

Pin-up Glottoplasty: Feasibility Study of a Novel Approach Medializing or Lateralizing Immobile Vocal Folds

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Summary: Principles in medializing and lateralizing vocal folds have not changed a lot within the last decades (Isshiki et al, 1974; Bruenings, 1911). We present a feasibility study for a completely new approach to perform medialization and lateralization of immobile vocal folds.

The method was tested on 20 human larynges by inserting a 21G needle into the vocal fold, medializing (or, in other cases, lateralizing) the vocal cord and fixing the needle at the cricoid cartilage posteriorly. The anterior and posterior fixation points of the needle allow for a stable positioning of the needle, which we consider necessary in both cases of medialization or lateralization. The needle position was examined visually as well as three-dimensionally via cone beam computed tomography.

Key Words: Laryngeal framework surgery–Vocal fold medialization–Vocal fold lateralization–Voice–Compromised airway.

INTRODUCTION

Background

Medialization and lateralization of an immobile vocal fold have been performed for at least 100 years without fundamental changes of methodology.^{1,2} All methods have their drawbacks. In medialization, they are either time-consuming or non-permanent—with the exception of silicone when injection during direct microlaryngoscopy is the preferred application method. In lateralization, the drawbacks include problems such as permanent voice damage, requirement of tracheotomy, or frequent need of revision surgery (eg, endolaryngeal cord laterofixation with the Lichtenberger technique³).

Medialization of an immobile unilateral vocal fold through transoral or percutaneous injection laryngoplasty is standard therapy today.^{4–6} This has the advantage that it can be performed in an office-based setting because the implant materials used are typically non-permanent. With existing permanent

injection materials, a suspension microlaryngoscopy is usually required because of the need for a more precise injection. Because of long-term problems with granulomas, migration, and difficult removal, some permanent implant materials (like paraffin, Teflon) have fallen out of favor.⁷

If the phonatory glottic gap is larger than 3 mm, augmentation is less successful, and an open thyroplasty is favored.¹ The surgical intervention is performed in a hospital setting and occasionally needs to be performed under general anesthesia. Operative durations of 2 and more hours⁸ are not uncommon in spite of careful preparation beforehand. The procedure is complex and time-consuming when trying to close the posterior glottis from an anterior approach.⁹ It requires a horizontal skin incision at the level of the mid-thyroid cartilage about 5 cm in length with incisional drainage postoperatively.¹⁰ Regardless of this preparation, sometimes the form or fit of the implanted wedge is not perfect; this can make another operation necessary.

To improve the voice or airway in a patient with bilateral vocal fold palsy, the main problem is the inevitable balancing of adequate voice with adequate airway. Apart from a permanent tracheotomy to preserve the airway, cordotomies and cordectomies were often the only permanent airway improvement solution.¹¹ Partial arytenoidectomy, usually performed with laser during microlaryngoscopy, or laterofixation of one or both vocal folds, may also be used for permanent or transient airway protection.^{12–14}

Goals

The aim of this study was to ascertain whether the membranous vocal fold and arytenoid cartilage could be fixed either medially or laterally by threading a needle through the vocal fold. The needle placement would be submucosal, lateral, and parallel to the vocal ligaments. The fixation points for the needle would be in the cricoid cartilage posteriorly and the thyroid cartilage anteriorly. Finally, we were hoping to be able to achieve a sufficient amount of medialization and or lateralization without damaging the laryngeal mucosa.

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Christina Pflug and Almut Niessen contributed equally to the manuscript and share first authorship.

Almut Niessen and Christina Pflug performed the preparations and finalized the manuscript; Christina Pflug approved the study and the manuscript; Almut Niessen analyzed the data and wrote the manuscript; Frank Müller supported the preparations, took the photographs, and prepared the statistics; Julie C. Nienstedt discussed the data, proofread, and corrected the manuscript; Clarissa Precht supported the CBCT scans, proofread, and corrected the manuscript; Markus Hess provided the original idea, prepared the graphics, and corrected the final version of the manuscript.

Disclosure: The authors report no disclosures relevant to the manuscript.

Ethical approval: The laryngeal research was approved by the Ethics Committee of the Medical Association of Hamburg and was conducted in accordance with the 1964 Helsinki declaration and its later amendments.

The principle idea of the method was first presented at PEVOC MAVEBA in Florence, Italy, in September 2015 and is also outlined in “A Practical Guide to Laryngeal Framework Surgery.”

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TABLE 1.
Subject Characteristics

Age (y)	Thickness of Cricoid Lateralized (mm)	Thickness of Cricoid Medialized (mm)	Angle Native (°)	Angle Lateralized (°)	Angle Medialized (°)
M 54	5.89	3.21	10.2	8.8	2.2
M 58	2.72	2.94	5.5	5.9	1.7
M 73	5.81	not measured*	7.0	9.8	not measured*
M 67	4.59	0.38	4.7	7.4	3.8
M 78	4.13	x	3.9	12.2	1.6
F 72	3.06	2.19	6.9	17.6	1.5
F 85	x	3.9	5.1	8.4	3.4
F 87	2.94	2.25	4.7	7.3	2.0
F 55	1.3	3.22	5.9	10.4	0.9
F 75	4.94	2.09	8.6	16.6	0.3
M 80	2.06	4.72	4.5	6.6	3.9
M 46	4.64	3.5	5.3	12.8	3.1
M 51	5.29	3.25	5.9	7.3	1.3
F 45	x	3.42	5.9	15.3	3.9
M 34	3.6	3.78	4.9	22.8	3.4
M 41	4.13	x	6.1	13.3	2.0
M 71	x	x	6.0	8.1	1.5
F 43	2.98	1.16	6.3	16.3	1.7
M 61	x	1.62	7.7	14.4	1.0
M 80	3.9	1.72	3.9	20.7	0

Marked in gray: insertion too high.

* Too much decay to medialize, because of coniotomy difficult to compare.

MATERIALS AND METHOD

Twenty human larynges from the Department of Legal Medicine were examined for this study.¹⁵ This included 13 male, seven female larynges of different ages (Table 1).

The laryngeal research was approved by the local Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

A three-dimensional cone beam computed tomography (3D CBCT, Accuitomo of the Japanese company Morita) of the native larynx was taken before the vocal fold's position was changed (Figure 1).

After removing soft tissue and perichondrium from the frontal aspect of the thyroid cartilage, we prepared a unilateral mini-thyroidotomy as described by Gray.¹⁶ Gray's mini-thyroidotomy is originally designed to dissect areas of adhesion without epithelial incision, not for substantial medialization. It requires suspension microlaryngoscopy as well as a 2–3 cm horizontal incision across the prow of the thyroid cartilage. Gray then inserts a 22G needle through the thyroid cartilage into the anterior commissure at the level of the vocal folds. The correct position of the needle is visualized by an assistant using a zero degree endoscope and corrected if required by reinserting it. The surgeon then marks the correct position on the thyroid cartilage. The thyrodotomy is then centered 3–5 mm off the midline at the level of the vocal fold and, using a 3-mm cutting burr, a tunnel through the thyroid cartilage is created. The inside margin of the thyroid cartilage should still remain intact and may be removed with a mastoid curette.

From our experience, the position of the drill hole has to be chosen as high as possible so that an inserted needle advanced

laterally alongside the inner vocal cord is shining initially through the epithelium of the vocal fold, avoiding a perforation. Further advancement of a straight needle with a slightly downward angle leads to a fixation of the needle in the cricoid cartilage. If the anterior hole is positioned as high as possible the degree of

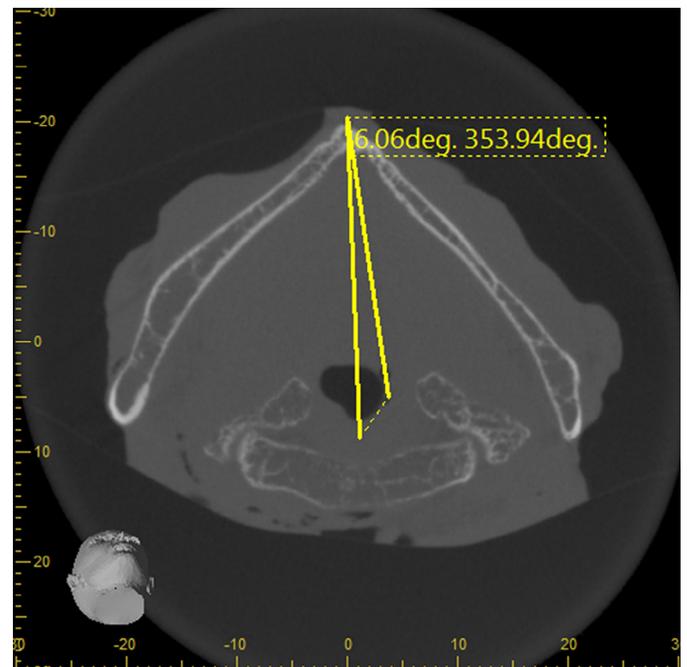


FIGURE 1. Larynx of a 41-year-old male, native view in CBCT.

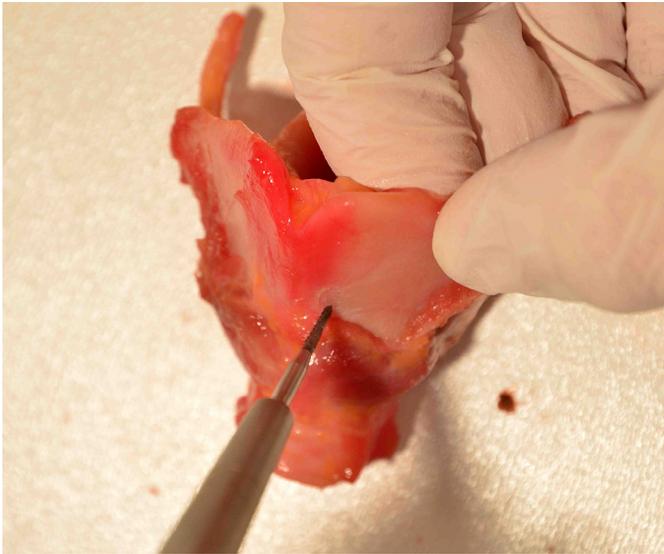


FIGURE 2. Position of the 2-mm drill hole.

freedom for moving the needle is higher; this enables a better posterior insertion of the needle tip into the cricoid cartilage.

Visual control of correct posterior pin position is possible via endolaryngeal inspection. The needle tip should not slide superior to the crest of the upper cricoid cartilage. The anterior cartilage hole should have a diameter of approximately 2 mm, enough for a 21G needle to pass through while causing minimal damage. With the inserted needle within the vocal fold, a medialization to a midline position is possible. The preparation process is shown in the following figures (Figures 2–4).

Then, again a CBCT was taken (Figure 5).

To make sure that the needle did not perforate the mucosa and indeed was located in the cricoid cartilage, the punch channels were checked in CBCT as well as the position of the needle *in situ*. We then checked the position of the needle in the cricoid cartilage, especially the height of the needle tip (Figure 6).

During the preliminary examinations we found that lateralizing the vocal fold sufficiently via the same surgical approach was also possible. Therefore, the vocal fold was lateralized as



FIGURE 3. Insertion of the 21G-needle into the drill hole; the necessary angle is well visible.

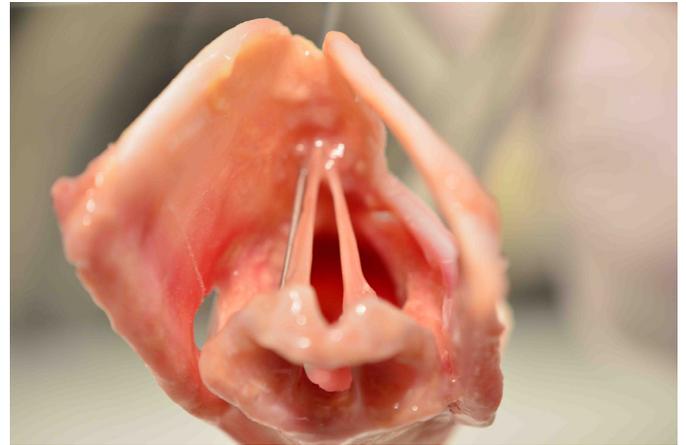


FIGURE 4. Larynx viewed from posterior and cranial onto the anatomic structures, needle parallels the left vocal cord; remaining vocal fold tissue is removed for better view.

far as possible via the same punch channel with a different fixation point in the cricoid (Figure 7).

Afterward, again a CBCT was performed (Figure 8).

The schematics of the methods are demonstrated in Figures 9 and 10.

In the end, we measured the angles between the extreme positions and the native position of the vocal fold in the CBCT scan, as seen in the CBCT pictures (Figures 1, 5, 8) and measured the thickness of the cricoid cartilage at the insertion point (Figure 11).

The measurements were taken from the analyzing program of the appliance (One Volume Viewer, J. Morita MFG Corp., Kyoto, Japan).

To accommodate the differences in size in the larynges used, we measured angles instead of millimeters distance to the midline.

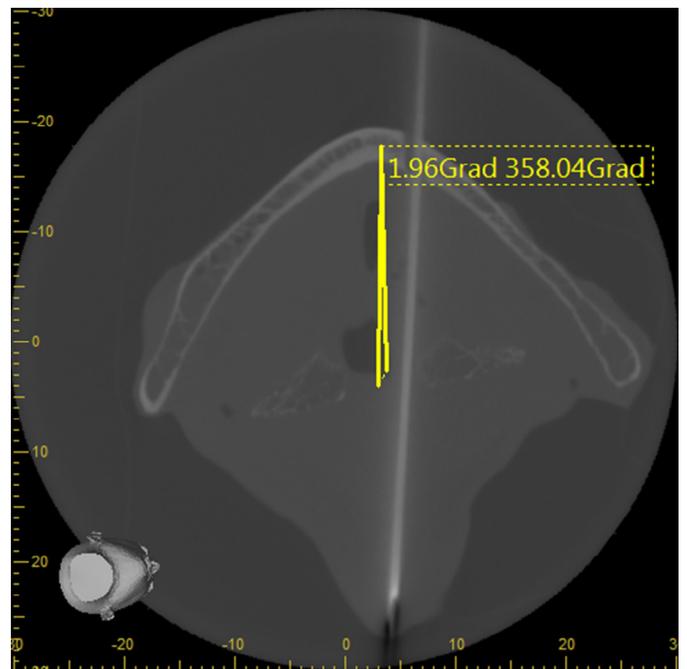


FIGURE 5. CBCT of the left vocal fold medialized.



FIGURE 6. Posterior view of needle position (perforation of the cartilage only for position control).

This eliminates the necessity to use larynges of similar size to have comparable figures, as the angle between the vocal folds is independent from anatomic proportions.

For the calculations, *SPSS Statistics 20* (IBM Corp., Armonk, NY) was used.

The principle idea of the method was first presented at PEVOC MAVEBA in Florence, Italy, in September 2015¹⁷ and is also outlined in “A Practical Guide to Laryngeal Framework Surgery.”¹⁸

RESULTS

It is possible to medialize and lateralize a vocal fold independent of age and size of the larynx with a needle via the same access using a minimal thyroid burr hole.

The method is, at least in the cadaveric larynx, performed quickly. With some practice, it was possible to prepare, drill, and lateralize or medialize one cadaveric larynx in 8 minutes.

To find out the best position of the burr hole, we compared our native CBCTs and the measurements of Friedrich and Lichtenegger.¹⁹ From that, we gathered that a useful reference point for the height of the hole would be the midpoint of a straight line between the laryngeal incisure and the lower rim of the thyroid cartilage. The hole then would have to be drilled 3–5 mm off the midline on the desired side.



FIGURE 7. View of the lateralized left vocal fold from above.

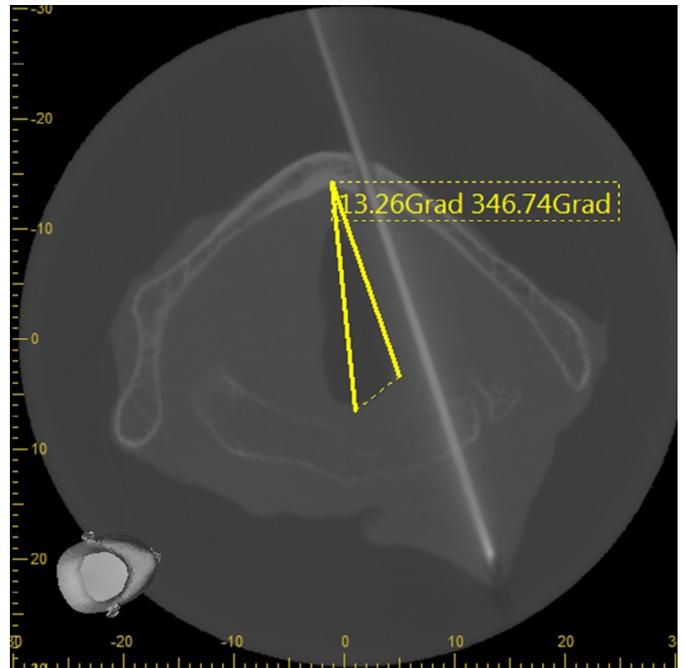


FIGURE 8. Same larynx as in Figure 5, lateralized, CBCT.

The expected problem of perforating the mucosa of the larynx never occurred; visual and CBCT control of the mucosa confirmed that the “line-up” of vocal fold, arytenoid cartilage, and cricoid (or tissue above) is easily possible.

An overview of the results of the study is given in Table 1. The angle values listed in the table were rounded; one pixel difference in the shown CBCT pictures amounts to 0.1 degrees.

An unexpected problem occurred during the three-dimensional examinations of the larynges. The needle missed the cricoid or just went into the very thin top of the cricoid several times. We found, from our experiences, that a cricoid cartilage thickness of fewer than 2 mm is too thin to keep any device anchored in the cricoid.

As shown in Table 1, the difficulty in the method seems to be anchoring the needle in the back of the cricoid. In our medialization experiments in three of the larynges, the needles had been inserted above the cricoid (marked with “x” in Table 1), in an additional four we just managed to get into the cricoid, but because of a very high position the needle probably would not be able to be anchored permanently. In four of the larynges, after lateralization, the needle went into the tissue above the cricoid (marked with “x” in Table 1); in one further larynx the needle was inserted only in the upper margin.

The problem does not seem to be related to gender or age. The main influencing factor seems to be the position of the drill hole; the lower this was positioned, the more likely it was to miss the cricoid. This brought us to the abovementioned difference to Gray’s method of locating a transthyroid hole position; the hole has to be positioned as high as possible without perforating into the laryngeal lumen anteriorly.

Demonstrated in Figure 12 is a well visible difference among the angles between the vocal folds and the midline if one com-

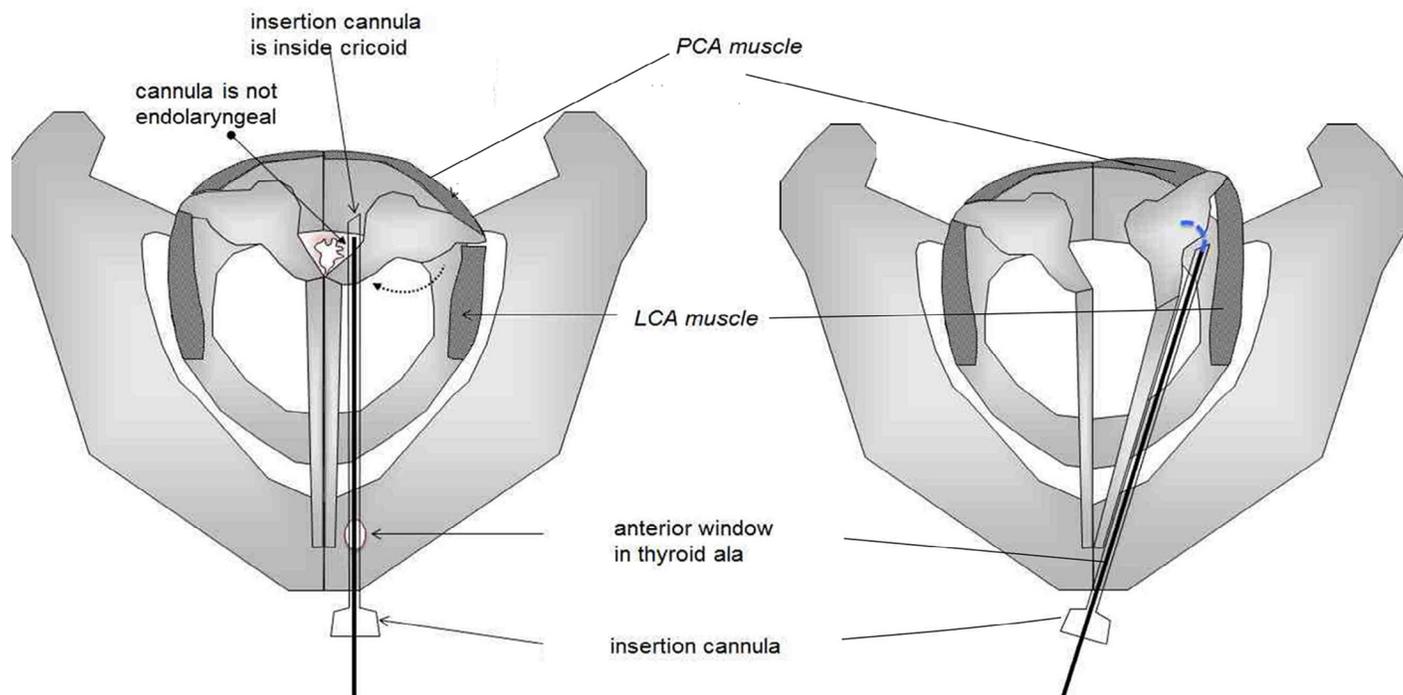


FIGURE 9. Schematics of medialization (left) and lateralization (right), viewed cranially. LCA, lateral cricoarytenoid muscle; PCA, posterior cricoarytenoid muscle.

pares lateralization and medialization. Both differ markedly from the native angle.

DISCUSSION

As one can deduce from our data, a medialization or lateralization of the vocal fold via “Pin-up glottoplasty” is feasible in principle. As visible in the boxplot (Figure 12), the achievable angles seem to be sufficient in medialization as well as in lateralization.

The main problem still presenting itself is the question of what kind of material should be used instead of the needle and how to fix it at both ends.

Several possibilities are imaginable, one being tissue compatible wire.²⁰ This could be pushed forward through the needle,

which would then function as a trocar. Possible materials would be titanium or stainless steel, but also materials with a shape memory like nitinol (an alloy consisting of nickel and titanium). This is already widely in use in several medical implantation devices,²¹ and long-term compatibility looks promising. There are some reports, however, describing the release of nickel from the material,²² and considering the high allergic potential of nickel, this needs to be watched. An allergic tissue reaction within the larynx, especially so close to the mucosal surface, would not be desirable.²³

Another possibility would be to use the needle as a trocar for placing a non-resorbable suture material with a fixation at the end. The suture material would need to resist sufficient force to keep the vocal fold medialized during phonation or lateralized

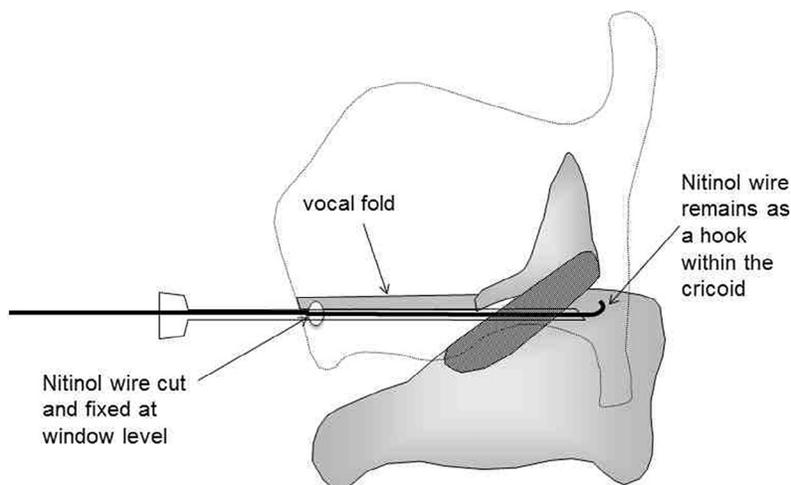


FIGURE 10. Schematic view, lateral.

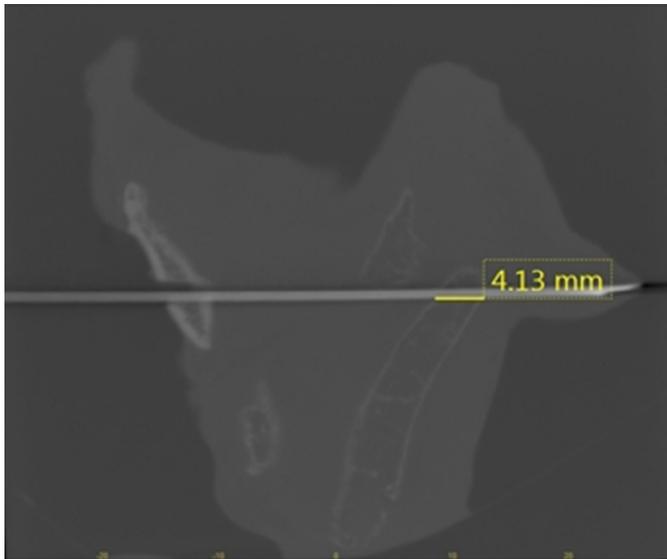


FIGURE 11. Thickness of cricoid cartilage in CBCT at point of perforation, lateralized.

during inspiration. This would also depend on adequate suture fixation to the thyroid cartilage anteriorly and the cricoid cartilage posteriorly to maintain sufficient tension during varying subglottic pressures.

The second operative problem, of course, is the material's fixation to the cricoid cartilage posteriorly. This fixation needs to hold in the cartilage and neither perforate it nor wear it down with movement or pressure over time. Ending in the upper esophagus would present a potentially critical complication. A possibility would be a kind of harpoon or hook, fixing the wire or thread to the cricoid cartilage internally. Finally, it would be nice to have a predetermined way to remove the material if necessary, because of always-possible allergic reactions. This would also be important if the method was used for temporary lateralizing of one vocal fold.

Pulling back a hook or harpoon would probably damage the vocal fold massively unless a sheath could be reinserted around it at removal. Potential allergic reactions to nickel are already described widely; several reports of nickel allergy causing nitinol devices to be removed are found in literature.²⁴⁻²⁶ This might preclude the long-term use of any nitinol material.

Another problem is a surgeon's learning curve for the implantation, which was already demonstrated in our study. Because of the very small burr hole, there is little space and degree of freedom positioning the needle correctly. Best position is probably found through CBCT preoperatively, but might also be determinable by clinical experience. As demonstrated in the pictures above (see [Figures 3, 4, 5, 7, 8](#)), the needle seems to be best positioned slightly downward from anterior to

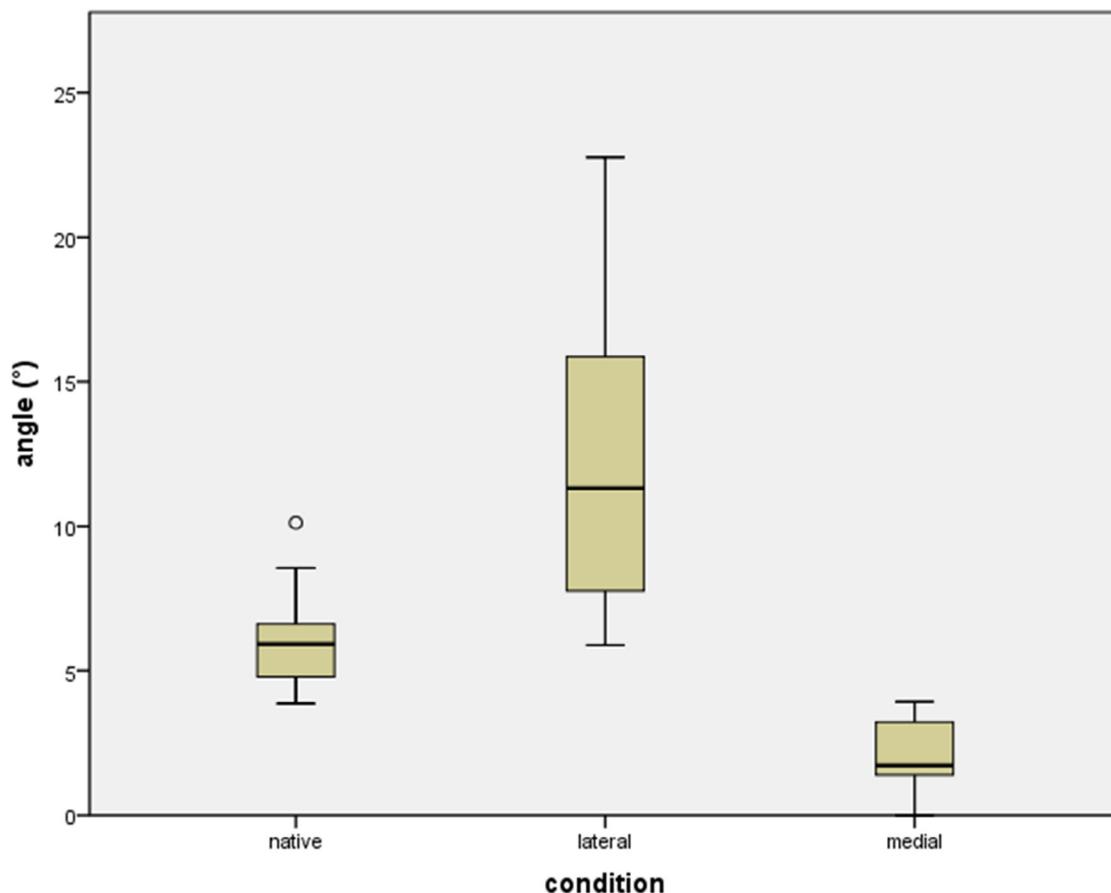


FIGURE 12. Boxplot of the results, left angles native, middle lateralized, right medialized.

posterior, and lateral of as well as parallel to the medial vocal fold edge.

However, it is easy to miss the cricoid cartilage medially by several millimeters because the vocal fold level is above the cricoarytenoid joint, and the articular cartilage of the joint may be almost 2-mm thick. Thus the “Pin-up” needle necessarily must enter the inner cricoid plate at a downward angle. Missing the cricoid lamina will make the needle end up in the hypopharynx or esophagus. In lateralization it may also be missed completely because of its quickly decreasing height as it curves anteriorly. Even hitting the cricoid at its thin superior extent (just beneath the cricoarytenoid articular cartilage) will cause difficulties fixing the wire. Measuring the prospective length in a CBCT and marking the wire preoperatively could reduce this risk.

CONCLUSIONS

It is possible to medialize a vocal fold in a cadaveric larynx without mucosa damage, but the position of the frontal drill hole has to be chosen carefully as to be able to fix the needle in the cricoid cartilage at the back.

Especially the speed in which a permanent medialization or lateralization of the vocal fold is possible could be interesting today, where saving time in operative procedures also means decreasing expenses.

In future studies, suitable materials have to be determined; possible material choices in place of the needle need to be carefully considered. Preoperative medical imaging seems to be sensible from today's point of view. But that done, it appears feasible that this method one day, perhaps even office based, may complement the now existing methods.

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