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The value of 1.5T MRI in the evaluation of vocal fold mobility in patients with goiter

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ABSTRACT

The laryngoscopic examination remains the gold standard in the perioperative evaluation of the mobility of the vocal folds in patients with goiter. During the COVID-19 pandemic, many medical procedures, including laryngoscopy are optimized in terms of epidemiological safety. Therefore, it seems deeply justified to implement methods like i.e. ultrasound or MRI which can provide the diagnostic information usually obtained via laryngoscopic examination.

Aim of the study: To determine the value of dynamic MRI examination in the 1.5 T field in the assessment of the mobility of vocal folds in patients with goiter compared to healthy people and in relation to ultrasound examinations and routine laryngoscopy.

Materials and methods: 35 healthy volunteers and 44 patients with goiter were subjected to videolaryngoscopy, dynamic examinations of the vocal folds during respiration and phonation using ultrasound and the MRI sequences: generic gradient echo (GRE) and true fast imaging with steady-state precession (TRUFI). The qualitative and quantitative data were analyzed, i.e. the angles of deviation from the midline of the vocal folds and the area of the right and left rima glottidis compartments.

Results: No statistically significant differences were found between the groups of healthy volunteers and patients with goiter in the values of the angles of deviation of the vocal folds with the use of ultrasound and two MRI dynamic sequences - GRE and TRUFI. There were also no statistically significant differences in the areas of the rima glottidis compartments between these two groups with the use of two MRI dynamic sequences - GRE and TRUFI. Among the analyzed parameters, the maximum size of each rima glottidis compartment was the only one to show features of sexual dimorphism and was significantly higher in men (GRE $p < 0.001$ and TRUFI $p = 0.001$). There was no correlation between the size of the minimum and maximum rima glottidis compartment and the total volume of the thyroid lobes in patients with goiter for the GRE and TRUFI sequences.

Conclusions: MRI is a promising tool for the objective assessment of the mobility of the vocal folds in patients with goiter, as well as for the qualification for treatment and monitoring its effects. It is particularly important during an epidemiological emergency due to its safety compared to laryngoscopy. The presence of the goiter and its volume do not limit the possibility of performing dynamic imaging studies of the vocal folds and do not affect the surface area of the glottis.

1. Introduction

The laryngoscopic examination remains the gold standard in the perioperative evaluation of the mobility of the vocal folds in patients with goiter [1]. This method has a number of advantages, but it causes various degrees of discomfort in subjects, depending on the anatomical conditions and particularly the experience of the examiner.

Moreover, during the COVID-19 pandemic, many medical procedures are optimized in terms of epidemiological safety. This especially pertains to laryngoscopy, which is a method with an increased risk of infection for both the examined and the examiner [2]. There are many clinical situations in which the assessment of laryngeal function, including the mobility of the vocal folds, is necessary. Therefore, it seems deeply justified to implement methods that prevent infection much more efficiently, such as ultrasound or MRI, and which can provide diagnostic information usually obtained during laryngoscopic

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examination [3]. These methods can be used in the detection of vocal fold mobility disorders in large groups of patients - in long-term intubated patients due to COVID-19, in oncological patients suspected of paralysis of the vocal folds, as well as those after mediastinum, head and neck surgery.

The incidence of preoperative vocal fold paralysis in patients with goiter is estimated as rare, its detection may indicate the presence of an aggressive neoplastic process with invasion of the adjacent structures, e.g. the recurrent laryngeal nerve [4,5]. An increased risk is also observed in the group of patients after mediastinal, head and neck surgery [1]. Detection of this pathology prior to thyroidectomy requires particular care to avoid paralysis of the contralateral laryngeal nerve. Moreover, preoperative examination may be used to clarify any conflict of responsibility for the resulting postoperative complications.

Therefore, it is reasonable to search for non-invasive diagnostic methods that would allow for effective and atraumatic verification of the mobility of the vocal folds prior to surgery, especially in patients with goiter. The imaging diagnostic methods that allow for dynamic imaging of the vocal folds include ultrasound and MRI. Previous reports have proved that ultrasonography is a sensitive tool for detecting disorders of fold mobility and also in the perioperative evaluation of patients with goiter or cardiovascular pathologies [6,7]. In this field, magnetic resonance imaging is undoubtedly a technique worth verifying.

The aim of the study was to determine the value of dynamic MRI examination in the assessment of the adduction and abduction of the vocal folds in patients with goiter compared to healthy volunteers and in relation to ultrasound examination and routine laryngoscopy. Of particular note were the MRI tests in a 1.5 T field, as such scanners are most widely available in clinical practice.

2. Materials and methods

The study was conducted after obtaining the approval of the Bioethics Committee at the Medical University of Lodz (decision no. RNN / 187/18 / KE of May 15, 2018). In 2018–2020, healthy people and patients with goiter were selected for the study.

The control group included 35 healthy volunteers (25 women, 10 men, aged 20–59; Me = 34). They were people with no hoarseness, chronic diseases of the thyroid gland or the upper respiratory tract, and without any prior head, neck or chest surgery. Before the vocal folds imaging using ultrasound and MRI methods, healthy volunteers underwent a basic laryngological examination.

44 patients from the Clinic of General and Oncological Surgery (39 women, 5 men, aged 18–70; Me = 43) were qualified for the study group. Each patient underwent a full range of diagnostic tests: laryngoscopy, ultrasound and MRI. However, all the men in this group had massive calcifications of the thyroid cartilage, what made impossible to visualize the vocal folds in USG in this group. It resulted that ultrasound measurements were obtained only for 39 women in the group of patients with goiter.

In both control and study groups, the laryngoscopic examination was carried out in the Clinic of Surgery by the same doctor using a standard gastrofiberoscope via oral access. Laryngoscopy was the reference study to which the results of the dynamic radiological tests were compared.

Ultrasound examinations were carried out with the Logiq S8 machine (GE Healthcare) using the ML6−15 linear probe with a frequency range of 5−13 MHz. The following output parameters were used: frequency 8 MHz, depth of field of view 4−5 cm, gain (Gn) 43 %, dynamic range (Dr) 69 dB. The obtained examination results consisted of images and videos. The ultrasound examination was conducted with the patient in a supine position with the head slightly tilted back. The probe was applied transversely to the long axis of the body, in the midline, at the level of the mid-segment of the thyroid cartilage. Moving the probe along the patient's long axis, an image was sought that showed both vocal folds in the transverse plane. All of the above anatomical structures: the vocal folds, vestibular folds and arytenoid cartilages were identified in each ultrasound examination. The mobility of the vocal folds was observed during normal breathing and phonation. The "heee" was used as the reference sound during phonation because the glottis is the narrowest at the time when the "e" vowel is pronounced. During the data acquisition, on the examiner's command "start", the subject produced a sound until he heard the word "stop". Then, the presence of the respiratory dependent fold mobility was assessed visually - the maximum opening during inspiration and slight adduction on exhalation as well as the symmetry of the glottis. On the basis of the obtained material the angles of the minimum and maximum deviation of the vocal folds from the midline were measured using the ImageJ program (https://imagej.nih.gov/ij/).

MRI was performed with a 1.5 T MagnetomAvanto scanner (Siemens) with the use of an eight-channel cervical coil and a four-channel head coil. No contrast agents were administered. For morphological evaluation, T2-weighted sequences were used: turbo spin echo in the transverse plane (TSE, Siemens; repetition time – 3440 ms, echo time – 76 ms, IR - 0.9 × .09 mm^2, slice thickness – 3 mm, number of slices - 25, flip angle – 150°, total acquisition time – 4 min 42 s) and turbo inversion recovery magnitude in the frontal plane (TIRM, Siemens; TR - 3600 ms, TE - 82 ms, IR - 0.8 × .08 mm^2, slice thickness – 4 mm, number of slices - 45, flip angle - 127°, total acquisition time – 3 min 43 s). The following sequences were used for dynamic tests: generic gradient echo (GRE, Siemens; TR - 23 ms, TE - 3.64 ms, IR - 1.1 × 1.1 mm^2, slice thickness – 6 mm, number of slices - 3, flip angle - 20°, total acquisition time – 1 min 8 s, number of dynamic scans - 15) and Balanced gradient echo (TRUFI - True fast imaging with steady-state free precession, Siemens; TR - 364.76 ms, TE - 1.29 ms, IR - 1.4 × 1.1 mm^2, slice thickness – 10 mm, number of slices - 1, flip angle - 62°, total acquisition time – 22 s, number of dynamic scans - 60) in the axial plane (Fig. 1). The assessment of the adduction and abduction of the vocal folds was performed with the use of the dynamic gradient sequences GRE and TRUFI during normal breathing and phonation, including the use of the "hee" sound. The slices were analyzed with the software provided by the scanner manufacturer (Syngo.via, Siemens). Each area of compartment of rima glottidis was measured manually with the use of Region of Interest (ROI) Freehand function because we considered it as the most precise approach considering small dimensions of the studied structures. The reference plane was the line passing through the anterior and posterior commissures. Both the glottal angle and the glottic area were measured between the aforesaid plane and each of the vocal folds, separately for the right and left compartment.

Moreover, on the basis of the obtained T2-weighted images in the frontal and axial planes, the volume of the thyroid lobes was calculated. A simplified formula for the volume of the ellipsoid was used [8]: The volume of the lobe (ml) = π / 6 × thickness (cm) × width (cm) × length (cm). The total goiter volume was calculated based on the sum of the volumes of both lobes using the above-mentioned formula.

Statistical analysis of the results was carried out with Statistica 10 software (StatSoft, USA). Qualitative variables (results of laryngoscopy, US and MRI) were verified using the chi-square test of independence. The analyzed data: glottic angles and the areas of compartments of the rima glottidis were quantitative. The normal distribution of the quantitative variables was tested with a Shapiro-Wilk test, which revealed that none of them had a normal distribution. The quantitative variables with distributions other than normal were analyzed with Dunn's post hoc tests or Kruskal-Wallis test. The Spearman's rank correlation coefficient (rs) was used to describe the relationship between the volume of the thyroid lobes in patients with goiter and the area of the glottis. The results were considered significant for p-values <0.05.

3. Results

The observations based on laryngoscopy, ultrasound (US) and MRI examinations of patients and healthy volunteers showed no

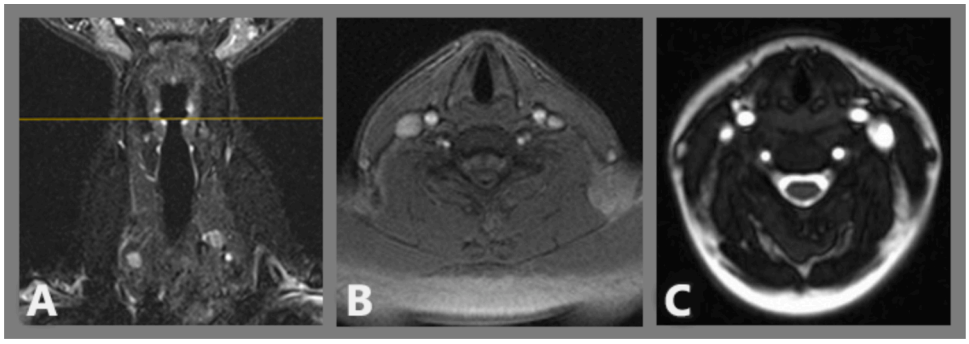

Fig. 1. MRI sequences: A – TIRM (Siemens), B – GRE (Siemens), C – TRUFI (Siemens).

abnormalities in the mobility of the vocal folds. In all methods, the mobility of the vocal folds during calm breathing was fully preserved, symmetrical, the glottis during phonation was completely closed in each case.

An analysis of quantitative data obtained with the use of dynamic examinations of the larynx was performed during calm breathing:

3.1. Glottic angles

No statistically significant differences in minimum and maximum angles of deviation of the vocal folds were found between a group of healthy volunteers and patients with goiter with the use of two MRI dynamic sequences - GRE and TRUFI ($p > 0.05$). No statistically significant differences also were found in minimum and maximum angles in the US between whole healthy volunteers' group and females from group of patients.

The mean values, medians and standard deviation of the obtained results from groups of healthy volunteers and patients with goiter are presented in Tables 1 and 2. Table 1 shows also the values for men and women separately, and Table 2 only for women. We did not provide the values for men in Table 2 due to the burden of a high error with their small number in the group.

The distribution of the minimum and maximum vocal fold angles was presented in the graphs only for women from the control and study groups (Figs. 2 and 3). Slight differences can be detected in the medians of the minimum and maximum angles, which are higher in the group of patients compared to healthy volunteers - both in US and MRI.

3.2. The areas of compartments of the rima glottidis

No statistically significant differences in minimum and maximum areas of compartments rima glottidis were found between the whole

Table 1
Minimum and maximum values of angles obtained by the methods: USG and MRI during normal breathing in the group of healthy volunteers.

parameter	min. angle [°]			max. angle [°]		
method	USG	MRI-GRE	MRI-TRUFI	USG	MRI-GRE	MRI-TRUFI
all	7.17 ± 1.69 (Me = 7)	9.54 ± 3.18 (Me = 8)	8.11 ± 2.14 (Me = 8)	17.09 ± 4.00 (Me = 17)	16.63 ± 4.46 (Me = 16)	17.46 ± 3.73 (Me = 18)
females	7.35 ± 1.57 (Me = 7)	9.55 ± 3.36 (Me = 9)	7.95 ± 2.21 (Me = 8)	17.00 ± 3.85 (Me = 17)	16.95 ± 4.05 (Me = 17)	17.95 ± 3.17 (Me = 18)
males	6.93 ± 1.87 (Me = 7)	9.53 ± 3.02 (Me = 8)	8.33 ± 2.09 (Me = 8)	17.20 ± 4.33 (Me = 16)	16.20 ± 5.07 (Me = 15)	16.80 ± 4.40 (Me = 15)

Table 2
Minimum and maximum values of angles obtained by the methods: USG (female group) and MRI (the whole group) during normal breathing in the group of patients with goiter.

parameter	min. angle [°]			max. angle [°]		
method	USG	MRI-GRE	MRI-TRUFI	USG	MRI-GRE	MRI-TRUFI
all		10.57 ± 2.42 (Me = 10)	10.62 ± 2.24 (Me = 10)		18.34 ± 2.71 (Me = 18)	19.56 ± 2.95 (Me = 19)
females	9.59 ± 2.11 (Me = 9)	10.57 ± 2.42 (Me = 10)	10.35 ± 2.78 (Me = 10)	19.87 ± 2.27 (Me = 20)	18.34 ± 2.71 (Me = 18)	19.00 ± 4.25 (Me = 19)

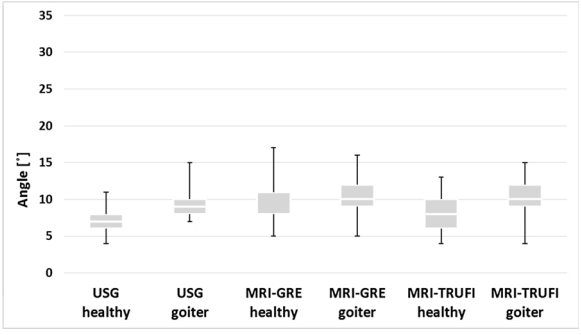

Fig. 2. The minimum values of the angles of the vocal folds of healthy women and women with goiter.

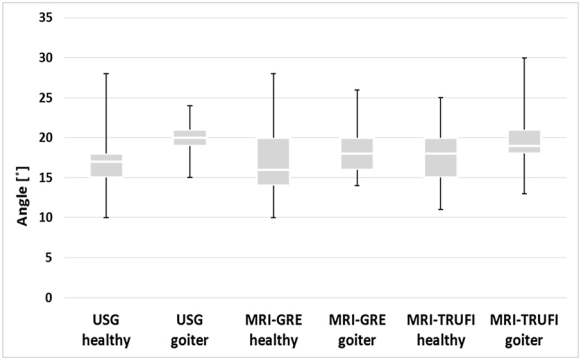

Fig. 3. The maximum values of the angles of the vocal folds of healthy women and women with goiter.

groups - of healthy volunteers and patients with goiter with the use of two MRI dynamic sequences GRE and TRUFI ($p > 0.05$).

The mean values, medians and standard deviation of the glottis area during normal breathing for both sequences and groups are presented in Tables 3 and 4. Table 3 shows also the values for men and women separately, and Table 4 only for women. We did not provide the values for men in Table 4 due to the burden of a high error with their small number in the group. The values of the areas of the rima glottidis compartments in the control and study groups are shown in the graphs (Figs. 4 and 5).

3.3. Glottic angle and the area of compartments of rima glottidis depending on sex in a group of healthy volunteers

In a group of healthy volunteers no statistically significant differences were found between sexes for the minimum and maximum angles in US and dynamic MRI sequences ($p > 0.05$).

The values of the maximum opening of the rima glottidis compartments differed significantly for the GRE sequence $p < 0.001$ and TRUFI $p = 0.001$ respectively. For the minimum values for the both sequences no differences were detected ($p > 0.05$).

3.4. The relationship between the volume of the goiter and the surface area of the glottis

There was no correlation between the values of the minimum and maximum total glottis area and the total volume of the thyroid lobes in patients with goiter for either the GRE or TRUFI sequences. The rs correlation coefficient was: for the minimum surface area of the glottis and for the GRE sequence -0.1771, and for the TRUFI sequence 0.0261, and for the maximum surface areas: GRE 0.0565, TRUFI -0.0574 ($p > 0.05$) respectively.

4. Discussion

To the best of the Authors' knowledge, this is the first study comparing dynamic measurements of rima glottis between ultrasound and MRI methods and also in a group of patients with goitre before surgical interventions.

.The study of 35 volunteers and 44 patients with goiter showed no abnormalities in the mobility of the vocal folds during normal breathing in both imaging methods, i.e. US and MRI. In each case, the glottis was completely closed during phonation. These observations are consistent with the reports of Wong et al. who performed preoperative laryngoscopic examinations in 1000 patients with an enlarged thyroid gland [4]. Only 9 cases of unilateral vocal fold paralysis were detected. Therefore, it can be concluded that the paralysis of the vocal folds is sporadic among patients with pathologies within the thyroid gland.

In this study the qualitative and quantitative data obtained from ultrasound examinations were analyzed. Only a few studies by other authors assessed the value of imaging tests in detecting vocal fold paralysis in this way [7,9], although many authors have proven the great potential of ultrasound in this area. Its sensitivity was assessed in various ways - in the range from 33 to 100 % [10–13]. This can be justified by the use of different types of ultrasound heads, data acquisition parameters, analysis of diverse populations or differences in the time elapsed since the procedure. Compared to other medical imaging techniques, ultrasound has the advantage of being atraumatic, easy and readily available for bedside use. The limitations of the method include the inability to visualize the vocal folds in the group of people with massive calcifications in the thyroid cartilage [14,15].

In our work, we refrained from assessing the area of compartment of rima glottidis due to the difficulty in establishing a clearly reproducible vocal fold cross-section and the presence of artifacts created at the border of the soft tissues and air. In literature, no data has been found that any of the researchers measured the area of the glottis based on ultrasound examinations. In a group of 100 adult patients Lazard et al. assessed the mobility of the vocal folds by ultrasound in a subjective way, i.e. visually and quantitatively, based on two coefficients calculated with the use of special software [9]. They marked three landmarks, which were the two arytenoid cartilages and the antero-middle part of the thyroid cartilage. These points marked two areas, which were then compared in patients during normal breathing, i.e. the coefficients of symmetry and mobility were calculated on their basis. In this report, the

Table 3
Minimum and maximum values of the areas of the rima glottidis compartments obtained by dynamic MRI sequences in a group of healthy volunteers.

parameter	min. area. [cm^2]		max. area. [cm^2]	
method	MRI-GRE	MRI-TRUFI	MRI-GRE	MRI-TRUFI
all	0.36 ± 0.15 (Me = 0.30)	0.26 ± 0.11 (Me = 0.25)	0.62 ± 0.21 (Me = 0.60)	0.66 ± 0.20 (Me = 0.60)
females	0.23 ± 0.08 (Me = 0,30)	0.20 ± 0.09 (Me = 0.20)	0.48 ± 0.10 (Me = 0.50)	0.56 ± 0.16 (Me = 0.53)
males	0.47 ± 0.15 (Me = 0.45)	0.34 ± 0.10 (Me = 0.35)	0.81 ± 0.17 (Me = 0.80)	0.78 ± 0.19 (Me = 0.80)

Table 4
Minimum and maximum values of the areas of the rima glottidis compartments obtained with dynamic MRI sequences in the group of patients with goiter.

parameter	min. area. [cm^2]		max. area. [cm^2]	
method	MRI-GRE	MRI-TRUFI	MRI-GRE	MRI-TRUFI
all	0.32 ± 0.09 (Me = 0.3)	0.26 ± 0.09 (Me = 0.25)	0.60 ± 0.10 (Me = 0.6)	0.57 ± 0.11 (Me = 0.55)
females	0.32 ± 0.09 (Me = 0.3)	0.26 ± 0.09 (Me = 0.25)	0.60 ± 0.08 (Me = 0.55)	0.55 ± 0.10 (Me = 0.55)

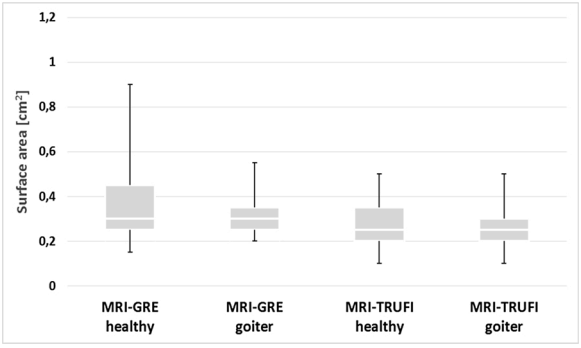

Fig. 4. Minimum values of the area of the rima glottidis compartment in healthy volunteers and patients with goiter.

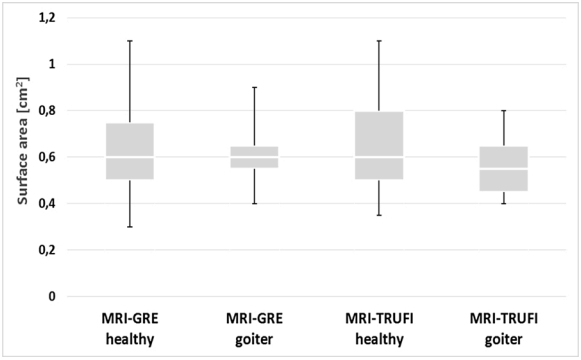

Fig. 5. The maximum values of the area of the rima glottidis compartment in healthy volunteers and patients with goiter.

visual assessment was characterized by high sensitivity and specificity - 100 % and 96 % respectively, while the quantitative data did not achieve such a good result: the calculated coefficients assessed separately were characterized by sensitivity and specificity at the level of 82 %, and in total - 94 % and 66 % respectively. The method of conducting measurements presented by the authors is easy to perform, but nevertheless requires additional software, which should also be significantly refined. Ongkasuwan et al. examined 46 newborns after cardiac surgery using US [7]. They measured the different types of angles between the vocal folds and the arytenoid cartilages during normal breathing. These measurements included also the angle formed by the vocal folds, which is the sum of the midline deviation angles of both vocal folds - as in this paper. The mean value of the angles between the maximally abducted vocal folds in Ongkasuwan's study was 40.1 ± 13.8 degrees, while in our study it was 34.2 ± 8 degrees in the group of volunteers and 39.7 ± 2.3 degrees in the group of patients. The slight differences in the obtained results can be explained by the small size of the analyzed groups, as well as the age-dependent differentiation of the structure of the larynx. Finally, the study by Ongkasuwan et al. found that it is the angle between the vocal fold and the arytenoid cartilage that has the highest diagnostic value in detecting disturbances in the mobility of the vocal folds. While performing this measurement poses no problems in the pediatric population, its use in adults is significantly limited due to the calcification of laryngeal cartilages.

Within the wide range of MRI sequences, there are those that enable dynamic imaging, maintaining satisfactory spatial resolution and short acquisition time. The data from literature confirm that imaging the movement of the vocal folds and recognizing their paralysis is indeed possible [16,17]. Nevertheless, research in this diagnostic segment is innovative, non-standard and is still performed almost exclusively in research centers.

The first researchers to evaluate the glottis quantitatively were Ahmad et al. [18]. They examined the change in the position of the vocal folds in healthy people in the transverse and sagittal planes during prolonged phonation of various sounds, and then calculated the angles between them. The results obtained by us during the phonation of the "hee" sound are not consistent with the presented data: in people without paralysis, the adduction of the vocal folds was complete in each case, while Ahmad et al. obtained the values of the vocal fold angle for men of about 3.5° and for women of about 8.5°. The differences may result from various parameters of the sequences used and the methods of carrying out the measurements. Using the dynamic GRE sequence in the 3.0 T scanner, Baki et al. examined healthy individuals and patients with unilateral vocal fold paralysis [19]. The advantage of 3.0 T scanners over 1.5 T is well-established in the radiological environment [20,21]. They proved that MRI is a reliable method for the assessment of adduction and abduction of the vocal folds, and it is also possible to diagnose their paralysis. On the basis of the obtained images, they determined the angles formed by each of the folds and the center line and calculated the area of the right and left rima glottidis compartments. In our work, we used the same methodology, but what is important - using a 1.5 T scanner. On the other hand, it is also true that examinations in the 3 T field may be subject to distortion artifacts, which was outlined by Sinko et all [22]. They found that 1.5 T may be preferable over 3.0-T trueFISP for the evaluation of the movement of velopharyngeal structures. Thus, it has been proven that dynamic imaging of the vocal folds is possible and effective with the MRI scanners most commonly available in everyday clinical practice. Despite a similar methodology, a direct comparison of the obtained results with the report by Baki et al. is not possible due to the complexity of their data presentation. They defined their results as the coefficients of changes in the glottis surface area or the glottic angle during phonation, but without absolute values. However, the use of absolute values, while perhaps slightly simplified, has real significance in clinical practice as a straightforward, time-saving and effective method.

For the dynamic examination of the vocal folds the GRE sequence was used. It allows to obtain 15 scans from 3 levels during the acquisition time of 68 s. A noteworthy advantage of this sequence is the possibility of obtaining transverse scans on 3 different levels at the same time, thanks to which it can be used in patients with more complex anatomical conditions and / or with greater phonational mobility of the glottis in the sagittal plane. In our project, the protocol was extended to include a second dynamic sequence - TRUFI. It is characterized by the possibility of obtaining the largest number of images per time unit among the available sequences in a 1.5 T scanner - 60 scans in 22 s. We used a single scan width of 10 mm, which was to ensure effective imaging of the vocal folds with the variable position of the larynx during the production of sounds or swallowing.

In the group of healthy volunteers, we compared the values of the angles and areas in relation to gender. The dimorphic analysis was performed only for this group due to the lack of significant disproportions between the number of women and men and the completeness of the measurements - calcifications in the thyroid cartilage in men did not preclude the assessment of vocal folds in any case. Significantly larger maximum glottis surface areas were detected in males compared to females in both MRI sequences, with a higher statistical significance for the GRE sequence. No significant differences were found between the sexes in the minimum and maximum values of the vocal fold angles, both in the ultrasound and the MRI techniques. Based on the evidence, the measurement of the maximum area of the compartment of rima glottidis is the only parameter that shows differences between men and women. The data from literature confirm that the vocal folds are longer and the thyroid cartilage is larger in men than in women, which was reflected in our results [23,24]. It may be concluded that the measurement of the areas of compartments of rima glottidis is a parameter with a higher diagnostic value than the measurement of the glottic angle and the best method to detect differences is the GRE sequence.

No statistically significant correlation was found between the minimum and maximum values characterizing the surface of the glottis area during normal breathing and the volume of the thyroid gland. Therefore, it can be concluded that the presence of a goiter does not affect the surface area of the glottis and does not reduce the effectiveness of dynamic vocal fold studies.

5. Conclusions

Dynamic MRI studies in 1.5 T field constitute an effective diagnostic tool in the objective assessment of the mobility of the vocal folds in healthy subjects and in patients with an enlarged thyroid gland. This technique is a source of qualitative and quantitative data, which determines its objectivity. The significance of this method will undoubtedly increase due to its considerably higher epidemiological safety compared to laryngoscopy.

In a healthy volunteers group only the maximum values of the areas of the rima glottidis compartments show signs of sexual dimorphism which indicates this measurement as of higher diagnostic value than the glottis angle.

The presence of the goiter and its volume do not limit the possibility of performing dynamic imaging studies of the vocal folds and do not affect the surface area of the glottis.

Authors contribution

We state the contributions of the authors:

- Conceptualization: D-K. M., M.A.
- Methodology: D-K. M., M.A.
- Validation: M.M.
- Formal analysis: D.-K. M.
- Investigation: D.-K. M., M.M.
- Resources: L.K., M.A.
- Data Curation: M.M., L.K.
- Writing - Original Draft: D.-K. M.

- Writing - Review & Editing: M.M., M.A
- Visualization: L.K.
- Supervision: M.A.
- Project administration: D.-K. M.

Ethical statement

The study was conducted after obtaining the approval of the Bioethics Committee at the Medical University of Lodz (decision no. RNN / 187/18 / KE of May 15, 2018). Each subject was obliged to fill written consent form before addition to the study.

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Declaration of Competing Interest

The authors report no declarations of interest.

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