Evaluation of the vocal tract with real time MRI in professional male altos

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Introduction: For many years vocal registers and their origins have been the subject of extensive investigation revealing heterogeneous results. In particular, the role of the vocal tract is still not completely understood. In previous studies, we used dynamic real-time MRI (frame rate of up to 8 images / second) to analyze vocal tract configurations during register transitions in professional opera tenors[1, 2]. We found only minor changes when these tenors shifted from modal register to falsetto[1, 2]. Here, the larynx was elevated and tilted. Marked changes were found when those tenors continued their stage voice above the passaggio region instead of shifting to a naïve falsetto register. In the stage voice condition, the subjects widened the pharynx, increased lip and jaw opening and jaw protrusion. In addition, one professional baritone was analyzed. Similar to tenors, a register shift from modal to falsetto was associated with only minor changes of vocal tract configuration. To avoid a register shift the baritone raised his tongue dorsum, widened his jaw opening, and retracted his lower jaw. Since the revival of baroque operas in the middle of the last century an increasing number of male professional altos (countertenors) are now performing at international concert halls and opera houses. In contrast to basses or most tenors it is assumed that their stage voice is derived from the falsetto register.
The present study aims to identify vocal tract modifications that occur when professional male altos change register function from modal register to naïve (untrained) or stage (trained, countertenor) falsetto and vice versa.

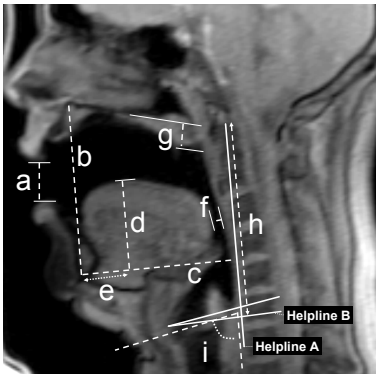

Figure 1: measured distances

Methods: Eight professional male altos (age 24 to 35years) served as subjects. All subjects were examined radiologically on a 3T MR system (TIM TRIO, Siemens, Germany, Gmax = 40mT/m, rise time = 200ms, standard 12-channel head and neck coils) in a supine position. Real-time MR imaging was performed with a temporal resolution of 8 images per second. Images were acquired in a gittal slab of 11 mm thickness using an rf-spoiled 2D GRE sequence with the following sequence parameters: spatial resolution = 1.4 x 2.2 mm^2, TE=0.84 ms, TR=2.53 ms, flip angle=5°, band width=650 Hz/Px, matrix=192x144, FOV=250x215mm^2, parallel imaging using GRAPPA and R=2. In addition, the audio signal was recorded by means of an optic microphone (Fa. MR confon, Magdeburg, Germany, OptiMRI Noise Reduction Software, Fa. Optoacoustics Ltd., Or-Yehuda, Israel).
The subjects were asked to sing an ascending diatonic major scale from G3 (196Hz) to E4 (330Hz), starting in modal register. In the first condition the subjects were asked to perform a register shift to stage (countertenor) falsetto between B3 and C4, while in the second condition, they should perform a register shift to a naïve falsetto (like an untrained falsetto). Third, all subjects sang the same scale avoiding a register shift. After the ascending scales the singers were asked to perform the same scale with and without register shifts descending from E4 to G3. The vowel /a/ was chosen for all sequences in order to avoid the articulatory effects that can be expected when the fundamental frequency exceeds the normal value of the first formant.
In each frame of the MRI material a series of measures were taken (figure 1): (a) lip opening, (b) jaw opening, (c) jaw protrusion, (d) tongue dorsum, (e) tongue position, (f) pharynx width, (g) uvula elevation, (h) larynx position and (i) larynx tilt

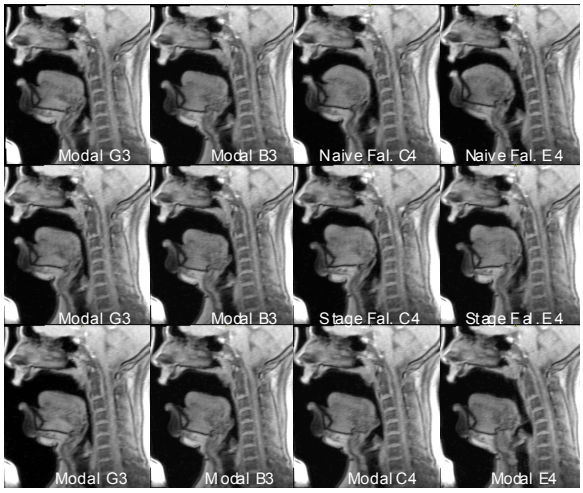

Fig. 2: representative vocal tract shapes in relation to registers and pitches

Results: As illustrated in figure 2, the MR images showed clear modifications of vocal tract shape in transitions between the modal register and the stage falsetto for most subjects. In addition, register shifts from modal register to naïve falsetto or vice-versa were associated with modifications of the vocal tract configuration. Figure 2 shows representative MR images of ascending sequences.
Ascending and descending sequences in all three conditions (register shift between modal and stage falsetto, modal and naïve falsetto or maintaining modal register) revealed similar tendencies. However, modifications were stronger for ascending sequences. Register shifts between modal register and stage falsetto were associated with a significant sudden increase of lip and jaw opening for the stage falsetto. Both lip opening and jaw opening were strongly correlated. As shown in figure 3, the equation for the trend lines indicate that, for a given jaw opening, the lip opening was larger for the stage falsetto compared to modal register and naïve falsetto.
Stage falsetto was associated with strong modifications regarding tongue shape. Here, the jaw was retracted, the tongue lifted and slightly positioned in the back of the mouth. As a consequence the pharynx tube was narrowed. Modal register at high pitches showed opposite tendencies. High pitches in modal register were strongly associated with a continuous elevation of the larynx. In contrast, register shifts showed a statistical significant lowering of the larynx for both the stage and naïve falsetto. Additionally, the larynx was found to be more tilted for both falsetto functions.

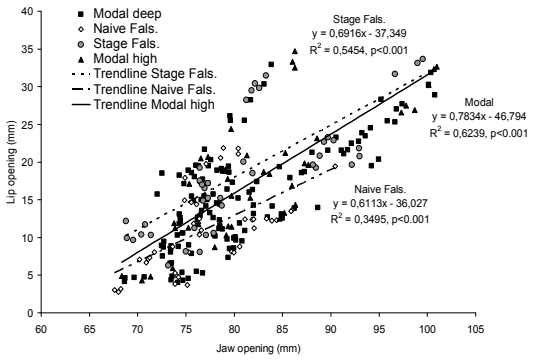

Fig. 3: Lip opening across jaw opening

Discussion: This investigation presents the successful application of real time MRI for the evaluation of vocal tract modifications associated with a shift of vocal register in a group of 8 professional male altos. In contrast to professional tenors[2] register shifts from modal to falsetto register are associated with major modifications of vocal tract shapes. Differences of the vocal tract configurations might contribute to perceptive differences observed in these vocal register functions in professional male altos.

References: (1) Echternach M et al. Vocal Tract and Register Changes Analysed by Real Time MRI in Male Professional Singers - a Pilot Study. Logoped Phoniatr Vocol. 2008;33(2):67-73. (2) Echternach M et al. Professional Opera Tenor`s Vocal Tract Configurations in Registers. Folia Phoniatr Logop. 2010;62(6):278-287.