~Table 1 details the characteristics of the study population. The laryngeal pathologies included were suprastomal granuloma, laryngomalacia, ventricular dysphonia, vocal polyp, glottic web, papillomas, glottic carcinoma, bilateral cord palsy, subglottic cysts, subglottic stenosis, and subglottic hemangioma/lymphangioma.

| Records identified through database searching (n=284) | Abscets excluded based on title (n=234) |
|---------------------------------------------|----------------------------------------|
| Abstract screened (n=50) | Abstracts duplicated (n=36) |
| Abstracts after duplicates removed (n=14) | Abstract removed (n=1) |
| Full-text articles assessed for eligibility (n=13) | Full-text articles excluded (n=2) |
| Relevant articles from reference lists (n=0) | Studies included (n=11) |

Fig. 1 Diagram of eligibility criteria.
Table 1 Population characteristics for included studies

| Study     | Year | Country | No. of patients | F | M | Age Range | Mean Age | Type of Laryngeal Disease | Study Year | Country | No. of patients | F | M | Age Range | Mean Age | Type of Laryngeal Disease |
|-----------|------|---------|-----------------|---|---|------------|----------|---------------------------|------------|---------|-----------------|---|---|------------|----------|---------------------------|
| Saeidi et al 2003 | Italy | 39      | -               | - |   | 35–84      | 59       | Laryngo | Saril et al 2008 | Italy | 27       | -               | - |   | -          | -        | -                        |
| Ferri et al 2006 | Italy | 18      | 3               | 15 |   | 0          | 0        | Ventricular | Ferri et al 2008 | Italy | 18       | 6               | 12 |   | 51–84   | 59       | Laryngo | Saril et al 2008 | Italy | 27       | -               | - |   | -          | -        | -                        |
| Saeidi et al 2008 | Italy | 27      | -               | - |   | 11–13      | 51       | Vocal | Bajaj et al 2008 | UK     | 31       | -               | - |   | 1–10     | 51       | Laryngo | Saril et al 2008 | Italy | 27       | -               | - |   | -          | -        | -                        |
| Saril et al 2008 | Spain | 21      | 1               | 11 |   | 1·1–1·3y   | 1·1y     | Vocal | Ferri et al 2008 | Italy | 45       | 6               | 39 |   | 35–81   | 51       | Laryngo | Saril et al 2008 | Italy | 27       | -               | - |   | -          | -        | -                        |
| Edzer et al 2013 | Turkey | 37      | 7               | 51 |   | 32–71y     | 60·3y    | Papillomas | Edzer et al 2013 | Turkey | 45       | 7               | 51 |   | 32–71y     | 60·3y   | Papillomas | Edzer et al 2013 | Turkey | 45       | 7               | 51 |   | 32–71y     | 60·3y   | Papillomas |
| Liu et al 2013 | Taiwan | 8       | 1                | 7 |   | 24–83y     | 48·8y    | Glottic web | Liu et al 2013 | Taiwan | 8        | 1                | 7 |   | 24–83y | 48·8y    | Glottic web | Liu et al 2013 | Taiwan | 8        | 1                | 7 |   | 24–83y | 48·8y    | Glottic web |
| Tuncel et al 2013 | Turkey | 64      | 3                | 61 |   | 35–69y    | 52·y     | Bilateral tracheal web | Tuncel et al 2013 | Turkey | 64       | 3                | 61 |   | 35–69y | 52·y     | Bilateral tracheal web | Tuncel et al 2013 | Turkey | 64       | 3                | 61 |   | 35–69y | 52·y     | Bilateral tracheal web |
| Karasu et al 2014 | Turkey | 26      | 10               | 16 |   | 28–61y    | 49·9y    | Subglottic cysts | Karasu et al 2014 | Turkey | 26       | 10               | 16 |   | 28–61y | 49·9y     | Subglottic cysts | Karasu et al 2014 | Turkey | 26       | 10               | 16 |   | 28–61y | 49·9y     | Subglottic cysts |
| Gomert et al 2014 | Turkey | 72      | -               | 31–75y | 51| 8 | 0          | 0        | Subglottic stenosis | Gomert et al 2014 | Turkey | 72       | -                | 31–75y | 51 | 8 | 0        | 0        | Subglottic stenosis | Gomert et al 2014 | Turkey | 72       | -                | 31–75y | 51 | 8 | 0        | 0        | Subglottic stenosis |
| Total        | -    | -       | 357             | - |   | -          | -        | Subglottic hemangioma / lymphangioma | -         | -       | -                | - |   | -          | -        | Subglottic hemangioma / lymphangioma |

*There was more than one laryngeal pathology in many patients. One patient data excluded (tracheal stenosis).

Abbreviations: F, female; M, male.

Carbon dioxide laser has been predominantly used since the introduction of laser surgery. However, it has some limitations, such as increased cost and difficulty in the management of deep and curved areas. In addition, it has short penetration depth (0·1–0·3 mm on average). This reduces effective sealing of vessels (0·5 mm) and it appears to be more precise and less invasive. The cutting precision of the Nd:YAG (1064 nm) is considerably lower, and the instrument also led to greater morbidity and intraoperative complications, such as increased cost and difficulties in handling the laser. In contrast, the diode laser has a wavelength of 810 nm, which is absorbed by melanin and hemoglobin. This characteristic makes the diode laser ideal for photocoagulation, thus decreasing blood loss during surgery. The penetration depth depends on the concentration of these chromophores and generally, it reaches 0·1–1·0 mm in diode laser application, which is ideal for photocoagulation. In addition, it has a shorter length compared to other devices, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules. The diode laser also appears to be more precise and less invasive. The cutting precision of the diode laser is 3·0 μm, compared to the 1·0 μm of the carbon dioxide laser. Furthermore, the diode laser is carried by flexible optical fibers that can be bent and positioned in deep and curved areas, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules.

The penetration depth of the diode laser depends on the concentration of chromophores and generally, it reaches 0·1–1·0 mm. This makes the diode laser ideal for photocoagulation, thus decreasing blood loss during surgery. The penetration depth of the carbon dioxide laser is 0·3 mm on average, which reduces effective sealing of vessels to 0·5 mm. Additionally, the color of the diode laser is blue, which is absorbed by hemoglobin and melanin (near infrared spectrum).

Carbon dioxide laser has been predominantly used since the introduction of laser surgery. However, it has some limitations, such as increased cost and difficulty in the management of deep and curved areas. In addition, it has short penetration depth (0·1–0·3 mm on average). This reduces effective sealing of vessels (0·5 mm) and it appears to be more precise and less invasive. The cutting precision of the Nd:YAG (1064 nm) is considerably lower, and the instrument also led to greater morbidity and intraoperative complications, such as increased cost and difficulties in handling the laser. In contrast, the diode laser has a wavelength of 810 nm, which is absorbed by melanin and hemoglobin. This characteristic makes the diode laser ideal for photocoagulation, thus decreasing blood loss during surgery. The penetration depth depends on the concentration of these chromophores and generally, it reaches 0·1–1·0 mm in diode laser application, which is ideal for photocoagulation. In addition, it has a shorter length compared to other devices, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules.

The diode laser also appears to be more precise and less invasive. The cutting precision of the diode laser is 3·0 μm, compared to the 1·0 μm of the carbon dioxide laser. Furthermore, the diode laser is carried by flexible optical fibers that can be bent and positioned in deep and curved areas, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules.

Carbon dioxide laser has been predominantly used since the introduction of laser surgery. However, it has some limitations, such as increased cost and difficulty in the management of deep and curved areas. In addition, it has short penetration depth (0·1–0·3 mm on average). This reduces effective sealing of vessels (0·5 mm) and it appears to be more precise and less invasive. The cutting precision of the Nd:YAG (1064 nm) is considerably lower, and the instrument also led to greater morbidity and intraoperative complications, such as increased cost and difficulties in handling the laser. In contrast, the diode laser has a wavelength of 810 nm, which is absorbed by melanin and hemoglobin. This characteristic makes the diode laser ideal for photocoagulation, thus decreasing blood loss during surgery. The penetration depth depends on the concentration of these chromophores and generally, it reaches 0·1–1·0 mm in diode laser application, which is ideal for photocoagulation. In addition, it has a shorter length compared to other devices, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules.

The diode laser also appears to be more precise and less invasive. The cutting precision of the diode laser is 3·0 μm, compared to the 1·0 μm of the carbon dioxide laser. Furthermore, the diode laser is carried by flexible optical fibers that can be bent and positioned in deep and curved areas, making it ideal for treating laryngeal stenosis, vocal fold paralysis, and vocal fold nodules.
Diode Laser for Laryngeal Surgery

Table 2 Intervention treatment - parameters of diode laser in larynx

| Study          | Year | No. of patients | Wavelength (nm) | Fiber diameter (μm) | Output power (W) | Frequency (Hz) | Wave Radiation | Contact Mode          |
|----------------|------|-----------------|-----------------|---------------------|------------------|----------------|-----------------|----------------------|
| Saetti et al   | 2003 | 39              | 810             | 300–600             | 10               | –              | –               | Direct contact        |
| Ferri et al    | 2006 | 18              | 810             | 600                 | 10               | –              | Continuous       | Direct contact        |
| Saetti et al   | 2008 | 27              | 810             | 300–600             | 5–8              | –              | Continuous/Low frequency pulsation | –                   |
| Bajaj et al    | 2008 | 31              | 805             | 400                 | 3–5              | –              | Continuous       | Direct contact        |
| Fanjul et al   | 2008 | 21              | 820 + 20        | 400–600             | 10–15            | –              | –               | Direct contact        |
| Ferri et al    | 2008 | 45              | 810             | 600–1000            | 5–60             | 60 Hz          | Continuous       | Direct contact        |
| Edizer et al   | 2013 | 58              | –               | –                   | 6–12             | –              | Continuous       | –                    |
| Liu et al      | 2013 | 8               | 810             | 1400                | max 5            | –              | Continuous       | –                    |
| Tunçel et al   | 2013 | 64              | 980             | 400                 | 4–9              | –              | Continuous       | Direct contact        |
| Karasu et al   | 2014 | 26              | 980             | 400                 | 3–5              | –              | Continuous       | Direct contact        |
| Cömert et al   | 2014 | 72              | 980             | 400                 | 4–9              | –              | Continuous       | Direct contact        |

= data not available.

be coupled with telescopes permitting access to sites that are difficult to explore with other techniques, such as the subglottic region.5 Recently, a CO2 laser beam delivered through a flexible hollow tube has become available that delivers the beam close to the target.15 However, the use of diode laser by contact (or extremely close distance) makes it much safer than other laser sources by avoiding damage due to “beam scope” in an open field.5

As this review shows, the diode laser can be a useful tool for treatment of different laryngeal pathologies, such as suprastomal granuloma, laryngomalacia, ventricular dysphonia, vocal polyp, glottic web, papilloma, glottic carcinoma, bilateral cord palsy, subglottic cyst, subglottic stenosis, subglottic hemangioma and lymphangioma. In this sense, the laser parameters must be set depending on the goal (vaporization, section or coagulation) and the clinical problem.

With respect to output power, diameter of fiber and wavelength, the articles selected in this review presented different arrangements for diode laser. This reveals the lack of standardization in setting the best parameters of diode laser for laryngeal surgery. Although these parameters may influence collateral tissue damage, the studies are difficult to compare, based on the following concepts of laser’s physics. Power, given in watts (W), measures the rate that the laser beam transmits. Beam energy, measured in joules (J), can be found by multiplying the power (W) by exposure time (in seconds). Power density, also called irradiance or spot brightness, determines the rate at which tissue is removed at the surgical site, measured in units of watts per square centimeter (W/cm2). Fluence is a key parameter once it combines previously mentioned parameters of power density and dosage, and is measured in units of joules per square centimeter (J/cm2). It is important to understand this to provide minimal damage to tissues adjacent to the incision site, as using a higher pulse power for a shorter period of time results in less tissue damage than using lower power for a longer period of time. Tissue damage is dependent upon the tissue absorption coefficient, the wavelength of the laser, power density, and the length of time over which the energy is delivered, which is largely technique dependent.16 These data were not provided by any of the included studies.

An additional property that can affect the severity of tissue damage is thermal relaxation time, the time required for tissue to lose 50% of its heat through diffusion.17 One can decrease tissue damage by allowing heated tissue to cool during a procedure. However, it could be accomplished through the use of a pulsed laser, spacing out laser impact, even for a continuous incision, that decreases thermal damage by allowing time for the tissue to cool between impacts.16 In contrast, the authors of studies included in this review opted for the continuous wave radiation, some followed by manual tissue cooling.

Special attention must be given to laser surgery for the treatment of glottic cancer, once it can be more cost-effective than ‘cold surgery’ when managing laryngeal tumors, as they allow briefer hospital stays and shorter wound recovery periods.18 The CO2 laser surgery was presented as one of the most accepted treatment options of early glottic carcinoma due to its high local control rates, low morbidity, and good postoperative voice quality.19 However, if the surgeon has difficulty in managing laryngeal anterior commissure tumors, he or she is encouraged by some authors to avoid CO2 laser microsurgery. Alternatively, the 810 nm diode laser has been recently used for the treatment of glottic tumors and may allow better exposure and resection of tumors in the anterior commissure. The first to establish long-term results for glottic cancer treatment were Ferri et al, in 2008. However, it seems that diode laser has not been well accepted worldwide for
| Study          | Year | Follow-up Range (Mean) | Type of laryngeal disease | Main outcome findings                                                                 | Complications                                                                 |
|---------------|------|------------------------|---------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Saetti et al  | 2003 | (6m)                   | bilateral vocal cord palsy | Good (no exertional dyspnea after physical effort), sufficient (no resting dyspnea and normal everyday activity) results, and decannulation of previously tracheotomised patients were obtained from all patients after one or two procedures. | No significant intraoperative complications occurred. The only complications observed, in the post-operative period, were 3 cases of granulation, which was removed on an outpatient basis, and 1 case of posterior synechia that required no further treatment. |
| Ferri et al   | 2006 | (20m)                  | bilateral vocal cord palsy | The improvement in respiratory function was evident already between the first hours, stabilizing on the first week. By the second day, all patients could eat without aspiration. The nine patients with tracheostomy cannula previous from the endoscopic surgery were decannulated in a maximum of sixty days after surgery. | None                                                                         |
| Saetti et al  | 2008 | –                      | Subglottic hemangioma / lymphangioma | Diode laser was the primary treatment in 22 patients, showing a success rate of 95% (21 of 22). One children experienced a recurrence of stridor after systemic steroids therapy and required diode laser vaporization. The same secondary laser treatment was used in 2 cases in which a progression of the tumor with worsening of respiratory symptoms was recorded notwithstanding steroid treatment. Other 2 patients that underwent intraleisional corticosteroid injection underwent secondary laser treatment. | No early complications (intraoperative or postoperative bleeding). One tracheal posterolateral bridge synechia (resolved after treatment with a diode laser section); and one laser-induced subglottic granuloma - successfully removed by means of videoscopic forceps. |
| Bajaj et al   | 2008 | 6m - 3y                | Mainly subglottic stenosis, but included various (8) diagnosis | 19/31 (61.3%) patients have been cured of their initial pathologies and were not under further review. Another 9/31 (29.0%) had to undergo different operations. The remaining 3/31 (9.6%) (all three recurrent respiratory papillomatosi) are undergoing repeated laser and other adjuvant treatments. | None                                                                         |
| Fanjul et al  | 2008 | –                      | Various (5) diagnosis      | The saccular lesions, mucous membranes, granulomas and arytenoid abnormalities resolved by the exclusive application of laser (78.6% with a single procedure). In other situations, such as vascular anomalies (hemangiomas and lymphangiomas) and subglottic stenosis, we have pointed to other treatments (surgical and medical in 87.5% and 12.5% respectively) for resolution. | None                                                                         |
| Study       | Year | Follow-up Range (Mean) | Type of laryngeal disease | Main outcome findings                                                                                                                                                                                                 | Complications                                                                                                                                                                                                 |
|------------|------|------------------------|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ferri et al | 2008 | 24–86m (36m)           | Glottic carcinoma         | There were 5 recurrences (11.1%): 4 local (8.9%), in which 3 were salvaged, and 1 (2.2%) regional (N2a). Three patients (6.7%) developed second primary cancers on the opposite cord after a mean of 18 months (range, 9–47 months) (1 was salvaged with total laryngectomy, 1 with repeat laser surgery and RT, 1 with partial laryngectomy with open surgery). | No major complications were observed. The development of small granulomas was uncommon (6.6%) and they usually resolved within a few weeks without any further surgery. |
| Edizer et al | 2013 | 24–48m (35.3m)         | Glottic carcinoma         | The involvement of the anterior–commissure was present in 13 (22%) of the patients. During the follow-up period, in 8 of these patients, granulation tissue or synchiae developed at the anterior part of the larynx. Local recurrence was encountered in 5 (8%) patients (1 case with T1a, 3 with T2 and one patient with T3 primary tumor at the initial presentation). | Thyroid cartilage exposure in 1 patient. Intraoperative laser-induced fire occurred due to thermal injury of the laser on the intubation tube in 1 patient. Two patients developed cutaneous emphysema which resolved in one day without intervention. In the postoperative period, infection and foul smelling halitosis developed in 5 patients in whom relatively more extended laser surgery was performed. Laryngeal stenosis was seen in 2 patients. |
| Liu et al   | 2013 | 13–58m (40.8m)         | Ventricular dysphonia     | No neo-growth of false folds was noted. (OBS: the role of diode laser was not improving the vocal quality but offering better visualization of true vocal behavior).                                                                 | None                                                                                                                                                                                                       |
| Tunçel et al | 2013 | 15–32m (20.4m)         | Glottic carcinoma         | Local control and larynx preservation rates were 93.8% and 100%, respectively. There were 4 recurrences (6.2%), all within the first 15 months after treatment (range, 10–15 months).                                                                 | Fistula formation (1.5%), hemorrhage (1.5%), and massive recurrent granuloma formation (1.5%) were the main complications. Minor complications, including synchiae and granuloma, were seen in 20.2% of the patients. Four (6.2%) patients had synchiae, and 25% of these patients needed surgical treatment. Nine (14%) patients had mild granuloma formation. Almost all complications were related to anterior–commissure surgery. |
| Karasu et al | 2014 | 2m                     | Vocal polyp               | Postoperatively, in terms of voice handicap index and voice analyses, no statistically significant differences were found between the diode laser group and cold knife group and both improved significantly from baseline measurement (p < 0.001).                                                                 | None                                                                                                                                                                                                       |
| Cömert et al | 2014 | 12–37m (29.3m)         | Glottic carcinoma         | Initial control of the primary lesions was achieved in 97.4% (n = 38) for T1 and 87.8% (n = 29) for T2 patients.                                                                                                                                                                   | 5 patients (6.9%) developed a locoregional recurrence.                                                                                                                                                      |

Abbreviations: m, months; y, years.
laryngeal surgery, as our review shows a gap of publications between 2008 and 2013. According to that, we speculate that most institutions continued using the CO2 laser, due to doctors’ familiarity with its use, capabilities, and limitations.9,10 On the other hand, the 980 nm diode laser is a new technology, and has been reported for the treatment of early glottic tumors and vocal fold polyps since 2013.7–9 The main difference between these two diode laser wavelengths is their distinct absorption by the vocal fold, as the 980 nm is slightly more absorbed by water than the 810 nm one. The three studies that used the 980 nm diode laser were among those with a better design in our review. Two referred to controlled trials8,9 and the other was an uncontrolled trial.7 These studies showed good efficacy results and low rates of major complications.

Concerning functional outcomes, as measured by the voice handicap index (VHI), Karasu et al showed good results of 980 nm diode laser in treating vocal fold polyps.8 A comparison between diode and CO2 laser could be quite useful to highlight the differences and compare the results, especially the functional ones. The ideal comparison to assess both types of lasers would involve a randomized clinical trial with these two techniques, which is nonexistent in the literature. Even though the comparison of non-controlled studies of two different techniques can involve bias, in Table 4 we show some results of some authoritative works related to the use of CO2 laser for larynx surgery in the literature in similar conditions to those with diode laser on our review, so that the reader can grossly compare with Table 3.

Regarding safety issues, five authors reported no complications or side effects by the use of the diode laser, but none of these studies was related to glottic cancer or extensive procedures. The major complications were related to more extensive surgeries and with anterior commissure involvement.7 Possibly the most feared complication is the endotracheal tube airway fire, which can be catastrophic or even fatal.24 To avoid that, some authors use reinforced tubes for laser surgery6 while others described the tube being inflated

**Table 4** Results of comparable studies of CO2 laser in larynx surgery

| Study / Country | Year | Follow-up Range (Mean) | Type of laryngeal disease | No. of patients | Main outcome findings | Complications |
|-----------------|------|------------------------|--------------------------|-----------------|-----------------------|--------------|
| Bajaj et al / UK | 2009 | 3m-4y (28m)            | Bilateral vocal cord palsy | 9               | None of the patients required post-operative tracheostomy, and all three patients with a previous tracheostomy were successfully decannulated within one month of their operation. | Tracheotomy was performed on 4 (6%) patients postoperatively because of dyspnea caused by vocal edema; 12 patients (18%) required a second operation, including the 4 who underwent postoperative tracheotomies. Four patients (6%) underwent a revision procedure for postoperative tracheotomies. Four patients (6%) underwent contralateral posterior cordotomy because of an insufficient airway in a second operation. |
| Özdemir et al / Turkey | 2013 | 4–120m (40m)          | Bilateral vocal cord palsy | 66              | For 58 patients (88%), airway restoration was maintained by performing a successful 1-step surgical procedure. 7 patients (11%) had vocal edema in the postoperative hospitalization period. Medical treatment with oral corticosteroids corrected edema in 3 patients. | |
| Bitar et al / USA | 2005 | 12–69m (33m)          | Subglottic hemangioma     | 81              | Thirty-six patients receiving CO2 laser combined with systemic corticosteroids had 80.6% success rate. | Complications in all patients receiving CO2 laser included subglottic stenosis (5.5%), web formation, pneumothorax, and interarytenoid scarring. Used on 58 tracheotomized patients, the CO2 laser resulted in a decrease in the mean cannulation duration from 21 to 7.3 months. |
| Canis et al / Germany | 2015 | 0.03–236.3m (78.2m) | Glottic cancer           | 404             | Recurrence developed in 56 patients (14.4%). Site of recurrence was local in 50 patients and locoregional in 6 patients. Nineteen patients experienced a second and 7 patients a third recurrence. A total laryngectomy was required in 11 patients for salvage after primary laser microsurgical resection. | The overall complication rate was 1% (4 of 404) and included airway obstruction in 2 patients (0.5%), which were successfully treated with corticosteroids and postoperative bleeding that required microlaryngoscopic electrocaugulation in 2 patients (0.5%). Sixty-six patients (15.1%) underwent a second microlaryngoscopy for removal of granulation tissue. No patient needed a tracheostomy or nasogastric feeding tube. |
| Benninger / USA | 2000 | 5–12 w                 | Benign lesions           | 37              | Significant improvements in video-stroboscopic parameters were found over time. | None |

Abbreviations: m, months; y, years.
using saline with methylene blue dye, so that a puncture could be immediately diagnosed.\textsuperscript{7}

This review highlights the lack of good evidence for the use of diode laser in laryngeal surgery. Furthermore, it is clear that there is wide variation in how it is used around the world. The 980 nm diode laser seems to be a promising laser device, so we would expect that, as experience increases, it will be more extensively used as well as new lasers wavelengths can emerge.\textsuperscript{8}

Final Comments

Despite the heterogeneous populations, varied inclusion criteria, and retrospective designs of most the studies considered in this review, they do provide useful information to the surgeon who intends to use diode laser for transoral laser microsurgery. The evidence from recent studies suggests an improvement in diode laser technology (especially the 980 nm wavelength). Further long-term multicenter prospective research is needed, although the findings of this review suggest that diode laser is a useful tool that should be considered in laryngeal surgeries.

References

1 Strong MS, Jako GJ. Laser surgery in the larynx. Early clinical experience with continuous CO\textsubscript{2} laser. Ann Otol Rhinol Laryngol 1972;81(6):791–798
2 Bajaj Y, Pegg D, Gunasekaran S, Knight LC. Diode laser for paediatric airway procedures: a useful tool. Int J Clin Pract 2010;64(1):51–54
3 Fanjul M, García-Casillas MA, Parente A, et al. Utilización del láser diodo en la vía aérea pediátrica. Cir Pediatr 2008;21(2):79–83
4 Vilaseca I, Bernal-Sprekelsen M, Luis Blanch J. Transoral laser microsurgery for T3 laryngeal tumors: Prognostic factors. Head Neck 2010;32(7):929–938
5 Saetti R, Silvestrini M, Cutrone C, Narne S. Treatment of congenital subglottic hemangiomas: our experience compared with reports in the literature. Arch Otolaryngol Head Neck Surg 2008;134(8):848–851
6 Ferri E, Armato E. Diode laser microsurgery for treatment of Tis and T1 glottic carcinomas. Am J Otolaryngol 2008;29(2):101–105
7 Tunçel Ü, Çömert E. Preliminary results of diode laser surgery for early glottic cancer. Otolaryngol Head Neck Surg 2013;149(3):445–450
8 Karasu MF, Gundogdu R, Cagli S, et al. Comparison of effects on voice of diode laser and cold knife microlaryngotomy techniques for vocal fold polyps. J Voice 2014;28(3):387–392
9 Çömert E, Tunçel Ü, Dizman A, Güney YY. Comparison of early oncological results of diode laser surgery with radiotherapy for early glottic carcinoma. Otolaryngol Head Neck Surg 2014;150(5):818–823
10 Saetti R, Silvestrini M, Galiotto M, Derosas F, Narne S. Contact laser surgery in treatment of vocal fold paralysis. Acta Otorhinolaryngol Ital 2003;23(1):33–37
11 Ferri E, García Purriños FJ. Diode laser surgery in the endoscopic treatment of laryngeal paralysis. Acta Otorrinolaringol Esp 2006;57(6):270–274
12 Edizer DT, Cansiz H. Transoral Laser Microsurgery for Glottic Cancers - Complications and Importance of the Anterior Commis- sure Involvement. Istanb Med J. 2013;14:12–15
13 Liu S-C, Lin D-S, Su W-F. The role of diode laser in the treatment of ventricular dysphonia. J Voice 2013;27(2):250–254
14 Sullins KE. Diode laser and endoscopic laser surgery: Vet Clin North Am Small Anim Pract 2002;32(3):639–648, vii viii
15 Rubinstein M, Armstrong WB. Transoral laser microsurgery for laryngeal cancer: a primer and review of laser dosimetry. Lasers Med Sci 2011;26(1):113–124
16 Yan Y, Olszewski AE, Hoffman MR, et al. Use of lasers in laryngeal surgery. J Voice 2010;24(1):102–109
17 Benninger MS. Microdissection or microspot CO\textsubscript{2} laser for limited vocal fold benign lesions: a prospective randomized trial. Laryngoscope 2000;110(2 Pt 2, Suppl 92)1–17
18 Xu W, Han D, Hou L, Zhang L, Yu Z, Huang Z. Voice function following CO\textsubscript{2} laser microsurgery for precancerous and early-stage glottic carcinoma. Acta Otolaryngol 2007;127(6):637–641
19 Lucioni M, Marioni G, Bertolin A, Giacomelli L, Rizzotto G. Glottic laser surgery: outcomes according to 2007 ELS classification. Eur Arch Otorhinolaryngol 2011;268(12):1771–1778
20 Bajaj Y, Sethi N, Shayah A, et al. Vocal fold paralysis: role of bilateral transverse cordotomy. J Laryngol Otol 2009;123(12):1348–1351
21 Özdemir S, Tuncer Ü, Tarkan Ö, Kara K, Sürmelioğlu Ö. Carbon dioxide laser endoscopic posterior cordotomy technique for bilateral abductor vocal cord paralysis: a 15-year experience. JAMA Otolaryngol Head Neck Surg 2013;139(4):401–404
22 Bitar MA, Moukarbel RV, Zalzal GH. Management of congenital subglottic hemangioma: trends and success over the past 17 years. Otolaryngol Head Neck Surg 2005;132(2):226–231
23 Canis M, Ihler F, Martin A, Matthias C, Steiner W. Transoral laser microsurgery for T1a glottic cancer: review of 404 cases. Head Neck 2015;37(6):889–895
24 Dhar P, Malik A. Anesthesia for laser surgery in ENT and the various ventilatory techniques. Trends Anaesth Crit Care. 2011;1:60–66