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OSAHS

Role of functional and anatomic study in sleep endoscopy for treatment of OSA

Ruolo dello studio funzionale e anatomico durante la sleep endoscopy nella terapia delle OSAS

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SUMMARY

Objective. To describe a clear and intuitive way to analyse the anatomical meaning of images observed in Drug-induced Sleep Endoscopy (DISE) to fully understand the obstructive dynamics and therefore opt for a tailor-made pharyngeal surgical technique.

Methods. From January 2016 to December 2020, 298 patients who underwent DISE were selected according to inclusion criteria.

Results. The case series consisted of 204 males and 94 females with a mean age of 56 years. Body mass index ranged from 19 kg/m^2 to 34 kg/m^2 with a median of 26.5 kg/m^2. Median Apnoea-Hypopnea Index (AHI) was 27 (range 5-62.3). The authors also observed four palate pharyngeal phenotypic patterns of collapse and clarify the morphology and role of the main muscles involved in upper airway collapse.

Conclusions. DISE is fundamental to determine the collapse site in patients affected by obstructive sleep apnoea syndrome. The velopharyngeal region is the most common site of obstruction and lateral pharyngeal wall collapse is the major determining factor. DISE can lead to a deeper understanding of the obstructive dynamic patterns and a more precise identification of the muscle bundles responsible for upper airway collapse.

KEY WORDS: barbed sutures, OSA surgery, palatal surgery, drug induced sleep endoscopy, palatopharyngeal muscles

RIASSUNTO

Obiettivo. *Descrivere in modo chiaro e intuitivo il significato anatomico delle immagini osservate durante la Sleep Endoscopy (DISE) per comprendere appieno la dinamica ostruttiva e per poter poi indirizzare la scelta terapeutica verso una chirurgia personalizzata.*

Materiali e metodi. *Da gennaio 2016 a dicembre 2020, 298 pazienti sottoposti a Sleep Endoscopy sono stati selezionati, sulla base di criteri di inclusione.*

Risultati. *I pazienti inseriti nello studio erano 204 maschi e 94 femmine con un'età media di 56 anni. L'indice di massa corporea variava da 19 kg/m^2 a 34 kg/m^2 con un valore mediano di 26,5 kg/m^2. L'indice di apnea-ipopnea (AHI) medio era di 27 (range 5-62,3). Gli autori hanno anche osservato quattro modelli fenotipici di collasso del palato e chiariscono la morfologia e il ruolo dei principali muscoli coinvolti nel collasso dell'UA.*

Conclusioni. *La DISE è fondamentale per determinare il sito di collasso nei pazienti affetti dalla sindrome dell'apnea ostruttiva del sonno (OSA). La regione velofaringea è il sito più comune di ostruzione e il collasso laterale della parete faringea è il principale fattore determinante. La DISE può portare a una comprensione più profonda dei modelli dinamici ostruttivi e a un'identificazione più precisa dei fasci muscolari responsabili del collasso delle vie aeree superiori.*

PAROLE CHIAVE: *sutura barbed, chirurgia dell'OSAS, chirurgia palatale, sleep endoscopy, muscoli palatofaringei*

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Introduction

Obstructive sleep apnoea (OSA) syndrome is a respiratory sleep disorder characterised by partial or complete recurrent episodes of upper airway collapse which occur during the night. Although multilevel collapses of the upper airways (UA) are not rare, the velopharyngeal region is believed to be the most common site of obstruction, with lateral pharyngeal wall collapse as the major determining factor [1]. It is widely accepted that Drug-induced Sleep Endoscopy (DISE) is fundamental to determine the collapse site and select the most appropriate therapeutic strategy [2,3]. Moreover, also thanks to sleep endoscopic observation, pharyngeal surgical techniques have undergone a rapid evolution shifting from uvulopalatopharyngoplasty (UPPP) [4] towards the latest surgical techniques of lateral pharyngoplasty such as custom-made barbed technique [5,6]. Dynamic assessment during DISE can lead to a deeper understanding of the obstructive dynamic patterns and a more precise identification of the muscle bundles responsible for UA collapse, thus enabling more targeted therapeutic and surgical planning [7]. The purpose of this work is to clarify the morphology and role of the main muscles involved in UA collapse. Furthermore, the authors propose a clear and intuitive way to analyse the anatomical meaning of images observed in DISE. A clear description of known anatomical structures, such as the palatal muscles, lateral palatal wall and pharyngeal airway phenotypes, enables a better understanding of obstructive dynamics and patterns observed in DISE and to subsequently opt for a tailored pharyngeal surgical technique. Muscle bundles composing the soft palate are tensor veli palatini and its aponeurosis (TVP), salpingopharyngeus muscle (SP), palatopharyngeus muscle (PP), palatoglossus muscle (PG), levator veli palatini (LVP), muscle of the uvula (UV), superior pharyngeal constrictor muscle (SC) [4] (Fig. 1). The muscular sling, serving as the margin of the retropalatal lateral pharyngeal

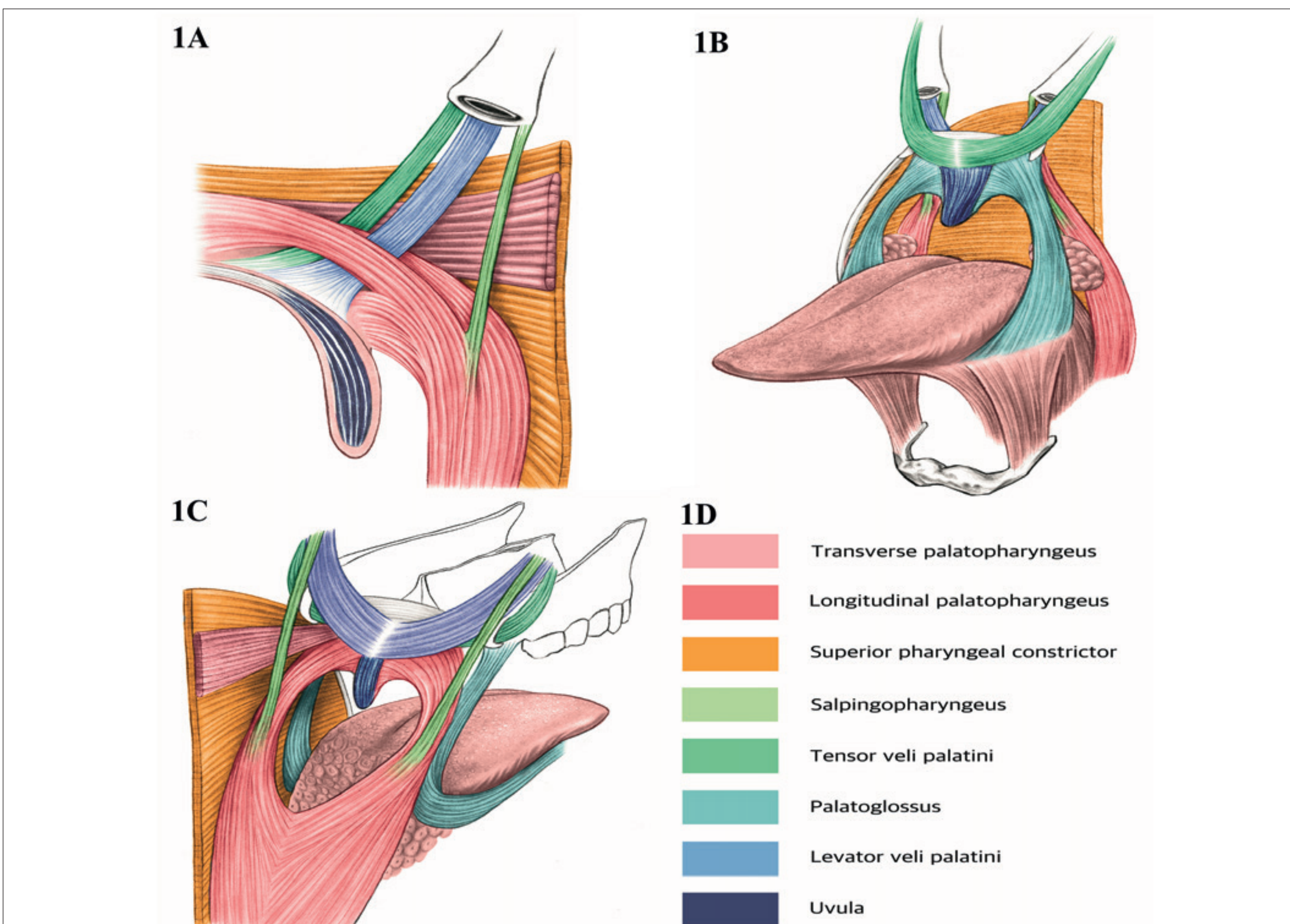


Figure 1. Muscles of the palatopharyngeal complex. (**A**) lateral view; (**B**) anterior view; (**C**) posterior view; (**D**) figure legend.

wall, is the SP proximally and the PP distally [8]. The TVP attaches to the palatine aponeurosis from its origin at the medial pterygoid plate of the sphenoid and lateral wall of the Eustachian tube and runs postero-lateral to the hamulus. Its function is to open the Eustachian tube and to tense the soft palate during swallowing. The SP originates from the cartilaginous part of auditory (Eustachian) tube and its insertion blends with dorsal bundle of the longitudinal part of the palatopharyngeus muscle. The muscle extends through the salpingopharyngeal fold and elevates the lateral pharyngeal walls, opening the auditory tube during swallowing. The PP muscle originates from the palatal aponeurosis as three separated fascicles that inferiorly combine into a unique muscle and it is composed of two major divisions: the longitudinal PP and the transverse PP. The longitudinal fascicle consists in a ventral (or medial) and a dorsal (or lateral) bundle that hug the LVP before combining into a more concise muscle bundle within the palatopharyngeal arch and lateral wall of the pharynx. Dorsal and ventral bellies of PP muscle lie medial to the SC in the oropharynx before inserting on the thyroid cartilage and diffusing into fibres of the inferior constrictor muscle [9]. The PP muscle shrinks during swallowing medializing both the lateral walls [10]. Anatomically, it may function as an airway constrictor or dilator depending on the resting position of the muscle. The transverse fascicle contributes to the nasopharyngeal sphincter to separate the oropharynx from the nasopharynx. Moreover, it seems that the muscle length of the paired transverse fasciculi contributes to maximize retropalatal airspace size. The PG muscle pulls the soft palate towards the tongue. It arises from the inferior edge of palatine aponeurosis and travels within the palatoglossal fold to attach into the side of the tongue [8]. The PG also separates the superior pole of the tonsil from the "supratonsillary fat" [11]. The LVP muscle come from the inferior aspect of the Eustachian tube cartilage and the petrous temporal bone, enters the soft palate and runs to the midline. It is distributed within the nasal side of the soft palate and attached to the inferior surface of the fascia and aponeurosis with the function of elevating the soft palate against the posterior pharyngeal wall during swallowing to prevent the entry of food into the nasopharynx. The SC muscle constitutes grossly the lateral and posterior boundary of the pharynx. Muscle bundles originate from the buccinators, maxilla, pterygomandibular raphe, and tongue to insert posteriorly into the midline where it relates to the pharyngobasilar fascia [7]. The UV functions to shorten the uvula; it derives from the palatine aponeurosis and the posterior nasal spine and attaches to the mucous membrane of the uvula. Ipsilateral contraction of the musculus uvulae muscle draws up the uvula on the same side.

The purpose of this study is to correlate endoscopic images of DISE with anatomical muscle structures in order to design a mini-invasive and customised surgical procedure.

Materials and methods

From January 2016 to December 2020, we selected 298 patients who underwent DISE.

Inclusion criteria were age > 20 years and < 72 years, body mass index (BMI) < 34, simple snoring or apnoea-hypopnoea index (AHI) > 5 as documented by polysomnography and no prior surgical intervention for sleep apnoea.

All examinations were conducted with a flexible rhinolaryngoscope introduced in one of the nasal cavities and subsequently in the mouth. The endoscopic system was always equipped with an audio-video recording system. The desired deepness sleep level was generally reach and maintained by propofol intra-venous infusion using target-controlled infusion (TCI).

A Bispectral Index (BIS™) device has generally been used to obtain a numerical instrumental support in evaluation of the level of sedation of patients. However, the presence or absence of this monitoring, as well as the TCI, were not considered inclusion criteria in this study. At least two skill sleep surgeons and one anesthesiologist were present at all DISE investigations.

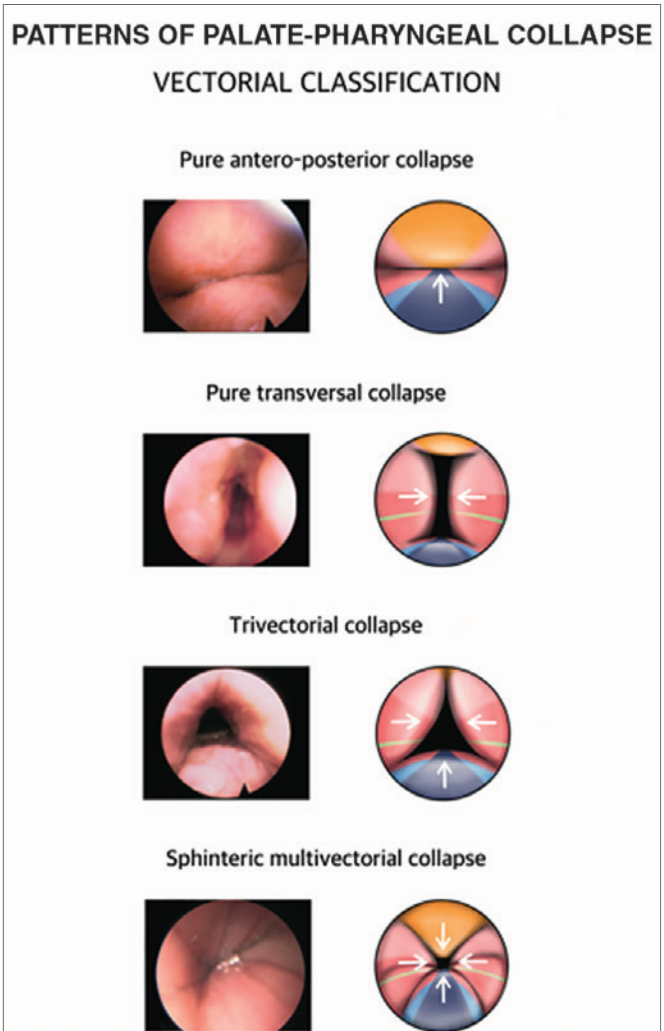
Results

Case series

We collected data on a sample of 298 patients for whom the recording of a fully satisfactory sleep phase was obtained in terms of probable reproduction of natural sleep characteristics: 204 males and 94 females with a mean age of 56 years. BMI ranged from 19 kg/m^2 to 34 kg/m^2 with a median value of 26.5 kg/m^2. Based on preoperative polysomnography, our sample was classified as follows: 18 patients had simple snoring and 280 patients presented with OSHAS; median AHI was of 27 (range 5-62.3).

Based on DISE data, we observed three palate pharyngeal phenotypic patterns already recognised in the literature and, additionally, a fourth (Fig. 2):

1. in the *pure antero-posterior palatal collapse* the muscles that seem to be involved are the Levator Veli Palatini (LVP), Palatopharyngeus (PP) and Uvula (UV);
2. *transverse collapses* are most likely attributable to the hyperkinetic action of the ventral and dorsal fascicles of the longitudinal portion of the PP. In case of transverse collapse, one must distinguish between nasopharyngeal origin and oropharyngeal origin. In the first case, the causal factor is the hyperkinetic action of the LVP and



V: Velum; PPW: posterior pharyngeal wall; LPW: lateral pharyngeal wall; PP: palatopharyngeus muscle; SP: salpingopharyngeus muscle

Figure 2. Vectorial classification of palatopharyngeal collapse patterns.

SP muscle. The latter in almost all cases continues with the action of the ventral fascicles of the longitudinal portion of the palatopharyngeal muscle;

3. the *sphincteric collapse* at the Passavant ridge, according to the anatomical findings by Sumida [10], originates by the simultaneous action of the superior constrictor of the pharynx and the transverse fasciculus of the PP muscle that unfolds the latter at the transition point between the nasopharynx and the oropharynx;
4. *triple vector collapses* in which the lumen narrows in a triangular manner by the concomitance of two transverse vectors and one anteroposterior which are attributable to the simultaneous but non-uniform action of the previous structures (LVP, TLV, PP, SC). Actually, this collapse is the sum of both the pure antero-posterior and transverse collapses.

In all patients, a clear velopharyngeal collapse was observed in DISE with different patterns: 54 pure antero-posterior, 93 transversal, 72 sphincteric and 79 triple vector collapses. In 72 patients, the antero-posterior component of the velopharyngeal collapse was evaluated as a result of the retropulsion of the dorsum of the tongue.

In 26% of patients, it was possible to completely resolve the collapse with a chin lift or mandibular suspension manoeuvre. In these cases, resolution was subjectively evaluated as a resumption of ventilation phases without significant sound production. In 78 patients potentially candidate to treatment with a Mandibular Advancement Device (MAD), a George Gauge device was used to record the resolving jaw position. In 48% of cases, applying a greater force in mandibular advancement, it was possible to obtain only a partial resolution of the collapse with an interruption of apnoea but a persisting ~~a~~ strong sound vibration of the velopharyngeal structures.

Discussion

The complete anatomic and functional description of the palato-pharyngeal unit should include a deep understanding of the dynamics created when the muscles work simultaneously and a correct interpretation of specificity for each patient. To date, we believe that DISE provides the most useful information of upper airway collapse during sleep compared to other evaluation techniques available (e.g., awake fibroendoscopy, Muller's manoeuvre) especially related to the tongue and epiglottis collapse [12]. In fact, the use of transoral and trans-nasal fiber-optic endoscopic during DISE, in association with the mandibular pull up and chin lift manoeuvre, enables to more clearly understand the role of the tongue. In particular, the degree of tongue retraction and position highlights a secondary anteroposterior soft palate collapse (Fig. 3). Moreover, DISE has been demonstrated to be useful in predicting satisfactory outcomes in intraoral devices users and in understanding ventilatory therapy failures. Finally, in case of non-responders to surgery, DISE provides insights to the residual causes of UA collapse, addressing further therapeutic strategies [2,3,5,7].

Many surgical techniques have been described in the modern evolution of OSA surgery and mostly contain the same fundamental concepts: preservation of soft palate and tonsillar pillars mucous margins, preservation of the function of the uvula, concept of rigid anchoring structures, muscle transposition and tensioning, slow resorption self-locking sutures and muscle vectors.

In the literature, it is well established that DISE, in addition to being a dynamic, safe and easy to perform technique that

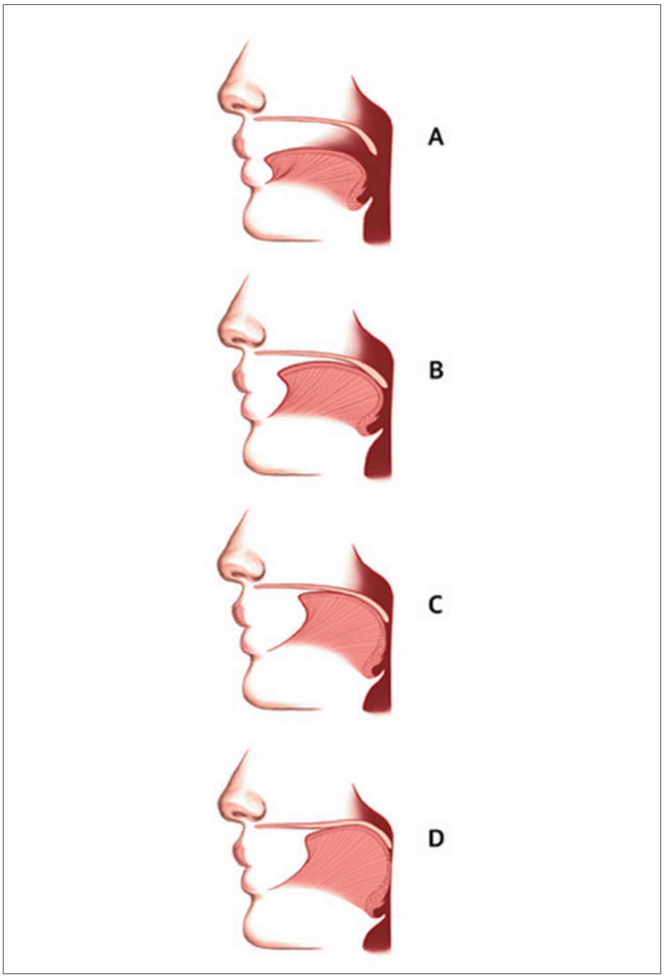


Figure 3. Secondary palate collapse. (**A**) no secondary collapse; (**B**) partial palatal collapse; (**C**) total palatal collapse (TPC); (**D**) TPC with palatal elevation.

allows visualisation of the anatomical sites of vibration or collapse, can lead to patient-tailored treatment [8].
Following the conclusions of Ravesloot and De Vries [13] and taking to an extreme the evolutionary concept of a patient-tailored approach, we can affirm that DISE allows identification of the collapse pattern severity and understand the muscular structures responsible, thus enabling to selectively intervene only on those structures, changing the force vector of involved muscles. In our experience, we have achieved good surgical success in sphincter collapse with lateral pharyngoplasty. In this study, we introduce trivectoral collapse, which requires both an anterior palatoplasty and lateral pharyngoplasty to resolve the obstruction and vibration. In fact, in a small percentage of patients with severe OSAS and trivectoral collapse treated with lateral pharyngoplasty and/or anterior palatoplasty alone, we observed the persistence of a vibratory and/or obstructive site with the untreated vector in postoperative DISE.

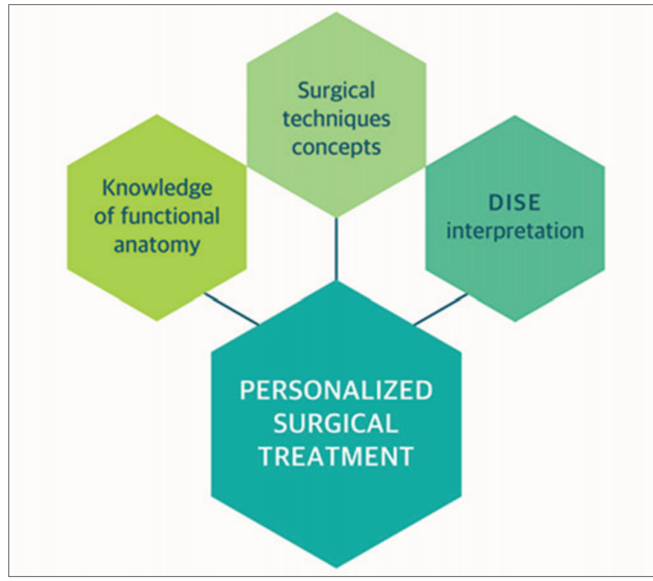


Figure 4. How to achieve an eclectic approach to OSA surgery.

To our knowledge this is the first study establishing a link between detailed anatomical description and characterisation of muscle bundles to the dynamics observed in DISE during collapse patterns.

Conclusions

In conclusion, DISE is the most important diagnostic tool to study anatomic-functional dynamics. DISE enables identification of the collapse pattern of soft palate, pharyngeal lateral wall collapse, epiglottic trapdoor phenomenon, secondary epiglottic collapse and involvement of ary-epiglottic folds. In our experience, the study about the role of functional and anatomic dynamics in sleep endoscopy for treatment of OSA is important and represents the first step in a mini-invasive, personalised, eclectic and anatomy-driven use of barbed surgery with reduced damage to anatomical structures (Fig. 4).

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Conflict of interest statement
The authors declare no conflict of interest.

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Author contributions

AM: work design, first operator, final revision. CT: acquisition, analysis, and interpretation of data, draft manuscript preparation. IR: draft manuscript preparation, analysis of data.

All authors reviewed the results and approved the final version of the manuscript.

Ethical consideration

The present work is a retrospective study and DISE is a well estabilished procedure in literature.

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