

1064-nm Nd: YAG Laser-Assisted Cartilage Reshaping for Treating Ear Protrusions

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Background: Correction of prominent ears is a common plastic surgical procedure. The laser-assisted cartilage reshaping (LACR) technique for protruding ears was developed at the French National Institute of Health and Medical Research in Lille, France, using both the 1064- and 1540-nm wavelengths, with a view to simplifying the surgical procedure. Herein we report our results with the 1064-nm wavelength.

Methods: Between 2008 and 2010, twenty-six 1064-nm LACR procedures in 14 patients were performed. Twelve patients received treatment to both ears, and 2 patients received treatment to one ear. Each procedure consisted of a single treatment session. The treatment consisted of laser irradiation of both sides of the helix with single pulses of 70 J/cm². The beam diameter was 6 mm. Early and late complications were defined and reviewed for all patients. Satisfaction was assessed by patients using a visual analogue scale from 0 (unsatisfied) to 20 (highly satisfied). The superior and middle cephaloauricular distances were prospectively evaluated at 6 months after treatment.

Results: Complications included eight cases of localized skin burns and one case of dermatitis. The mean right/left superior and middle cephaloauricular distances were 10.5 ± 1.5 mm/10.7 ± 1.0 mm and 16.3 ± 2.2 mm/16.3 ± 2.8 mm, respectively, as compared to 17.5 ± 2.9 mm/18.6 ± 2.5 mm ($P < 0.01$) and 24.5 ± 2.6 mm/24.7 ± 1.7 mm ($P < 0.01$) before the operation. Mean patient satisfaction was 16.8/20 ± 3.3.

Conclusion: Despite promising results for cartilage reshaping, the 1064-nm LACR procedure often leads to skin burns and inflammatory tissue reaction after treatment. Moreover, LACR with the 1064-nm wavelength is painful and necessitates local anaesthesia.

Key Words: 1064-nm laser; 1540-nm laser; cartilage reshaping, ear protrusion, flulence.

Level of Evidence: IV.

Laryngoscope, 00:000–000, 2015

INTRODUCTION

Failure of scaphal folding, flat antihelix, deep concha, and increased concha scaphal angle create prominence of the ear. Protruding ears are the most common congenital ear deformity, with a frequency of 13.5% and a well-known hereditary component.¹ Applications for facial laser-assisted cartilage reshaping (LACR) have generated increasing clinical interest ever since the first report of the correction of cartilaginous deformities in the head and neck was published by Sobol in 1993.^{2,3}

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Editor's Note: This Manuscript was accepted for publication March 5, 2015.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

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DOI: 10.1002/lary.25294

The LACR technique for protruding ears was developed on animal ear cartilage at the French National Institute of Health and Medical Research (INSERM) in Lille, France, using both the 1064- and 1540-nm wavelengths, with a view to simplifying the surgical procedure, improving patient comfort, and reducing complications. In this procedure, the laser is applied on both sides of the entire helix and concha. In 2006,⁴ 2008,⁵ and 2011,⁶ we have reported our experience with the 1540-nm wavelength.

In this article we present our results with another wavelength (1064 nm), which was used until 2010 in one center working in cooperation with the INSERM U703. We compare the present results with our previous clinical studies. We also discuss the potential risk of complications and the stability of ear reshaping.

MATERIALS AND METHODS

Patients

The prospective study was approved by the Ethics Committee of the Antoni De Gimbernat Foundation. Fourteen adult patients were treated with 1064-nm Nd:YAG (yttrium aluminium garnet) laser LACR between January 2008 and June 2010. Twelve patients received treatment to both ears and 2 patients received treatment to one ear. All patients underwent procedures at the Antoni De Gimbernat Foundation in

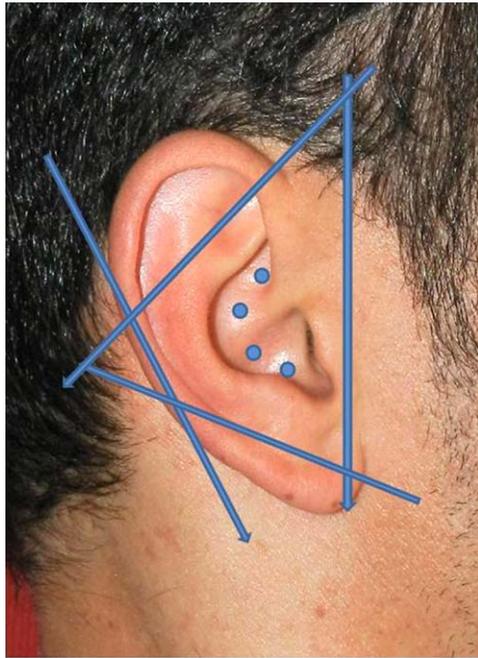


Fig. 1. Injection model for anaesthesia block of the whole ear. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

collaboration with INSERM U703. All patients were informed of the purpose and possible outcomes of the study, signed forms of consent for the study, and agreed to clinical photography. The patients' mean age was 44.2 ± 10.9 years (range = 28–68 years) with skin phototypes II to IV.

The 1064-nm LACR Technique

The 1064-nm YAG laser (CoolTouch; CoolTouch Corporation, Roseville, CA) was set for repetition pulse emission of 1 Hz; therefore, pulses were given 1 per second, without overlapping, to cover the whole area of irradiation of both sides of the helix. Treatment was carried out using 25 ms in length pulses of 70 J/cm^2 fluence per pulse. Beam diameter was 6 mm, using a handpiece with integrated cooling spray programmed for dynamic cooling of the cyro spurts were of 20 ms prior to the laser pulse, followed by a 5-ms delay time of the cooling and then a further 20 ms of cyro spurt after the laser pulse. Laser pulses covered both sides of the entire helix and concha. However, the cartilage fold, which divides the concha and helix, was irradiated with an extra pass (two passes of laser pulses in total). Treatment was firstly tried without anaesthesia, using only the dynamic cryo cooling of the laser device. However, patient reaction to pain required the use of local anaesthesia with mepivacaine 2% without vasoconstrictor, for blockage of the whole ear. Anaesthesia injections were given following the design shown in Figure 1 (arrows and dots).

Silicone Elastomer

Immediately after irradiation, a steroid ointment of prednicarbate (Peitel; Ferrer Internacional-Ferrer Grupo, Barcelona, Spain) was carefully rubbed over the whole irradiated area of the ear. Then, a silicone elastomer (Hydro-C; Detax, Ettlingen, Germany) was inserted gently inside the helix to accommodate it and give it the desired new shape. Three minutes later, the elastomer hardened and a solid mold was

obtained. Following this, a band was firmly placed for compression and to hold the mold in place. Patients were asked to wear the bandage with this mold at all times for the first 2 weeks and then only at night for an additional 4 weeks. A nonsteroidal antiinflammatory drug, (ibuprofen; Aldo-Unión, Barcelona, Spain), was prescribed to all patients for 3 days.

Analysis of Complications

Early complications were defined as burn, dermatitis, perforation of the skin, hematoma, or infection. Late complications were defined as asymmetry, recurrence, hypertrophic scar and keloid, alteration in sensitivity, and skin alterations or further ear deformities.

Subjective Parameters

Patient satisfaction was recorded using a visual analogue score (0–10), with 0 being the worst and 10 being the best aesthetic for each ear. This reflects the overall appearance and symmetry of the reshaped ears. Patients scored their own satisfaction directly using mirrors and pictures (3 mirrors that allowed the patients to get a front view, back view, and a lateral view). The global score for each patient was obtained by the sum of each side and was divided into three categories according to the scores: pleased (16–20), satisfactory (11–15), and unsatisfactory (1–10). Considering long-term outcomes and comprehensive care, patients were also asked if they would be willing to undergo the operation again.

Objective Parameters

The superior and middle cephalo-auricular distances were measured before treatment and at the control 6 months postoperatively in 13 of the 14 patients (the 14th patient did not

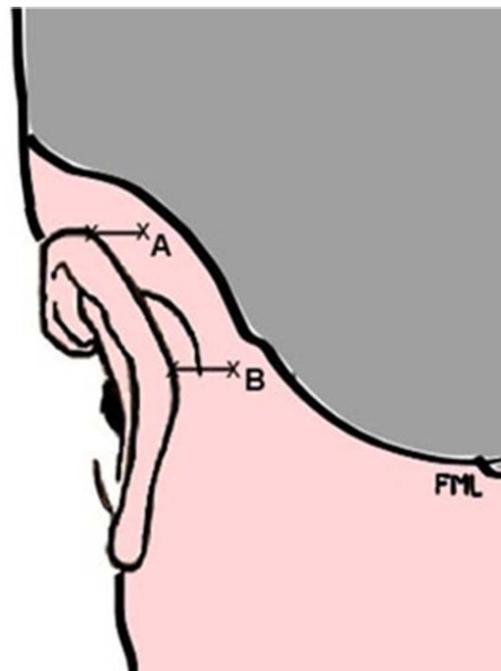


Fig. 2. (A) Distance from the ear to the head at the superior helix. (B) Distance from the ear to the head at the top of the ear canal. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

TABLE I.
Our Series of Reshaped Protruding Ears Using the 1064-nm Laser on 14 Patients.

N	Age (Years)	Skin Phototype (Fitzpatrick)	Follow-up (months)	Distance Ear to Head Superior Helix (mm) (Nle 10–12 mm)		Distance Ear to Head Top Ear Canal (mm) (Nle 12–20 mm)		Late Complications (none = 0; asymmetry = 1; residual deformity or recurrence = 2; alteration in, sensitivity, and growth = 3; hypertrophic, scar, and keloids = 4)	Patients Satisfaction VAS 0 to 20				
				Ear Right		Ear Left							
				Before	After	Before	After						
1	39	III	6	19	12	21	11	25	14	27	14	0	18
2	51	II	6	20	9	22	11	27	19	26	21	2	10
3	34	IV	6	–	–	18	9	–	–	23	12	0	18
4	43	III	6	22	10	21	11	26	17	24	16	0	18
5	55	III	No control	16	–	15	–	23	–	25	–	–	–
6	32	II	6	18	11	17	11	24	17	23	17	0	20
7	28	III	6	23	12	21	12	29	18	27	18	0	20
8	49	IV	6	17	12	19	12	22	16	23	15	0	18
9	46	II	6	16	9	21	10	26	17	27	21	1, 2	12
10	38	II	6	14	9	15	11	21	13	23	14	0	16
11	57	III	6	14	8	18	9	24	16	23	18	0	20
12	42	III	6	18	11	19	11	22	13	24	14	0	18
13	68	IV	6	17	12	–	–	21	16	–	–	0	18
14	37	II	6	14	11	15	10	28	20	26	16	1	12
Average	44.2			17.5	10.5	18.6	10.7	24.5	16.3	24.7	16.3		16.8
SD	11.0			2.9	1.5	2.5	1.0	2.6	2.2	1.7	2.8		3.3

SD = standard deviation; VAS = visual analogue scale.

attend the final appointment). Measurements were compared to the preoperative values: the superior cephalo-auricular distance being defined as the distance from the most lateral point of the helical apex to the mastoid. The middle cephalo-auricular distance was defined as the distance from the ear to the head at the top of the ear canal (Fig. 2). Using these two measurements, it was possible objectively to define asymmetry as a difference of more than 3 mm between each ear (right vs. left).

Histological Examination

Punch biopsies of the whole helix thickness were taken in four randomly chosen patients. None of the patients presented any skin burns. Tissue samples were taken before and immediately after finishing laser irradiation. In the same four patients, samples of equal characteristics were taken 6 months after LACR.

Statistical Analysis

Data are presented as mean. Student's test (2 samples) is used to calculate the *P* values and *P* < 0.05 was considered to be statistically significant.

RESULTS

Early and Late Complications

There were six cases of I-degree burns and two cases of IIa-degree burns. Early postoperative follow-up was uneventful for all patients, except in one case where minor contact dermatitis developed because of inappropriate mold design. This patient stopped wearing the mold, leading to incomplete shape correction (Table I).

Additionally, one patient without any burns presented incomplete reshaping. Two cases presented a slight asymmetry. There were no cases of scarring or alteration in sensitivity, skin changes, or worsening of ear deformity.

Comparative Cephaloauricular Measures

Mean preoperative right/left superior and middle cephaloauricular distances were, respectively, $17.5 \pm 2.9/18.6 \pm 2.5$ mm, and $24.5 \pm 2.6/24.7 \pm 1.7$ mm. At the 6-month follow-up mark, the measurements were $10.5 \pm 1.5/10.7 \pm 1.0$ mm (*P* < 0.01) and $16.3 \pm 2.2/16.3 \pm 2.8$ (*P* < 0.01) (Table I).

Histology

Microscopic analysis of all samples of the four random patients who were examined showed normal skin and cartilage structure with standard anatomical characteristics. Immediately after treatment, samples showed no skin damage, but inflammatory infiltration of the dermis and separation of fibres were noticed. The perichondrium cartilage showed a hyalinization phenomenon with gel-like appearance and loss of normal patterns (Fig. 3). Chondrocytes presented differences in their normal appearance and signs of partial coagulation and a few zones of isolated necrosis. At 6 months, histology showed signs of cartilage maturation with few binuclear chondrocytes. Typical chondrocyte vacuoles were present, together with signs of thicker perichondrium, indicating a broader new cartilage growth.

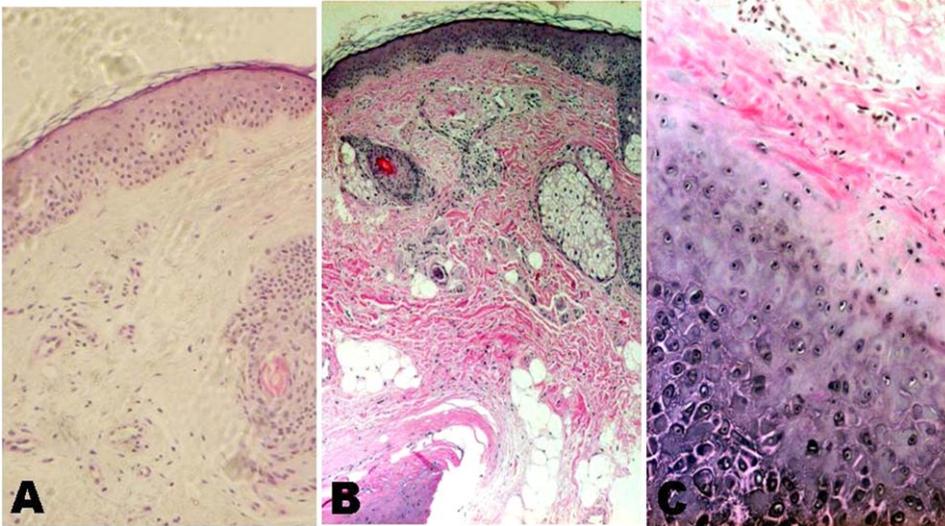


Fig. 3. (A) H&E/EO $\times 125$. Ear skin; epidermis and dermis of standard characteristics. (B) HE/EO $\times 125$. Immediately after laser-assisted cartilage reshaping LACR; epidermis is preserved. Signs of coagulation in dermis with inflammatory infiltration. (C) HE/EO $\times 250$. Immediately after LACR, signs of coagulation and hyalinization (gel-like) of the cartilage. EO = eosin; H&E = hematoxylin and eosin; LACR = laser-assisted cartilage reshaping. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Patient Satisfaction

Mean global satisfaction, observed and calculated at 6-month follow-up for all but one case, and measurements at follow-up are shown in Table I. All 13 patients interviewed at the 6-month follow-up reported that they would be willing to undergo the procedure again but using anaesthesia. Regarding satisfaction outcome scores, 10 patients were in the pleased group, two in the satisfactory group, and one patient in the unsatisfactory group. These three patient scores corresponded to two patients who did not achieve total reshaping and one patient who presented a slight asymmetry. However, all were satisfied with the natural curvature of their newly shaped ears (Figs. 4–7).

DISCUSSION

In this study, 14 patients underwent 1064-nm LACR for protruding ears. Complications included eight cases of localized skin burn and one case of dermatitis. The mean right/left superior and middle cephaloauricular distances were $10.5 \pm 1.5/10.7 \pm 1.0$ mm and $16.3 \pm 2.2/16.3 \pm 2.8$, respectively, as compared to

$17.5 \pm 2.9/18.6 \pm 2.5$ mm and $24.5 \pm 2.6/24.7 \pm 1.7$ mm before the operation. Mean patient satisfaction was 16.8/20.

Alternative methods have been developed to provide nonsurgical approaches to reshaping cartilage. Specifically, cartilage biomechanics and cell proliferation and differentiation are temperature-dependent, with temperatures between 50°C and 70°C producing stress relaxation, which leads to gross shape change.^{7–11} Thus, thermal-based mechanisms such as radiofrequency,¹² electrical current,^{13–16} or lasers,^{4–6} have been investigated in order to provide cartilage reshaping in place of traditional surgery. The main advantage afforded by these optical technologies is that cartilage reshaping may be achieved through an incision-free procedure with limited cutaneous injury and no associated risks and economic costs of surgery and anesthesia. In 2004, we reported a new technique using a 1540-nm laser to reshape protruding ears.⁷ This wavelength allowed for cartilage reshaping with neither skin nor cartilage incision, without cartilage scoring, and even without local anesthesia. A first study was performed in eight patients. Four of them underwent LACR of both ears,



Fig. 4. Thirty-four-year-old patient with protruding left ear: Front view before (A) and after (B) 1064-nm laser-assisted cartilage reshaping (Table I, Patient 3). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]



Fig. 5. Thirty-four-year-old patient with protruding left ear: Lateral view before (A) and after (B) 1064-nm laser-assisted cartilage reshaping (Table I, Patient 3). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

four of one ear only.⁴ A thickening of the perichondrium and the cartilage layers were observed at 2 weeks. This thickening was confirmed at 3 weeks and 1 month with an intact matrix. The chondrocytes were viable and functional, as confirmed by the binucleation of some chondrocytes. This thickening, which appeared to be concomitant with the formation of apatite, seems to play a key role in the permanent shape change of laser-irradiated cartilage.

In a second series of patients treated with 1540-nm Er:Glass laser,⁵ we reported our experience on 24 patients, 14 adults, and 10 children who underwent LACR for treatment of bilateral ear protrusion; and again, treatment was well tolerated without the need for anaesthesia. No hematoma or skin necrosis occurred. Contact dermatitis was observed in four children and two adults as a result of inappropriate mold design. These patients stopped wearing the mold, and the shape of their ear did not improve. For the remaining 18 patients, the expected ear reshaping was obtained with fluences of 84 J/cm^2 . In that study, three adults obtained incomplete reshaping of the ears, which was correlated to a lower fluence of 70 J/cm^2 used. Those patients were retreated 3 months later with 84 J/cm^2 fluence, and all

achieved suitable reshaping. In a third study published in 2011, we reported the outcomes of 32 procedures after a follow-up from 11 to 48 months.⁶ Using the cephaloauricular distances, this study objectively showed that LACR could be performed at all ages with excellent results. Except for two cases of dermatitis, there were no early or late complications such as scars. The mean superior and middle cephaloauricular distances were 12.3 ± 1.9 and 13.7 ± 1.6 mm, respectively, as compared to 17.8 ± 3.1 mm and 23.9 ± 1.9 mm before the procedure. Mean patient satisfaction was 8.6/10, with all patients reporting that they would be willing to undergo the procedure again, if required.

In this new study, another wavelength was used: 1064 nm. Although the penetration depth of this wavelength is greater than that of the Er:Glass 1540-nm laser, the former wavelength remains lower in its absorption by the ear cartilage. This 1540-nm absorption will take place with less injury to the surrounding tissue to that of the 1064-nm wavelength, which has a much broader spectrum of absorption. As a result, 1) the surgical technique may be better performed under anaesthesia. This complicates the technique whose primary goal was simplification. This was not the case with the



Fig. 6. Forty-two-year-old patient with protruding ears: Front view before (A) and after (B) 1064-nm laser-assisted cartilage reshaping (Table I, Patient 12). [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]



Fig. 7. Forty-two-year-old patient with protruding ears: Back view before (A) and after (B) 1064-nm laser-assisted cartilage reshaping (Table 1, Patient 12).. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Er:Glass laser. 2) Moreover, the fact that the skin was burned in eight of the 14 cases treated indicates that heating is less controllable, with 1064 nm as compared to 1540 nm. The latter uses a cooling spray before firing the pulses, which were in form of a train of pulses to achieve a total energy of $84\text{J}/\text{cm}^2$. In the case of the Nd:YAG laser used in this study, single pulses of $70\text{ J}/\text{cm}^2$ were fired with spurts of cooling spray before and after the pulse. This would indicate that the delay time between the series of pulses used by the 1540-nm laser enables tissue to cool down, avoiding heat accumulation and thermal propagation. In the case of the 1064-nm laser, producing the skin burn and noticeable damage to the ear cartilage, there was a single pulse carrying less fluence, $70\text{ J}/\text{cm}^2$, but solid enough to lead to thermal propagation and skin burns. In this context, it is important to underline that we had no burn event in any of our previous series of patients treated with the Er:Glass laser. 3) Finally, from the histological point of view, no permanent cartilage damage due to by necrosis was observed with the Nd:YAG 1064-nm laser. A detectable coagulation phenomenon of skin and cartilage was noticed, as when compared to histologies of the 1540-nm Er:Glass laser of our previous studies.⁴ Checking cartilage recovery, tissue reaction was also stronger with the 1064-nm as compared with the 1540-nm laser. With the former, there is a more active dense population of chondrocytes and a strong perichondrium proliferation with fibrotic reparative reaction.

For Helidonis et al., the reshaping is obtained through increased cartilage malleability at temperatures between 65°C and 75°C .^{2,17} For Mordon et al., proliferation and regeneration of cartilaginous cells have been observed after LACR at lower temperatures and are considered as the main contributor to the stability of long-term shape change.^{4,7} Whatever the theory, this level of temperature must be achieved without skin damage. Compensation of skin heat absorption would be achieved with moderate level of energy contained in each laser pulse used. However, it is difficult to predict if these

laser settings would be efficacious to thermally reshape ear cartilage, maintaining a new shape. A second solution could be to perform laser as a complementary tool to surgery, in other words, in direct contact with cartilage during surgery. However, this method, which uses both laser and surgery, complicates the technique whose primary goal is simplification and the absence of scarring and anesthesia.

In this context, it is important to underline that this approach was recently proposed by Ragab but with another wavelength.¹⁸ The author accomplished LACR using ablation to a partial thickness of the medial surface of the antihelices. Use of the CO₂ laser permitted cartilage reshaping with both vaporization and incisions. In Ragab's technique, the open approach allocated precise laser application and cartilage suture, providing excellent stabilization. Postoperative care involved wearing a simple bandage for a week, representing a considerable advantage. However, although this method uses both laser and surgery, it once again complicates the technique for which the primary goal is simplification and the absence of scarring and anesthesia.

In our opinion, the 1540 nm is superior because the 1) wavelength's penetration depth matches the thickness of the cartilage, allowing for homogenous heat generation. 2) Contact cooling makes the treatment very tolerable. 3) The degree of correction appears similar to that obtained by conventional techniques. 4) Furthermore, LACR provides a smoother and more natural curvature than conventional techniques and without any scarring. The key point is the splint; it needs to be worn, which is sometimes difficult for patients, especially the younger ones. Although Mordon et al.⁷ and Holden et al.¹⁹ achieved reshaping in their respected animal studies within 1 week, an extended splinting duration was needed in the clinical studies in order to enhance shape change stabilization. In this study, the mold was designed based on an ideal shape of the ear and not the contralateral side. This was performed using a computer program.

Despite the long follow-up period covered in this study, its protocol was limited by its nature as a noncontrolled analysis and the small number of patients.

CONCLUSION

Despite promising results on cartilage reshaping, the 1064-nm LACR procedure often leads to skin burns and inflammatory tissue reaction after treatment. Moreover, LACR with the 1064-nm wavelength is painful and necessitates local anaesthesia.

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