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Endoscopic stapedotomy: A comparison between the conventional approach versus CO_2 laser-assisted surgery

Pradeep Pradhan | **Vinusree Karakkandy** | **Chappity Preetam** | **Pradipta K. Parida**

Department of ENT and Head Neck Surgery, All India Institute of Medical Sciences, Bhubaneswar, Odisha, India

Correspondence
Pradeep Pradhan, Department of ENT and Head Neck Surgery, All India Institute of Medical Sciences, Bhubaneswar, Odisha, India.
Email: padiapradhan@gmail.com

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Abstract

Background: Although the utility of laser fiber in microscopic stapes surgery has been documented in the past, their role can be highly emphasized in endoscopic stapes surgery, especially in difficult anatomical situations.

Methods: This is a retrospective analysis of cases where a total of 46 patients (22 in conventional stapedotomy and 24 in CO_2 laser-assisted stapedotomy) were included in the study. The clinical parameters were assessed both in the preoperative and postoperative periods in the respective groups and later compared 12 weeks after stapedotomy.

Results: A total of 90.90% (20/22) of the patients in the conventional stapedotomy and 95.83% (23/24) of patients in laser-assisted stapedotomy had <20 dB of AB gap in the postoperative period ($P = 0.71$). Canaloplasty was required in six patients in the conventional stapedotomy and none of the patients in the laser group needed the same ($P = 0.01$). Chorda tympani nerve was manipulated in 59.09% (13/22) and 25.00% (6/24) of cases in the conventional group and in the CO_2 laser group, respectively ($P = 0.01$).

Conclusion: Although the audiological outcomes with fiber-enabled CO_2 laser in endoscopic stapedotomy are comparable to conventional surgery, it is a better tool in a narrow auditory canal, requiring minimal manipulation of the chorda tympani nerve.

KEYWORDS

CO_2 laser, conventional approach, endoscopic stapedotomy, outcomes

INTRODUCTION

Since the introduction of modern stapes surgery by Shea,[1,2] there has been a significant improvement in hearing outcome, minimizing the complication rate.[3,4] The clinical outcomes mainly depend on the crucial steps in the stapes surgery, that is, making a fistula over the footplate. Different surgical methods have been developed to make the fenestra over the stapes footplate for a better hearing outcome with minimal damage to the surrounding soft tissue.[5] Based on the above facts, the CO_2 laser has been increasingly used in microscopic and endoscopic stapedotomy.[6] With the advancement in endoscopic ear surgery, endoscopic stapedotomy is often preferred to the standard microscopic stapedotomy by providing a wide field of visualization and minimizing injury to the chorda tympani nerve.[7–9]

Hence, fiber-enabled CO_2 Laser stapedotomy can be a preferred surgical technique, especially for surgeons who routinely practice endoscopic ear surgery. Besides the primary advantages of CO_2 laser for making a precise fistula over the footplate, it can be used in the narrow external auditory canal and deformed middle ear anatomy, where the laser fiber can be negotiated in a curved axis, unlike the microscopic stapedotomy.[10] In our study, we have shared our experience of fiber-enabled CO_2 laser in endoscopic stapedotomy and compared the clinical outcomes with conventional endoscopic stapes surgery.

MATERIALS AND METHODS

This is a retrospective analysis of patients who underwent conventional endoscopic stapes or laser-assisted surgery in the Department of ENT in a tertiary care hospital between June 2018 and July 2021. The study considered all the diagnosed cases of otosclerosis who underwent endoscopic stapedotomy during the defined period. A total of 49 patients underwent endoscopic stapedotomy for otosclerosis. Standard endoscopic stapedotomy was performed in 25 patients (group A) and a fiber-enabled CO_2 Laser was used in 24 patients (Group B) after quasi-randomization. A total of three patients (one in the conventional endoscopic group and two in the CO_2 Laser group) did not come for regular follow-up and they were not considered for the final analysis. A total of 46 patients were accounted for in the final statistical analysis. Among them, 24 patients underwent conventional endoscopic stapes surgery and 22 underwent endoscopic stapedotomy assisted with CO_2 laser, as demonstrated in Figure 1. The diagnosis was made based on the history, clinical examination, and the pure tone audiogram (PTA). All patients with conductive deafness of >25 dB with normal bone conduction (BC) and absence of stapedial reflex were included in the study. Patients having a history of ear discharge or air-bone gap remaining <25 dB were excluded from the study. The preoperative parameters, like the demographic data of the patient's hearing status (PTA, impedance audiometry), were noted in both groups. The intraoperative parameters like the manipulation of the chorda tympani nerve, requirement of canaloplasty, and duration of the surgery were noted. In the post-operative period, each patient was evaluated for hearing outcomes and complications attributed to stapedotomy. Patients were counseled regarding the outcomes of the surgery and the alternative treatment options before the primary surgery.

Surgical procedure

Written and informed consent was obtained from each patient before the endoscopic stapedotomy. All the cases were operated on under local anesthesia by one surgeon. A 3-mm, 0-degree rigid endoscope was used for all the stapes surgeries in both groups. Transcanal incision was given from 6 o'clock to −12 o'clock position after injection of local anesthesia in all four quadrants. The skin flap was elevated and the middle ear cavity was inspected. In particular cases of the narrow canal (incomplete visualization of all four quadrants of the tympanic membrane with 0 degree, 3 mm endoscope), canaloplasty(curettage of posterior superior bony wall and scutum) was performed. After the confirmation of the stapedial fixation, the stapedial tendon was cut, and the incudo-stapedial joint was dislocated. A small fenestra was made over the stapes footplate with the help of a 0.3 mm straight perforator and later was enlarged

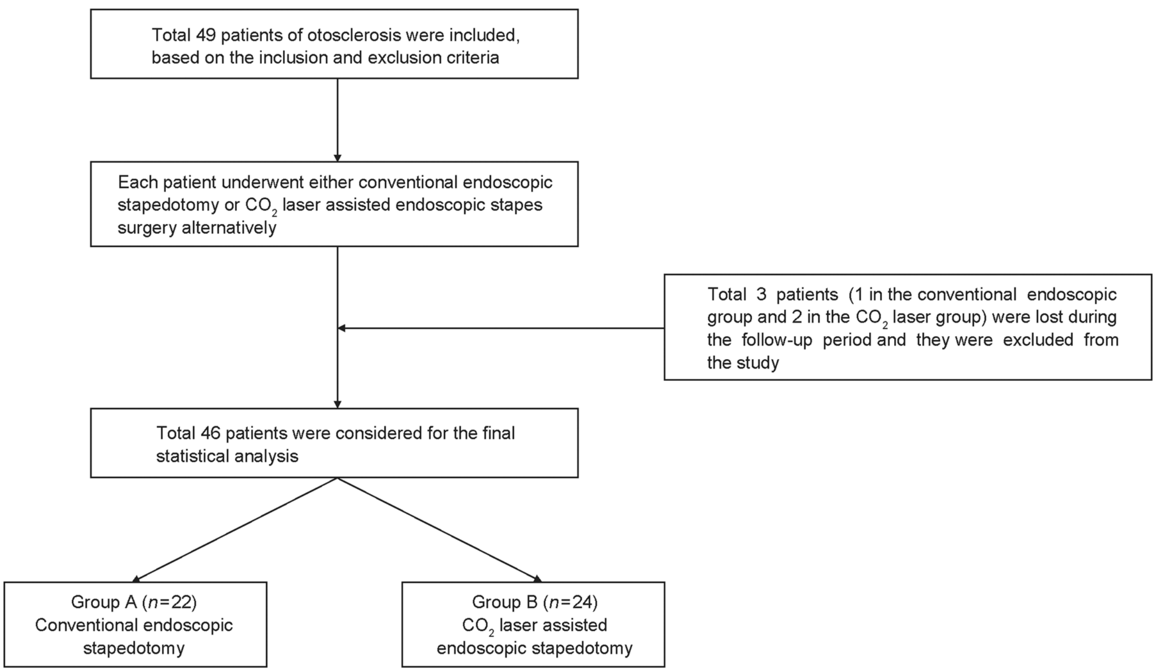

FIGURE 1 Study design.

to 0.3, 0.4, 0.5, 0.6, and 0.8 mm to achieve the final size. The surgical steps with CO_2 laser-assisted endoscopic stapedotomy was almost similar to the standard endoscopic stapedotomy except for some key steps where the laser was used instead of cold instruments. The fiber-Enabled CO_2 laser was used to cut the stapedial tendon, the posterior crus, vaporize the footplate and to make a precise fenestra over the footplate by noncontact technique.

The stapedial tendon was incised with two or three pulses of CO_2 Laser of 0.05 s at 2 W. The posterior crus is transected with four to eight pulses of 0.05 s duration at 6 W. Similarly, the fenestration of 0.5–0.7 mm diameter is made in the footplate using a single 20 W laser application of 0.03–0.05 s duration. After measuring the exact length, the Teflon piston (0.6 mm was inserted and hung over the long process of incus after opening to its fitting point. Then the stapes suprastructure was removed. The oval window was sealed with a piece of gelfoam placed around the piston. The metal flap was then reposited back and the subjective improvement in the hearing was assessed in each case. The sequential surgical steps of laser-assisted endoscopic stapedotomy have been demonstrated in Figure 2. The surgical findings, including the duration of surgery and the postoperative complications, were documented. The pure tone threshold before and after the surgery was compared in each group.

Follow-up

Patients were allowed to stay in the ward for 24 h after the surgery and then advised for discharge. Follow-up visits were recommended 1, 4, and 12 weeks after the surgery. During the follow-up visits, otoscopic examination and hearing assessment (PTA) was done on each patient. The audiological evaluation done at 12 weeks was compared with the preoperative value in each patient and later between the groups. The air conduction (AC) and BC thresholds were measured at the frequencies of 0.5k, 1k, 2k, and 4k Hz.

Statistical analysis

Paired *t*-tests were used to compare the preoperative and postoperative values of the patient in the same group. Unpaired *t*-tests compared the audiological parameters between the two groups. The χ^2 test or Fisher's exact test was used to compare the categorical variables between two groups. A *P*-value less than 0.05 with a 95% confidence interval was considered significant. The data were analyzed using the statistical package SPSS v 23.0.

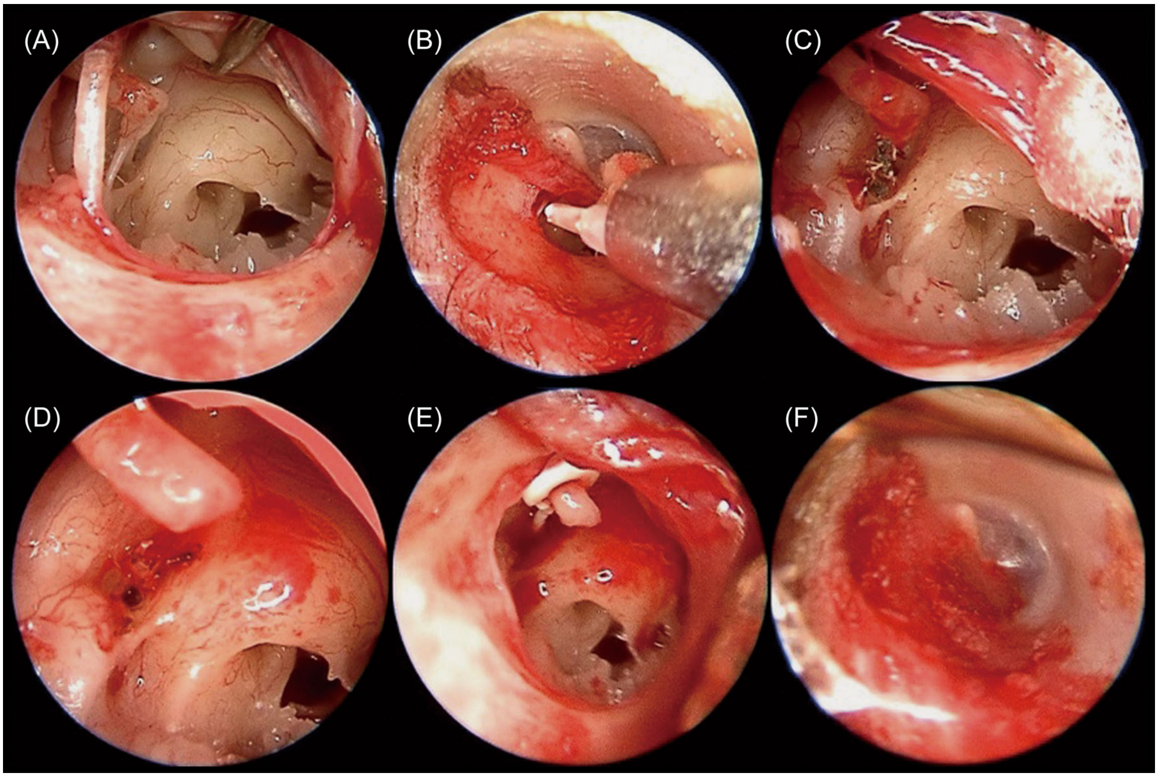

FIGURE 2 Key steps of laser-assisted endoscopic stapedotomy. (A) Complete exposure of the stapes superstructure. (B) The stapedial tendon was cut with a CO_2 laser attached to the handpiece. (C) Posterior crus of stapes was incised. (D) A hole was made over the posterior half of the footplate. (E) A Teflon piston of size 4.5 × 0.6 mm was inserted through the hole. (F) The metal flap was reposited back.

RESULTS

A total of 46 cases were included in the study and 22 underwent standard endoscopic stapedotomy (group A) and 24 patients (group B), underwent CO_2 laser-assisted endoscopic stapes surgery. The clinical profile of the patients is shown in Table 1. The minimum follow-up period was 3 months for patients of both groups. A total of 95.45% of patients in group A had bilateral otosclerosis and 83.33% of patients in group B had bilateral disease during the initial presentation ($P = 0.18$). Of 46 patients, seven patients in the conventional group and five patients in the laser B had a narrow external auditory canal. Of seven patients who had canal stenosis, six patients required canaloplasty for adequate exposure. None of the cases in laser-assisted stapedotomy needed canaloplasty ($P = 0.01$).

A total of 13 (59.09%) patients in group A needed manipulation of the chorda tympani nerve complete assessment of the footplate area. Similarly, 6 (25%) patients in group B required manipulation of the chorda tympani nerve ($P = 0.01$). The average surgical time in group A was 36 min (35–50) and in group B, it was found to be 39 min (from 34 to 52 min, $P = 0.06$). The preoperative ABG in group A and group B was found to be 39 dB (26–50 dB) and 40 dB (30–48 dB), respectively ($P = 0.38$). Likewise, the postoperative ABG in patients of group A was 10 dB (8–26 dB) and in group B, it was found to be 9 dB (from 8 to 26 dB, $P = 0.21$, Table 2).

At 12 weeks of follow-up, 40.90% of the patients in group A and 50.00% of patients in group B had ABG of <10 dB. Again, <20 dB ABG was found in 90.90% of the patients in group A and 95.83% of patients in group B after the primary surgery (Table 3). The ABG in the range 21–30 dB was found in two (9.09%) of cases in group A and one (4.16%) of cases in group B. When the difference in the ABG was compared between the two groups, we did not find any significant difference in any of the hearing level ($P = 0.71$). Again the preoperative and postoperative BC threshold was found in both groups and it was later compared between Group A and Group B at 12 weeks of follow-up. The mean preoperative BC threshold in group A was 10 dB and the average postoperative BC was found to be 11 dB ($P = 0.11$). At 12 weeks of follow-up, an improvement in BC threshold was detected at 500 Hz, 1 kHz, 2 kHz, and 4 kHz frequencies in patients of both groups. In the comparison of improvement in BC between the two groups, we did not find any significant difference concerning any of the described frequencies ($P > 0.05$) (Figure 3). Postoperative vertigo was noticed in 10 (45%) patients in group A and 7 (29%) patients in group B who required anti-vertiginous medication ($P = 0.60$). Overhanging of the facial nerve was detected in one patient in group A and one patient in group B had an obliterative footplate. Injury to the tympanic membrane during the procedure was detected in two patients in group A and one patient in

TABLE 1 Demographic data and patients characteristics of the study population ($n = 46$).

Characteristics	Conventional endoscopic stapedotomy ($n = 22$)	CO_2 Laser assisted endoscopic stapedotomy ($n = 24$)	P value, χ^2 test
Age (years)	31.00 ± 8.17	33.00 ± 7.11	0.26
Female (%)	86.36	75.00	0.33
Bilateral otosclerosis (%)	95.45	83.33	0.18
Narrow EAC (%)	31.81	20.83	0.01
Canaloplasty (%)	27.27	0	0.13
Translocation of chorda tympani nerve (%)	59.09	25.00	0.01
Chorda tympani nerve injury (%)	9.09	0	0.13
Postoperative giddiness (%)	45.45	29.16	0.33
Tympanic membrane injury (%)	18.18	12.50	0.59
Follow-up (months)	3	3	1.00
Operative time (min)	36	39	0.06

Abbreviation: EAC, external auditory canal.

TABLE 2 Comparison of hearing outcomes between conventional versus laser-assisted endoscopic stapedotomy.

Characteristics	Conventional endoscopic stapedotomy ($n = 22$)	CO_2 Laser assisted endoscopic stapedotomy ($n = 24$)	P, 95% CI, SED
Preoperative ABG (dB)	39.18 ± 7.28	40.75 ± 4.74	0.38, −5.19 to 2.05, 1.79
Postoperative ABG (dB)	10.41 ± 4.37	9.04 ± 3.00	0.21, −0.84 to 3.57, 1.09
Postoperative ABGC (dB)	40.09 ± 9.76	42.50 ± 4.79	0.29, −6.95 to 2.14, 2.25

Abbreviations: ABG, air-bone gap; ABGC, air-bone gap closure; CI, confidence interval; dB, decibel; SED, standard error difference.

TABLE 3 Mean air-bone gaps after 3 months.

ABG (dB)	Conventional endoscopic stapedotomy ($n = 22$) (%)	CO_2 Laser assisted endoscopic stapedotomy ($n = 24$) (%)	*P* value, χ^2 test
0–10	40.90	50.00	$P > 0.0$-5
11–20	50.00	45.83	
21–30	9.52	4.16	
>30	0	0	

Abbreviations: ABG, air-bone gap; dB, decibel.

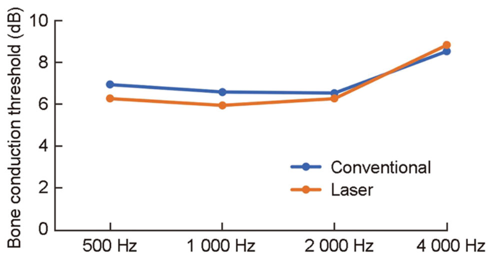

FIGURE 3 Comparison of bone conduction thresholds between the conventional and laser-assisted endoscopic stapedotomy at 12 weeks of follow-up.

group B, which were managed with fat grafting in the same sitting. Till 12 weeks of follow-up, we did not find any tympanic membrane defect in patients of both groups. The mean operative time in the conventional group was 36 min and in the laser-assisted surgery, it was found to be 39 min ($P = 0.06$). Two patients in the conventional group and one patient in the laser group had a change of taste sensation at the first follow-up period that was later improved within 12 weeks postoperatively.

DISCUSSION

The stapes surgery aims to improve hearing with minimal injury to the inner ear, which later causes serious complications. Various techniques have been tried in the past decade to precise the surgery and to reduce the associated complications in stapes surgery. Recently, the CO_2 laser has been recommended by various authors for better hearing outcomes, protecting the middle ear structures and reducing postoperative complications. This is because of the inherent property of the CO_2 laser, where it is well absorbed by the tissue-like bone with minimal penetration to the inner ear.[11] In patients with laser-assisted group, the CO_2 laser is fired in the “one-shot” technique to make a precise hole over the footplate as recommended by various authors.[4,12,13] The role of the CO_2 laser has been previously established in microscopic stapedotomy, where the laser beam is attached to a microscope with the help of a micromanipulator and the laser beam works in a straight line along the direct optical axis. Hence sometimes, it is difficult to work with the CO_2 laser, where there are abnormal anatomical structures like narrow external auditory canal and dehiscent/overhanging facial nerve during the microscopic stapedotomy.[10]

In contrast, the CO_2 laser-assisted endoscopic stapedotomy can overcome the disadvantages and can be safely used, especially in abnormal anatomical situations. The CO_2 laser is colorless; hence it is always coupled with a target beam (helium-neon Laser) as it is later can be safely carried out through a flexible fiber to the surgical site. Hence, it has to ensure that the two beams will couple accurately and a trial shot should be practiced before the routine endoscopic stapedotomy to check the alignment.

Although the utility of laser fiber in microscopic stapes surgery has been documented in the past,[14] its role can be highly emphasized in endoscopic stapes surgery, especially in difficult anatomical situations. Here, we have compared the clinical outcomes with respect to improvement in hearing and postoperative complications in patients undergoing endoscopic stapedotomy with and without the use of CO_2 laser. When the preoperative and postoperative air-bone gap (ABG) were calculated for both groups, we got a significant difference ($P < 0.05$). On comparing the ABG between the two groups, the difference was found to be insignificant ($P = 0.85$). In group A, 40.90% of the patients had an ABG of <10 dB and in group B, it was found to be 50% at 12 weeks of follow-up. Likewise, ABG of <20 dB was found in 90% in group A and 95% in group B ($P \geq 0.05$). Again, ABG of 20–30 dB was found in 9.52% of cases in group A and 4.16% cases in group B. A study was conducted by Naik et al. in patients who underwent endoscopic stapedotomy where he showed an ABG less than 20 dB in 85% of cases.[15] The most feared complication associated with stapes surgery is sensorineural hearing loss (SNHL), which is approximately 0.5%.[16] In the present study, none of the patients had such complications until 12 weeks of follow-up, possibly due to the small sample size. Most patients present with giddiness after the stapes surgery, which usually gets resolved within 24 h after the stapes surgery. As observed in the current study, although giddiness was more prevalent in patients undergoing conventional stapedotomy, no significant difference was obtained compared to laser-assisted surgery ($P = 0.33$).

Again, the endoscopic stapes surgery can be effectively performed in a narrow canal with less canaloplasty and preservation of the chorda tympani nerve.[8,17] As observed in the present study, seven patients in the conventional surgery group and five patients in the laser-assisted group had a narrow canal. Canaloplasty was performed in six patients in the conventional group and none of the patients in the laser Group required the same because of the narrow canal ($P = 0.01$). It could be due to a curved handpiece coupled with the fiber-enabled CO_2 Laser, which later better negotiates even in a narrow external auditory canal. Again, the fiber-enabled CO_2 Laser can be coupled through a curved handpiece which has the added advantage of approaching the mesotympanum away from the direct optical axis. Although the chorda tympani nerve was physically left intact in all cases in both the groups, it was still manipulated more in the conventional group. The latter could be due to the narrow diameter endoscope, which effectively negotiates with the curved laser handpiece. None of the patients in either group had an alteration in the taste sensation at 12 weeks of the follow-up period, which could be due to the mild stretching of the nerve, which recovered with time. The learning curve in endoscopic stapedotomy is always a challenge, especially for beginners.

The surgeon should at least operate 60–70 cases of microscopic stapes surgery before starting the endoscopic middle ear surgery.[18] In the present study, the operating surgeon had adequate expertise in both microscopic and endoscopic ear surgery. Although the duration of the surgery was a little more in laser-assisted stapedotomy, the difference was found to be insignificant ($P = 0.06$). No major intraoperative/postoperative complications were detected in any patients of either group. Despite the significant advantages, endoscopic stapedotomy has its own limitations, especially lacking stereoscopic vision and a long learning curve for beginners.[19] Although a fiber-enabled CO_2 laser is a valuable technique that can be effectively used in endoscopic stapedotomy, it is expensive and the fibers cannot be reused. Despite the satisfactory results with laser-assisted endoscopic stapedotomy, our study had a short follow-up period; hence a longer follow-up period may be needed for a clear understanding of the results.

CONCLUSION

Fiber-enabled CO_2 laser in endoscopic stapes surgery is a safe and effective procedure for managing patients with otosclerosis. Although the audiological outcomes with fiber-enabled CO_2 laser in endoscopic stapedotomy are comparable to conventional surgery, it is a better tool in a narrow external auditory canal, requiring minimal manipulation of the chorda tympani nerve.

AUTHOR CONTRIBUTIONS

Pradeep Pradhan: Manuscript writing and submission. **Vinusree Karakkandy**: Data collection. **Chappity Preetam**: Manuscript editing. **Pradipta K. Parida**: Final editing of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request due to privacy or ethical restrictions.

ETHICS STATEMENT

Not applicable.

ORCID

Pradeep Pradhan http://orcid.org/0000-0002-1462-4135
Vinusree Karakkandy https://orcid.org/0000-0001-5690-3186

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