Comparative Study of a Professional Tenor in a Tilting MR-Scanner - Does Supine Position Change the Configuration of the Vocal Tract?

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Introduction:

The movement pattern of the vocal tract with respect to vocal registers during singing has been subject to investigation in the past. MRI has proven to be a valuable imaging technique to directly visualize these structures during singing [1]. Only few studies provide quantitative results on such vocal tract changes in tenors/sopranos. During MR imaging in high field scanners, singers are required to perform in supine position. It remains an open question, whether studies in this unusual position are valid, as the supine position may influence muscle strain due to gravity [2]. The present study aims to compare the functional performance of the vocal tract structures of a professional singer in supine and upright posture using a dedicated MRI scanner. To our knowledge up to now no such comparative MR study of singers has been undertaken.

Methods:

All measurements were performed on a 0.25 T dedicated system (G-Scan, Esaote, Genoa, Italy). The G-Scan system is equipped with a permanent tilting magnet, which allows examination under weight-bearing conditions. Gradients support 20 mT/m with a slew rate of 25 mT/m/ms. The MR signal was acquired with a dedicated two-channel neck coil.

For the purpose of our study, a 34-year old professional lyrical opera tenor was MR imaged. First, measurements where done in supine position (0°). The singer was instructed to sing an ascending scale from C4 (262 Hz) to A4 (440 Hz) on the vowel /a/, from modal register to stage voice above passaggio, holding each note for as long as possible (>15s). Then, the table was rotated to an upright position (80°) and the task was repeated while the tenor was upright. The singer remained inside the scanner while it was rotated in order to ensure a high comparability of the images.

For quantitative analysis, one sagittal slice through the center of the vocal tract was acquired. For testing of reproducibility, two images were acquired at each note within 12 seconds.

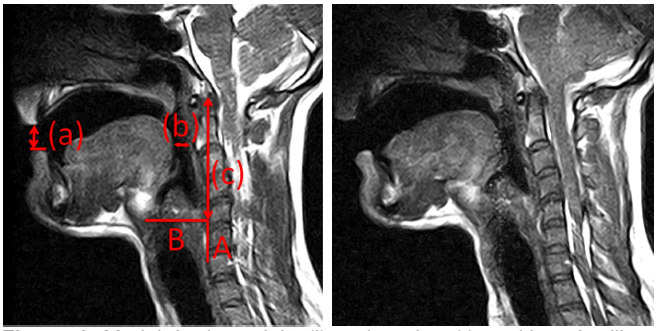

Figure 1: Modal A4 in upright (l) and supine (r) position. Auxiliary lines and distances measured in MR images: a=lip opening, b=oropharynx width, c=larynx position (see text).

A cine-MRI protocol based on a 2D TrueFISP sequence with large flip angle and in-vivo first order shimming during pre-scan was used for imaging. Parameters: TR=10ms, TE=5ms, Flip Angle=80°, FOV 300x300mm^2, Matrix=212x212, Pixel Size 1.42mm, ST 8mm. A total of 24 images were acquired.

In each image, several distances, as defined in [1], were measured (Fig. 1): (a) Distance between the lips; (b) pharynx width; (c) larynx position, which was measured as the distance from the cranial-most part of the dens axis to the point where auxiliary line A (which connects the apex of the dens axis and the lower anterior corner of the sixth cervical bone) crosses auxiliary line B (which runs through the anterior commissure perpendicular to line A).

Results:

Image quality, resolution and FOV were sufficient so that the anatomical structures could be discerned and measured in all images.

The measured anatomical values (Table 1, Figure 2) from two successive images of the same note were averaged. We could observe that the lip opening increased with ascending scale, as presented by Echternach, et al.[1]. A high correlation (R^2=0.70) could be found when comparing upright to supine condition (Table 1).

With increasing pitch the pharynx width increased, slightly more in supine position. A very high correlation between both conditions could be found (R^2=0.90).

As expected from previous studies, a continuous rise of the larynx could be seen with increasing pitch. In our study, an overall lower position of the larynx could be found in upright position than in supine position. Again, the measurements from the two conditions were well correlated (R^2=0.69).

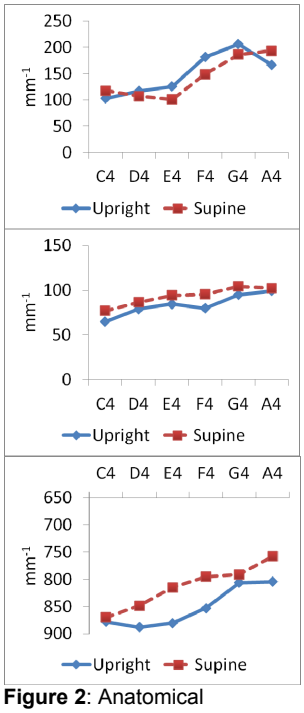

Figure 2: Anatomical measurements: lip opening, pharynx width, larynx position (top to bottom).

Discussion:

The measured values in upright and supine position were highly correlated and thus comparable, with small systematic differences concerning pharynx width and larynx position. The lower larynx position might be related to the difference in gravity, yet only by a small amount. Our preliminary results indicate only minor differences of the measured values with posture and encourage future studies to further validate supine MR measurements of singers.

		C4	D4	E4	F4	G4	A4	R^2
Lip Opening	upright	103	117	125.5	181.5	206.5	167	0.70
(mm^{-1})	supine	117.5	107	101	149	186.5	193.5	
Pharynx Width	upright	65	79	84.5	80	95	99.5	0.90
(mm^{-1})	supine	77	86.5	94.5	95.5	104.5	102.5	
Larynx Position	upright	878	888	880.5	853	806	804	0.69
(mm^{-1})	supine	870	848.5	814.5	795	791	757.5	

Table 1: Anatomical distances and coefficient of determination (R^2).

References:

[1] Echternach M., et al., Folia Phoniatr Logop, 2010, 62:278–287;

[2] Echternach M, Traser L, Markl M, Richter B., J Voice, 2011 (Epub ahead of print)