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MRI Evaluation of Vocal Fold Paralysis Before and After Type I Thyroplasty

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Magnetic resonance imaging (MRI) is a useful modality for three-dimensional evaluation of laryngeal anatomy. The authors present data on patients with unilateral vocal fold paralysis both before and after type I thyroplasty for medialization. Videoendoscopic and acoustic measures were obtained. MRI was performed preoperatively and postoperatively. Three-dimensional descriptive parameters were established to assess implant location. As well, vocal and endoscopic assessment were used to determine a successful result. Magnetic resonance images of two patients with satisfactory results were compared with images and vocal analysis of two dissatisfied patients. Use of MRI after type I thyroplasty provides additional information about implant location that can help determine the cause of poor results.

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INTRODUCTION

Vocal fold paralysis that clinically manifests as vocal breathiness or mild aspiration may be treated by a variety of methods.[1–10] Type I thyroplasty is one such method first popularized by Isshiki et al. in 1974[11] that uses a Silastic implant placed in a window in the thyroid ala between the inner and outer perichondrium for external medialization of the paralyzed true vocal fold by lateral compression. Traditional preoperative and postoperative assessment of this condition at our institution has included videostroboscopic examination, perceptual assessment, and acoustic analysis. Postoperative results often demonstrate improved glottic competence (reflected by a significant increase in maximum phonation time), greater vocal intensity, overall improved vocal quality, and higher fundamental frequency.[12] However, some patients undergoing thyroplasty do not achieve a marked improvement in vocal parameters, despite the appearance of effective medialization on endoscopic examination. Also, although improved, many patients who have undergone medialization procedures achieve neither the acoustic nor the perceptual characteristics of the normal voice.

Magnetic resonance imaging (MRI) of the larynx is now considered the imaging modality of choice for the evaluation of the larynx.[13] The application of surface coils and internal engineering improvements have substantially improved the resolution of laryngeal structures.[14] Three orthogonal planes are represented, thus allowing for three-dimensional analysis of vocal fold position. Also, radiation exposure is avoided. Application of MR imaging to the paralyzed larynx should provide a greater understanding of vocal fold orientation. The utility of MRI both before and after type I thyroplasty was thus investigated.

MATERIALS AND METHODS

Three men and one woman with vocal fold paralysis were examined before and after thyroplasty (Table I). Surgical procedures were performed by the third and fourth authors. All patients presented with severe dysphonia and aspiration. Characteristics of vocal performance were assessed endoscopically, acoustically, and via magnetic resonance imaging (for subjects 1 and 2, only postoperative MR imaging was performed).

Endoscopy

Videostroboscopic endoscopy was utilized to assess movement and vibratory characteristics of the vocal folds. A 70 degree angle rigid endoscope coupled with CCD camera and video recorder was used to observe extent of glottic closure, symmetry of closure, quality and amplitude of the mucosal wave, presence of any nonvibrating portions, and uniformity of vocal fold approximation based on a five point scale.[15] Additionally, the general appearance of the larynx during phonation of the vowel /i/ at different pitch and loudness levels was described. All endoscopic tapes were studied to assess possible return of motor function.

Acoustic Data

Acoustic measures were made from voice samples recorded on a Panasonic DAT SV-3700 digital tape recorder coupled with a Telex PU-91 head mounted microphone. Speech signals were preamplified, and filtered via SA instrumentation filter 411. Computer analysis of these signals

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TABLE I.
Historical and Postoperative Subject Data.

Subject No.	Age	Sex	Etiology	Side of Vocal Fold Paralysis	Vocally Satisfied (Preoperative/Postoperative)	Aspiration (Preoperative/Postoperative)	Months Postonset
1	53	M	Cervical fusion	Right	−/−	+/+	24
2	84	M	Carotid endarterectomy	Left	−/−	+/+	12
3	61	M	Thoracotomy	Right	−/+	+/−	11
4	65	F	Carotid endarterectomy	Right	−/+	+/−	2

was accomplished using RC electronics ISC-16 analog to digital card. Signals were analyzed using Computer Assisted Speech Evaluation and Rehabilitation (CASPER) software.[16] The norms used for this study were based on age-matched controls from the CASPER data. Using the midvocalic portion of sustained vowel, calculations of percent shimmer (amplitude perturbation) and percent jitter (frequency perturbation) were made. Harmonics-to-noise ratio (HNR) was calculated, assigning a numerical value to the degree of noise compared to harmonic energy in the voice signal. Maximum phonation time and pitch range of phonation were also assessed based on digital recordings.

Magnetic Resonance Imaging

Images were acquired using a General Electric Signa magnet specifically designed for diagnostic purposes. The Signa machine has a superconducting 1.5-T magnet that allows a fast imaging speed. Each subject was placed in the supine position with the head in a padded universal cranial molding with a built-in anterior neck coil that was specifically designed to image the vocal tract. Contiguous T1 fast spin echo images were obtained at rest and during the sustained production of the vowels /*i*/ and /*a*/. Axial and coronal images were acquired with TR=800 ms, using an image matrix of 256 × 256 over a field of view of 20 cm. MR axial and coronal images were inspected preoperatively with regard to bilateral vocal fold symmetry at rest and on phonation. Length, medial-to-lateral displacement, and height of both vocal folds were also evaluated. Postoperative MR images were inspected according to implant location in serial sections. Descriptive criteria for implant location in three planes were as follows:

1. Medial to lateral.
   a. Outside the thyroid cartilage.
   b. Within the thyroid cartilage.
   c. Submucosal (apparent disruption of inner perichondrium).
2. Superior to inferior.
   a. Above the true vocal folds (false vocal folds or ventricle).
   b. At the true vocal fold.
   c. Subglottic.
3. Anterior to posterior. Measurements were taken from axial sections from the most anterior midline thyroid cartilage to the most posterior aspect of the arytenoid on the side of the implant. This length was then divided by four and the location of the implant was described as first quarter (i.e., most anterior) through fourth quarter (most posterior).

TABLE II.
Preoperative and Postoperative Measures of Maximum Phonation Time.

Subject No.	Preoperative	Postoperative
1	4 s	10 s
2	3 s	5 s
3	4 s	15 s
4	2 s	18 s

RESULTS

Preoperatively, all subjects were noted to have poor vocal quality as assessed by standard methods of voice analysis. Noise measures (Fig. 1) were consistently outside the normal range including jitter, shimmer, and harmonics-to-noise ratio. Limited pitch range of phonation as well as pitch breaks were present. Glottic insufficiency was demonstrated by diminished maximum phonation times (Table II). Preoperative videostroboscopy demonstrated vocal fold paralysis in each patient, as well as incomplete closure and a diminished mucosal wave. Preoperative MR images were noted to have excessive artifact during respiratory and phonatory postures. Adequate assessment of vocal fold height, length, and lateralization were therefore not possible for the preoperative scans. It is of note that during preoperative imaging, all patients had difficulty clearing pooled secretions and did not tolerate the procedure well. Paralysis of one vocal

TABLE III.
Placement of Implant Material Described Relative to Laryngeal Structures as Observed on Postoperative Inspection of Magnetic Resonance Images.

Subject No.	Anteroposterior Dimension	Medial/Lateral Displacement	Superiorinferior Dimension
1	Second quarter	Within TC (close to submucosa)	At vocal fold
2	Third quarter	Submucosal	Below vocal fold
3	Third quarter	Within TC (partially out)	Above vocal fold
4	Second quarter	Within TC	At vocal fold (partially above)

TC = thyroid cartilage.

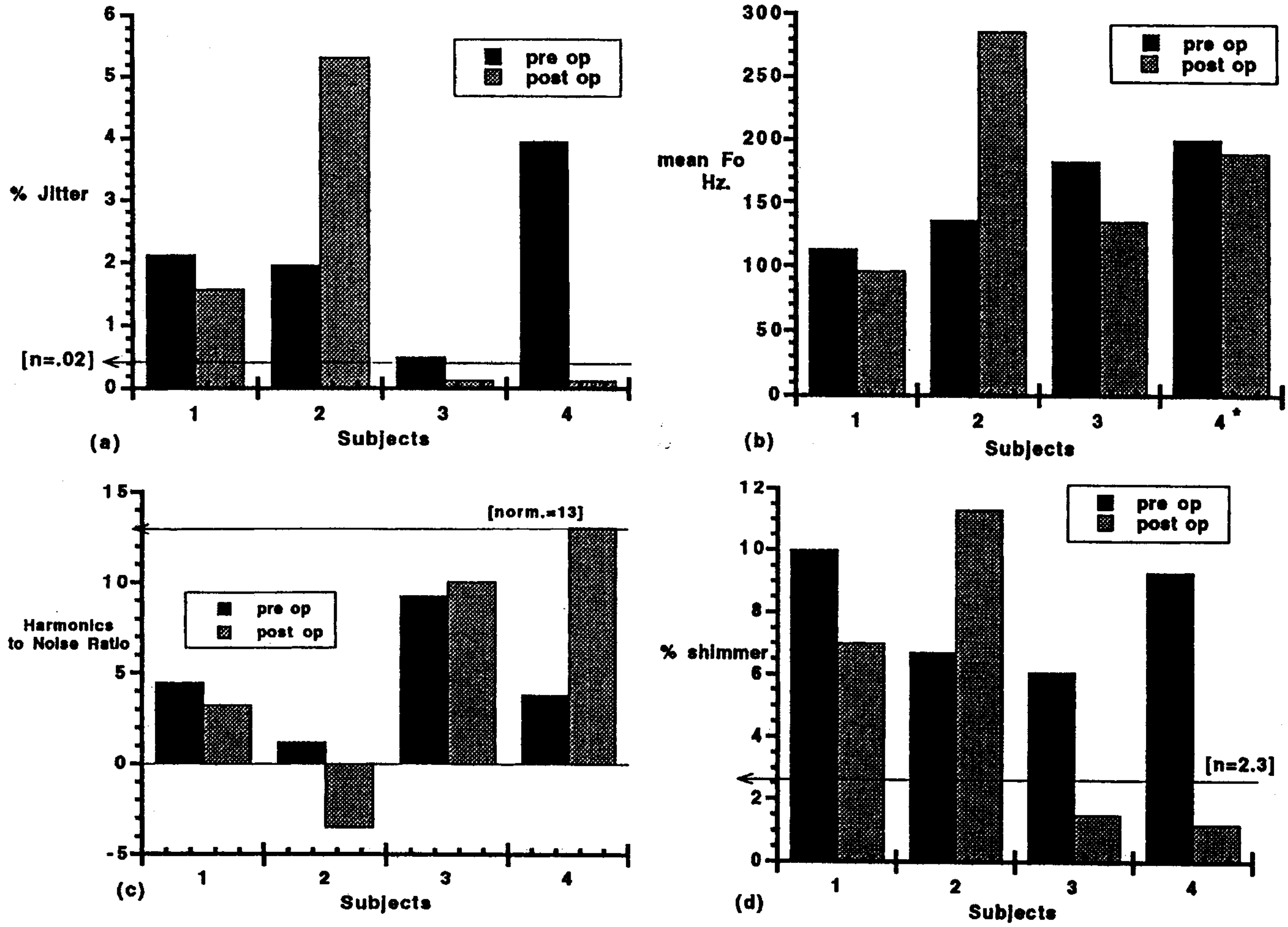

Fig. 1. Preoperative and postoperative **a.** jitter (frequency perturbation), **b.** fundamental frequency (Fo), **c.** harmonics-to-noise ratio (HNR), and **d.** shimmer (amplitude perturbation) measurements for all patients. Normal Fo range for males is 90 to 165 Hz, normal for the female subject in this age group (indicated by asterisk) is 142 to 234 Hz.

fold was suggested in each patient when the nonparalyzed vocal fold was noted to have greater movement artifact and medialization on phonation than the paralyzed side.

Postoperative voice recordings of all subjects showed improved fundamental frequency, jitter, shimmer, and HNR values as compared to preoperative values. In two patients (subjects 3 and 4) these values were drastically improved with diminished pitch breaks and a satisfactory voice quality. However, two patients (subjects 1 and 2) consistently maintained values outside the normal range for adult male speakers. Limited pitch range of phonation and pitch breaks continued to be present. Vocal quality continued to be grossly abnormal, and the patients were dissatisfied with their results.

Subject 1

Magnetic resonance images (Figs. 2, 3) revealed the implant in a relatively anterior position. Measurements of the location corresponded to the second quarter of the larynx as distanced from the anterior thyroid cartilage to the posterior arytenoid cartilage. Due to the anterior position of the implant, it approximated the laryngeal lumen. The implant appeared well positioned in the superior to inferior plane. Videostroboscopic evaluation (Fig. 4) revealed right vocal fold erythema with adequate vocal fold closure upon phonation. Anterior placement of the implant was suggested by relative fullness and stiffness of the anterior right true vocal fold that appeared to dampen vibration in the opposing true vocal fold. The mucosal wave was limited to a small segment of the posteromedial membranous portion. Thick mucous secretions were present, consistent with irritation.

Subject 2

Magnetic resonance images (Figs. 5, 6) clearly revealed medial displacement of the implant toward the laryngeal lumen. The overlying mucosa was intact. The implant was in a slightly subglottic position. Anteroposterior measurements revealed the implant to

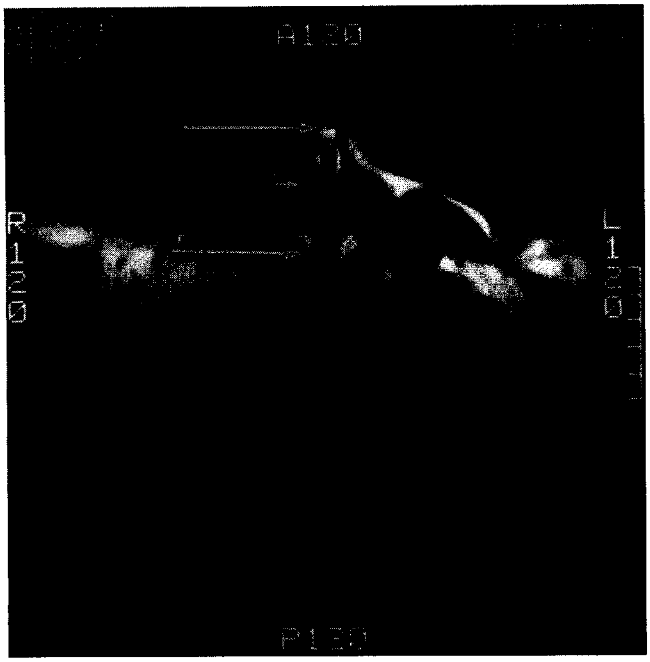

Fig. 2. Axial magnetic resonance (MR) image (subject 1) illustrates anterior placement of the implant lateral to the right vocal fold (small arrow). The implant was measured from the anterior thyroid cartilage to the posterior arytenoid cartilage on that side indicated by long arrows.

Fig. 3. Coronal image confirms anterior placement of implant (arrow).

be in the third quarter of the larynx. Videostroboscopic examination of subject 2 (Fig. 7) revealed irregular glottic closure with a small posterior glottic gap. However, a region of fullness was detected just beneath the left true vocal fold that projected into the lumen. The mucosa overlying this was intact, but did not participate in the mucosal wave. The left true vocal fold mucosa appeared post-hemorrhagic and stiffened with a greatly diminished mucosal wave that was out of phase with the opposing vocal fold.

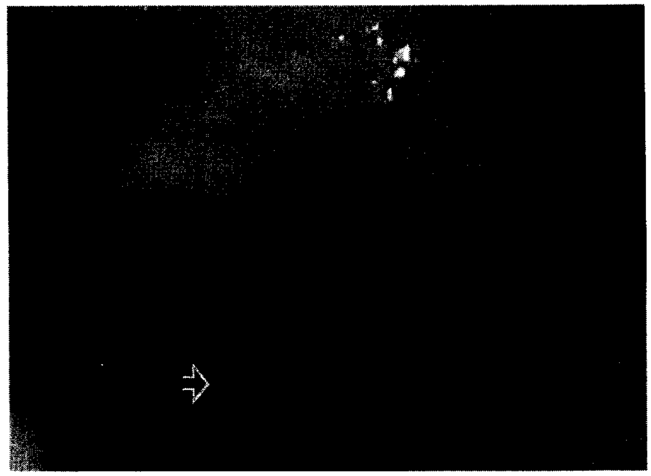

Fig. 4. Videostroboscopic image of subject 1 during phonation. Laryngeal asymmetry is present, and the anterior aspect of the right vocal fold projects medially due to the implant (arrow). Laryngeal closure appears almost complete but the amplitude of the mucosal wave was considerably reduced.

Fig. 5. Axial section of subject 2 demonstrates medial, luminal displacement of Silastic implant in the left vocal fold (arrow).

Subject 3

Magnetic resonance images (Figs. 8, 9) revealed a portion of the implant just lateral to the thyroid cartilage. The implant was positioned high in the superoinferior plane along the false vocal fold and ventricle. Anteroposterior measurements revealed the implant in the third quarter of the larynx. Postoperative videostroboscopic evaluation of subject 3 (Fig. 10) revealed symmetric vocal fold closure with improvement in amplitude and symmetry of the mucosal wave.

Subject 4

MRI (Figs. 11, 12) revealed good placement of the implant just medial to the thyroid cartilage. However,

Fig. 6. Coronal MR section of subject 2 illustrates the same medial, luminal displacement of the implant. The implant is slightly subglottic (arrow).

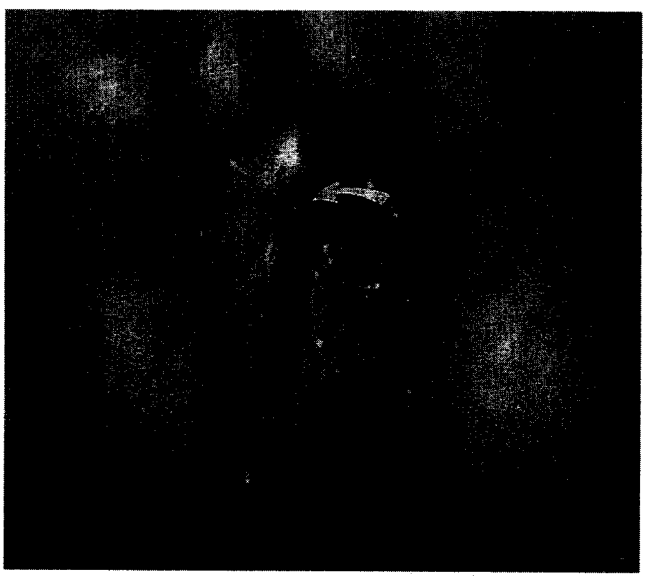

Fig. 7. This videostroboscopic image of subject 2 during phonation reveals the submucosal, subglottic location of the implant on the left (arrow). Post-hemorrhagic changes in the mucosa of the true vocal fold were also evident, as was greatly diminished mucosal wave on video exam.

it appeared somewhat anterior and measurements in the anteroposterior plane revealed that the implant was in the second quarter of the larynx. The implant was predominantly positioned at the level of the true vocal folds, but a significant portion of it was located at the ventricle and along the false vocal fold. Videostroboscopy (Fig. 13) postoperatively revealed improved glottic closure with a persistent small posterior glottic gap. Laryngeal rotation noted preoperatively persisted. The mucosal wave was markedly improved in amplitude and symmetry.

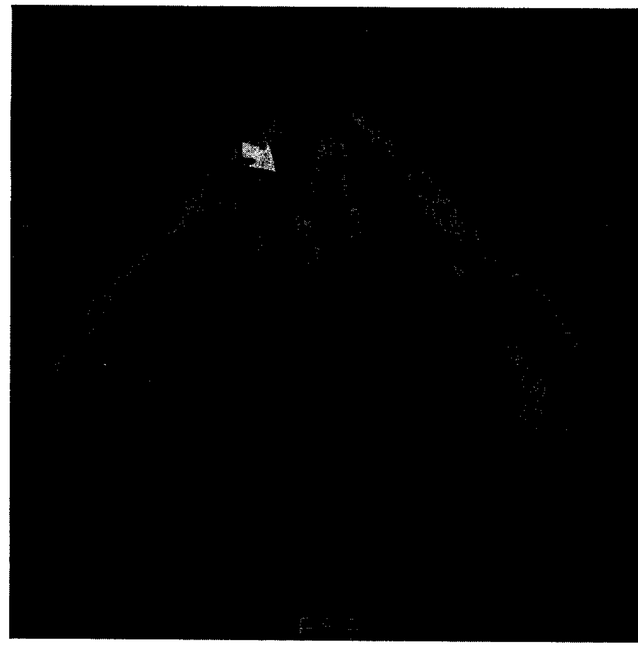

Fig. 8. Axial MR image of subject 3 reveals a portion of the implant just lateral to the thyroid cartilage (arrow). The implant has been placed in the third quarter of the larynx.

Fig. 9. Coronal section shows the implant at the level of the false vocal fold (arrow).

DISCUSSION

This study confirms the utility of magnetic resonance imaging for evaluation of implant location after type I thyroplasty, as reported elsewhere.[17] MRI provided additional information about implant location that was useful in combination with standard videoendoscopic and acoustic measures. Preoperative MR im-

Fig. 10. Videostroboscopic image of subject 3 during phonation demonstrates symmetric vocal fold closure bilaterally. Improved amplitude and symmetry of the mucosal wave were observed.

Fig. 11. Axial section of subject 4 demonstrates good placement of the implant just medial to the thyroid cartilage. The implant appears somewhat anterior in the second quarter of the larynx (arrow).

Fig. 12. Coronal section reveals the implant predominantly located at the true vocal fold, but partially adjacent to the ventricle and false vocal fold (arrow).

Fig. 13. Endoscopic image of subject 4 reveals good closure with a small posterior glottic gap and laryngeal rotation.

ages (subjects 3, 4) were marked by severe artifact, making three-dimensional description from these images futile. No assessments of vocal fold height, length, or medial/lateral displacement could be made. This was true both on phonation and during the resting position. Several reasons exist for why this artifact likely occurred—each patient preoperatively had evidence of decreased glottic competence with aspiration. Difficulty handling secretions, coughing, and throat clearing accounted for more movement during imaging than usually seen upon respiration and phonation. Of note was that in all patients, postoperative imaging proceeded more smoothly, with negligible artifact.

The implant was clearly visualized on MRI in all subjects. Postoperative acoustic analysis of these patients revealed obvious differences in vocal measures that corresponded to two patients being satisfied and two patients reporting dissatisfaction with their voices. Interestingly, MRI revealed implant position that was somewhat superior on both patients with good vocal results. This suggests that slight superior placement of an implant may have less of a negative effect on vocal outcome than excessive anterior or medial localization. Indeed, videostroboscopic evaluation of subject 1 revealed that anterior implant placement dampened anterior vocal fold vibration and increased mass and stiffness of the segment. This has also been reported elsewhere (C.N. Ford, personal communication, 1995). Medialization of the implant to a submucosal locale (subject 2) resulted in severe disruption of the mucosal wave and persistent dysphonia. No patient was observed to have return of vocal fold function on postoperative endoscopic examination.

It is difficult to explain why subject 4 did not have significant postoperative dysphonia relative to somewhat anterior implant location. Certainly she appeared to have good implant placement in the medial-to-lateral dimension, and the majority of her implant was alongside the vocal fold. It is likely that proper implant position in all three planes contributes to a good result. As the implant approximates optimal placement in all three dimensions, successively improved vocal results may occur. A greater number of subjects will need to be evaluated to determine the relative contribution of any one dimension.

Clearly, optimal implant positioning in all three dimensions is difficult. Differences in patient anatomy, implant size, and surgical technique make variability in placement likely. As well, partial regeneration of the recurrent laryngeal nerve may result in a good vocal result despite suboptimal implant position. These factors make it difficult to predict outcome of type I thyroplasty.

SUMMARY

MRI can provide useful information about implant localization in patients with suboptimal results after type I thyroplasty. However, it is not a substitute for videostroboscopic evaluation. Stroboscopy provides information related to closure patterns and mucosal vibration that is not seen on MRI and can correlate with acoustic analysis. Thus, MRI should be considered a valuable adjunct to endoscopic evaluation and acoustic analysis in planning for revision surgery in these patients.

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