Original article

Intraoperative Computed Tomography Imaging for Laryngoplasty

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ABSTRACT

Objectives: Intraoperative cone beam computed tomography (CBCT) imaging has the potential to facilitate the surgical procedure. The current preliminary retrospective chart review investigated the benefits of intraoperative CBCT during laryngoplasty.

Method: This study examined 26 cases that underwent intraoperative CBCT imaging during laryngoplasty, with one patient who counted twice due to first and revision surgery. The visual quality of structures of interest (glottal shape, thyroid cartilage, arytenoid cartilage, and implants) was determined using intraoperative CBCT during laryngoplasty. Each patient also underwent an aerodynamic assessment.

Results: CBCT provided unique information, such as surgical landmarks in severe scarring, the subglottal shape, and the rotation angle of the arytenoid cartilage during arytenoid adduction. Nonetheless, 26.9% (7 of 26) of cases were affected by motion artifact, due to the long acquisition time. When motion artifact-negative cases were evaluated, 100% of glottal shape and more than 89% of thyroid cartilage were well visualized. All arytenoids were well-visualized in patients $\geq$ 50 years of age and without motion artifact, while CBCT failed to visualize the arytenoids in 2 of 4 patients who were < 50 years, due to the lack of calcifications. After medialization surgery, the yields of improved maximal phonation times (MPTs) in the motion artifact-negative and -positive groups were 8.7 sec and 3.4 sec, respectively ($p = 0.032$; Welch's t test). This comparison indicates intraoperative CBCT would contribute in MPT improvement, if CBCT is taken in measurable quality.

Conclusion: The potential benefits of intraoperative CBCT during laryngoplasty were demonstrated. A corollary, prospective study is warranted to further confirmation.

Key Words: laryngoplasty, dysphonia, voice, computerized tomography

INTRODUCTION

Unilateral vocal fold paralysis (UVFP) causes hoarseness and a breathy voice, which would be a serious impact on patients' quality of life. Medialization laryngoplasty is an effective surgical treatment for UFVP[1,2]. Type I thyroplasty and arytenoid adduction are utilized to medialize the vocal folds[3,4].

Medialization laryngoplasty is not always successful. The causal factors for failed procedures have been suggested, based on the findings during revision laryngoplasty[5–7] and postoperative CT imaging[5,8]. The causes of failed type I thyroplasty can be divided into immediate and late failures[5]. Immediate failures are due to inappropriate size or malposition of implant, while late failures are associated with late atrophy of the vocalis muscles or a foreign body reaction. The causal factors of failed arytenoid adduction were suggested as arytenoid cartilage (AC) over-rotation, insufficient correction of vertical differences in glottis, or vocal fold shortening[9,10].

During laryngoplasty under local anesthesia, commonly applied intraoperative evaluation methods are endoscopic monitoring and perceptual evaluation of the voice; however, endoscopic examination depends on surgeon's impression. Even for an experienced surgeon, the precise location of the implant in a type I thyroplasty is difficult to determine.

Though CT imaging is a useful assessment tool of the pre- and post-operative glottal status in UVFP patients[8,11,12], a conventional fan beam CT (FBCT) is not usually equipped in operation rooms. Recently, intraoperative cone beam CT (CBCT) has been reported to be beneficial in other fields, such as reconstruction surgery for maxillofacial fractures[13], intracranial electrode implantation for epilepsy[14], and cochlear implantation[15]. Intraoperative imaging can confirm the immediate need of additional tuning or revision. Thus, an intraoperative CBCT imaging of the laryngoplasty is expected to ensure the immediate effect of surgery. In this preliminary study, the feasibility and potential benefits of intraoperative CBCT imaging during laryngoplasty were retrospectively investigated.

SUBJECTS AND METHODS

Patients

Patients with UVFP, who underwent intraoperative CBCT imaging during laryngoplasty at "Blinded for review" from September 2015 to May 2019 were enrolled. This retrospective observational study followed Helsinki Declaration and was approved by the Institutional Review Board of "Blinded for review".

Mobile Cone Beam CT

The applied mobile X-ray CBCT imaging system (3D Accuitomo M; J. Morita Mfg. Corp., Kyoto, Japan; Fig 1) uses a conical X-ray beam that is captured on a flat panel detector. This small system is equipped with 4 wheels to enable easy positioning. Before the surgical procedure commenced, a specialized head rest with high X-ray transparency (J. Morita Mfg. Corp.) was attached to the operating table.

The imaging settings were as follows: tube voltage, 100 kV; and tube current, 7.5 mA.

During imaging, the patient was asked to breathe gently. The unit reconstructs the three-dimensional volume data automatically after the exposure. It took 17.5 sec for exposure in the standard mode, and 1-2 min to data processing. Besides these, additional time is required for interpreting the processed data, as well as positioning and removal of the CBCT system. The whole procedure finishes within 10 min.

Surgical Procedure

Laryngoplasty was performed under local anesthesia, except for one patient who underwent a simultaneous phonomicrosurgery to improve vocal fold scarring under general anesthesia. Preoperative FBCT imaging was performed for most cases, prior to surgery. In each surgery, operators included at least one of four board certified surgeons who have experienced more than 20 of medialization surgery.

For UVFP patients, type I thyroplasty and/or arytenoid adduction was performed. Type IV thyroplasty was added, if extra voice improvement was observed by manual suppression test. For type I thyroplasty, a small window (5 x 5 mm) was made 5 mm lateral to the midline of the thyroid cartilage (TC)[16]. Through the window, a polytetrafluoroethylene sheet (Gore-Tex [width, 5 mm]; Gore, Newark, DE) was inserted. For arytenoid adduction, cricothyroid joint was released, and then the pyriform mucosa was elevated to identify the muscular process of AC. If needed, the posterior window approach[17] or the fenestration method[18] was utilized. Using nylon suture thread, the muscular process was pulled to the lower edge of the TC. Intraoperative CBCT was performed after all these procedures were completed, basically. Additional CBCT was also performed, depending on the surgeon's need.

Additional image evaluation, such as angle quantification after arytenoid adduction surgery, was performed after surgery, using ImageJ software (Version 1.51m 30).

Feasibility Assessment of CBCT Imaging

The acquired CBCT images were reviewed by two certified otolaryngologists who didn't participate in the laryngoplasty and were blinded to the outcomes of vocal function. Motion artifact was evaluated by cortical bone or calcified cartilage. If cortical discontinuity was apparent or the cortex was double-lined, that image set was regarded as motion artifact-positive. In assessment of the glottal area, the border between air and soft tissue was grouped as follows: 'good', fully visualized; 'fair', more than one-half of the structures of interest were visualized and available for essential clinical information; and 'poor', failed imaging lacking information. The same grouping was applied for visualization of the TC, AC, and implant.

To estimate the reproductivity of CBCT assessment, bias-corrected intraclass correlation coefficient(ICC) between raters was calculated. For ICC calculations, each visualization grade was converted into numeral score as follows; 0 is on 'poor', 1 is on 'fair', and 2 is on 'good'. Statistical analyses were performed using JMP 15.0.2 (SAS Institute, Cary, NC, USA) software.

Further feasibility assessment was performed based on the scores of rater 1. Cases that were motion artifact-negative were sub-grouped by age. One group was < 50 years of age and the other group was ≥ 50 years of age.

Evaluation of Vocal Function

The mean flow rate (MFR) was measured with a phonation analyzer (PA-500; Nagashima Co., Osaka, Japan). The maximal phonation time (MPT) was measured during sustained phonation of [/e/] at comfortable levels of sound pressure and pitch. The Japanese version of Voice Handicap Index-10 (VHI-10) was also evaluated[19]. These assessments were performed preoperatively, and 1-3 months after surgery.

RESULTS

Description of Patients

The current study included 26 cases of CBCT from 25 patients, with 1 patient who enrolled twice for the first procedure and revision surgery. There were 9 women and 16 men (1 man was counted twice), with an average age of 58.9 years (range; 23-81 years). Detailed information of each case is summarized in Table 1. Among 26 UVFP surgeries, 7 laryngoplasties were revision surgeries, after at least a 5-month interval.

Representative Cases

Case 18

An 81-year-old woman with left UVFP following a thyroidectomy for thyroid cancer, had experienced two type I thyroplasties and one arytenoid adduction. The patient wished to improve the weak voice to sing a song. Therefore, another type I thryroplasty was conducted on the contralateral right side. Due to the previous multiple surgeries, the severe scarring completely concealed the TC midline. As visualization of the midline is crucial to design the new thryroplasty window, CBCT was performed after placing a small piece of surgical gauze sponge containing lead at the suspected location. Based on the location of the surgical gauze on CT image, the new window was made. After another acquisition of CBCT to confirm the window position (Fig 2), a polytetrafluoroethylene sheet was implanted. The window was slightly supra glottic position, thus the sheet was inserted slightly inferior to the window.

Case 17

A 73-year-old man underwent a type I thyroplasty and an arytenoid adduction for idiopathic right UVFP. A CBCT was performed after implanting a polytetrafluoroethylene sheet

(Fig 3). On axial images, the implant was at the middle portion of the vocal fold. Coronal images revealed that the implant was at the portion vertically adjacent to the vocal folds.

Case 12

A 65-year-old man underwent an arytenoid adduction and a type I thyroplasty for left UVFP following an esophagectomy for esophageal cancer. A CBCT after the left arytenoid adduction, could visualize the arytenoid rotation (Fig 4). After a bisector of the crossing angle between the bilateral vocal folds was made, the angle of the arytenoid to the bisector was measured (Fig 4 C, D) using ImageJ software. The angle was changed from preoperative 50.0 degrees to intraoperative 71.3 degrees. We note the angle quantification was performed after surgery. Intraoperatively, we checked arytenoid shift only by placing pre-and post-adduction images side by side.

Feasibility of CBCT

We note rater 1 among two raters is the main rater, and following results were based on rater 1, except for ICC statistics between raters. The bias-corrected ICC statistics of motion artifact, glottis, TC, AC, and implant were 0.9917, 0.9812, 0.8654, 1, and 0.9624, respectively. As ICC values between 0.75 and 0.9 are indicative of good, and greater than 0.90 are excellent reliability[20], the represented values are good to excellent, in this standard..

The current study revealed that 26.9% (7/26 cases) of CBCT images were affected by motion artifact, which led to worse visualization of the glottis, TC, and AC (Table 1, Fig 5). When motion artifact-negative cases were evaluated, 100% of glottal shape and more than 89% of TC were visualized “good”.

The total number of implants was 23, including 2 leftovers from the previous surgery (cases 1 and 16). Leftovers were visualized in the revision arytenoid adduction. Even after excluding cases with motion artifact, visualization of 37.5% (6 of 16 implants) of the polytetrafluoroethylene sheets was “poor”. Interestingly, both leftovers were shown to be “good”. Case 1 underwent at least 5 laryngoplasties in another institute and the implant material was unknown. In case 16, polytetrafluoroethylene was implanted 5 months before the CBCT. Additionally, 4 of 7 revision surgery patients, including case 16, had a FBCT, and all four polytetrafluoroethylene implants were clearly visualized.

We sub-grouped cases based on age, after excluding motion artifact-positive cases. In the $\geq$ 50-year-old group, CBCT represented “good” or “fair” images in all physiologic structures of interest. In the < 50-year-old group, “poor” images were found in the AC, presumably due to less calcification.

Vocal Outcome

Medialization laryngoplasty elongated the MPT; the preoperative average was 5.2 sec, and the postoperative average was 11.7 sec. The MFR was decreased; the preoperative average was 706.6 mL/sec, and the postoperative average was 268.1 mL/sec. As shown in Table 1, one patient didn’t undergo the aerodynamic examination and one patient missed the post-operative MFR.

Additionally, the difference between pre- and post-operative MPT was calculated by motion artifact-positives and -negatives, excluding case 1 due to the lacked parameters, and case 5 who represented an unnaturally long pre-operative MPT because of ventricular dysphonia. The subtracted MPT amounts of motion artifact-positives and -negatives were 3.4 sec and 8.7 sec, respectively. Between these groups, the variance was statistically unequal ($p = 0.015$; F test) and following Welch’s t test showed significant difference ($p = 0.032$). The result indicated motion artifact would affect the post-operative MPT improvement.

As for the additional tuning after CBCT, most operation records did not describe the post CBCT tuning, unfortunately. Besides case 18, we could not confirm records about additional adjustment. Lack of record does not directly mean not-performed additional tuning. Considering the difference in vocal outcome, we believe additional tunings were performed in more cases.

DISCUSSION

In this preliminary study, the feasibility and potential benefits of intraoperative CBCT imaging on laryngoplasty were investigated retrospectively. While FBCT units, which are more conventional and common, emit thin fan-shaped X-ray beams, the CBCT units emit a cone-shaped X-ray beam to a flat panel detector. Generally, the pixel size of the detector on CBCT panel is smaller than detectors on typical FBCT, thus CBCT would show theoretically higher spatial resolution than FBCT.

Intraoperative CBCT provided unique information about anatomic landmarks in revision surgery. As presented in case 18, severe scarring after multiple surgeries can conceal the surgical landmarks, such as the midline. In this case, intraoperative CBCT imaging was a great help to determine the adequate position of the thyroplasty window. This case indicated intraoperative CBCT could be beneficial to cases that actual surgery does not go according to the pre-surgery planning. This would be another benefit of CBCT, other from the capability to confirm the need of additional tuning or revision.

We could assess the glottal shape, which would indicate how the post-medialized vocal fold shifted into the glottal midline. As all glottal shapes were well-visualized in motion artifact-negative cases, CBCT might be helpful enough in the evaluation of the vocal fold medialization. The greatest advantage of CT imaging over endoscopy may be the detailed observation of the vertical level. The information of subglottal area, which only CBCT images can display intraoperatively, would be invaluable to reconstruct the glottal airway into a more physiologic shape. A previous study[8] reported a high frequency of vertical implant malposition (8 of 22 cases), if the window position was determined only by the geometry of the TC.

The current CBCT visualized the rotation of AC after arytenoid adduction. In case 12, the rotation of AC was evaluated through measurement of the arytenoid angle to the bisector of the crossing angle between the bilateral vocal folds. An objective and quantitative evaluation of arytenoid rotation angle would be helpful to the optimal procedure; however, that could not be measured by endoscopic observation. CT imaging might enable an objective assessment of arytenoid rotation. We are aware of crucial flaw of current method. First, current angle evaluation procedure requires too long time to perform intraoperatively, which might be relieved by the development of more automated software. Second, vertical direction of arytenoid vocal process, which is also important structure to glottal closure, could not be evaluated, because of CBCT's limitation on visualizing small contrast tissue. This point would be described in later paragraph. Lastly, the definition of the image plane used for this angle measurement was not well determined, which would be crucial for the accurate measurement. Due to these crucial flaws, CBCT remains to be a supportive tool to the conventional intraoperative endoscopic evaluation, in arytenoid adduction procedure. A further study is warranted.

CBCT also has pitfalls. The CBCT used in this study required 17.5 s for rotation of the detector, while only 0.33 – 0.35 s is sufficient for a single rotation of a 64-slice multidetector CT. Although the longer rotation time of CBCT is a drawback of a wider scanning area, the scanning time disabled acquiring images under clinically relevant tasks, such as phonation or a Valsalva maneuver. The images at glottal closure will reveal the vertical and horizontal gaps of the vocal folds and the arytenoid angle difference at the time of phonation[8,12]; however, keeping the glottis closed during 17.5 s of CBCT acquisition is a difficult task. Furthermore, a high percentage of motion artifact (26.9%) is caused by the long scanning time, because we cannot expect patients to remain completely still during acquisition. Repeating CBCT on cases with motion artifact might be an option, but at the cost of extra radiation exposure. The effective radiation dose of a CBCT scan for the head has been reported to be 0.1–0.35 mSv, whereas the effective radiation dose of a MDCT scan is 1–2 mSv[21]. Radiation dose changes largely by the voltage (kVp), tube current (mA) settings, and the field of view. Because the radiation dose of CBCT for the larynx has not been determined, we withheld repeating CBCT in the current study, with exceptions like case 18.

Another pitfall of CBCT image is the insufficient soft tissue contrast[22]. Insufficient contrast complicates localization of implants. Even after excluding cases with motion artifact, 37.5% of polytetrafluoroethylene sheet implants were visualized as “poor”. This appears to be disappointing; however, good visualization of glottal shapes would be sufficient to evaluate the medialization of vocal folds, as described above. It was noteworthy that two of the implant leftovers were visualized as “good.” Not only these CBCT cases, but FBCT also clearly visualized polytetrafluoroethylene implants with high contrast, thus indicating that fresh implants exhibit minimal contrast compared to soft tissue; however, the contrast improves in a time-dependent fashion. This reaction might arise from the wound healing process.

Moreover, the shape of laryngeal cartilage would be obscured by the insufficient soft tissue contrast, which is relieved by age-dependent calcification. The current CBCT study failed to visualize 2 of 4 young arytenoids due to the lack of calcifications, whereas no “poor” visualization occurred in the ≥ 50-year-old group. An X-ray study reported consistent results; specifically, the AC is not calcified until 50 years of age, while the TC showed ossification in the 20s[23]. These findings suggest that CBCT might be helpful in arytenoid adduction involving ≥ 50-year-old patients.

The described pitfalls indicate CBCT cannot provide FBCT quality images. However, CBCT’s greatest advantage is its capability to acquire images in operation rooms. CBCT is expected to be useful enough to assess the need of additional tuning or revision, if images were acquired without motion artifact.

In the present study, the existence of motion artifact made a significant difference in the MPT improvement after surgery. Because motion artifact-positive CBCT contributed little to surgical procedure, the comparison might be close to the comparison between measurable CBCT and no CBCT groups. Thus, the use of intraoperative CBCT imaging might substantially contribute the clinical outcomes of laryngoplasty, if CBCT is taken without motion artifact.

However, it is quite obscure the mechanism how CBCT contributed to the better MPT or the occasion in which CBCT plays a crucial role, because most operation records lacked information about additional tuning, in current retrospective study. Further investigation is needed to clarify these points. We are hopeful of the technological improvement in the future CBCT, which might enable faster acquisition to reduce motion artifact.

Conclusions

The current study reported on feasibility and potential benefits of intraoperative CBCT imaging during medialization laryngoplasty. Although CBCT is vulnerable to motion artifact and insufficient visualization of non-ossified cartilage, CBCT imaging could display unparalleled information, such as the location of concealed anatomical landmark in severe scarring, the glottal and subglottal shapes, and the position of the AC and TC. Adequately acquired CBCT might contribute to the postoperative MPT improvement. The current new strategy has the potential to improve postoperative outcomes of laryngoplasty.

Disclosure Statement

All authors participated have no financial support or relationship that causes a conflict of interest.

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Figure Legends

Fig 1. Appearance of cone beam computed tomography (CBCT). The unit is 840 mm wide, 1630 mm high, with a depth of 1630 mm, and equipped with 4 wheels to move in any direction (A). After the patient was covered with a sterilized drape, the unit was set at the precise position (B). After the exposure, the unit reconstructed the three-dimensional volume data automatically, then showed the images on the unit display (C).

Fig 2. Case 18: After a small piece of surgical gauze sponge containing lead (arrowhead) was placed in the suspected window portion, the intraoperative CBCT image was performed. The image showed the surgical gauze sponge (arrowhead) near the midline of thyroid cartilage, then the correct window portion (square) was determined.

Fig 3. Case 17: The preoperative (A, B) and intraoperative CT images (C, D) for type I thyroplasty. The polytetrafluoroethylene implant was located at the middle portion of the vocal fold in the axial image (B) and at the vertical portion adjacent to the vocal fold in the coronal image (D).

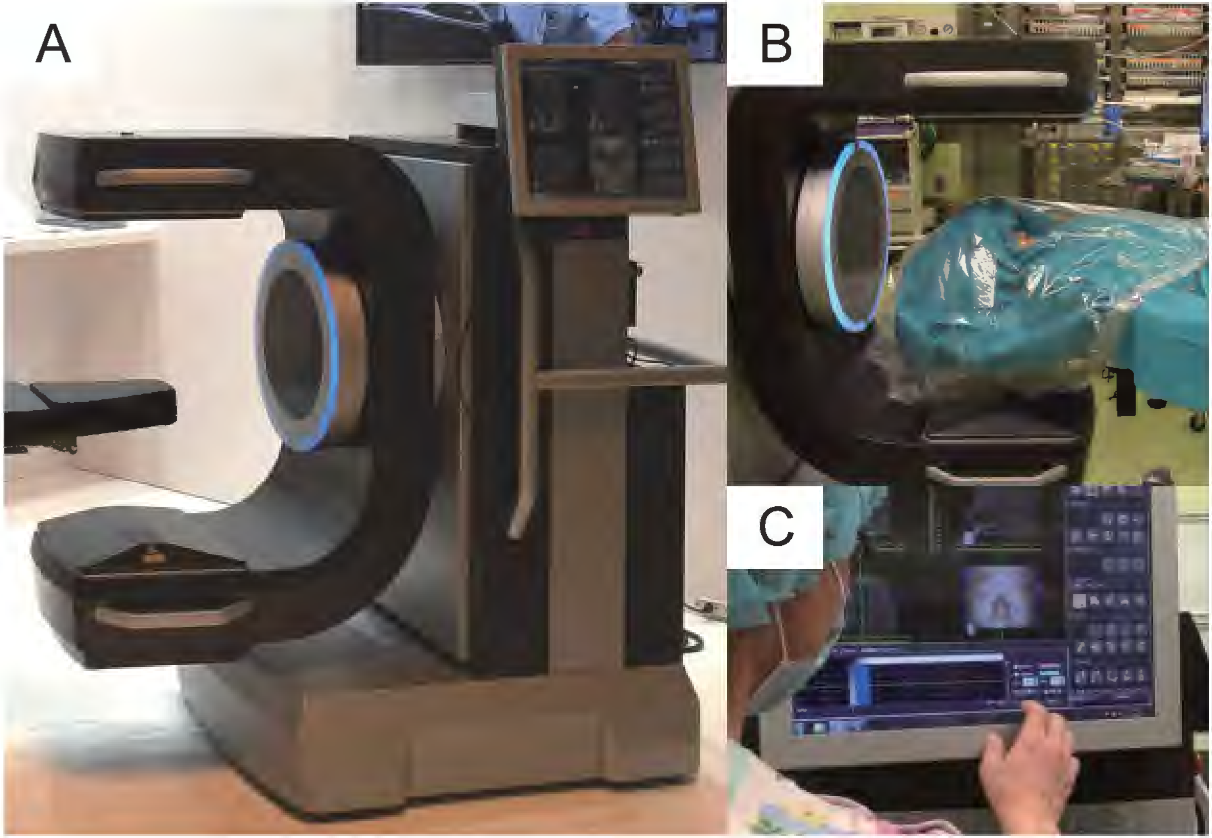
Fig 4. Case 12: The preoperative (A, C) and intraoperative CT images (B, D) for arytenoid adduction. The intraoperative CT image (B) revealed rotation of the AC compared to the preoperative image (A). After a bisector of the crossing angle between the bilateral vocal folds was made, the angle of the arytenoid to the bisector was measured (C, D). The angle of the AC was 50.0º preoperatively (C) and the angle was 71.3º intraoperatively (D).

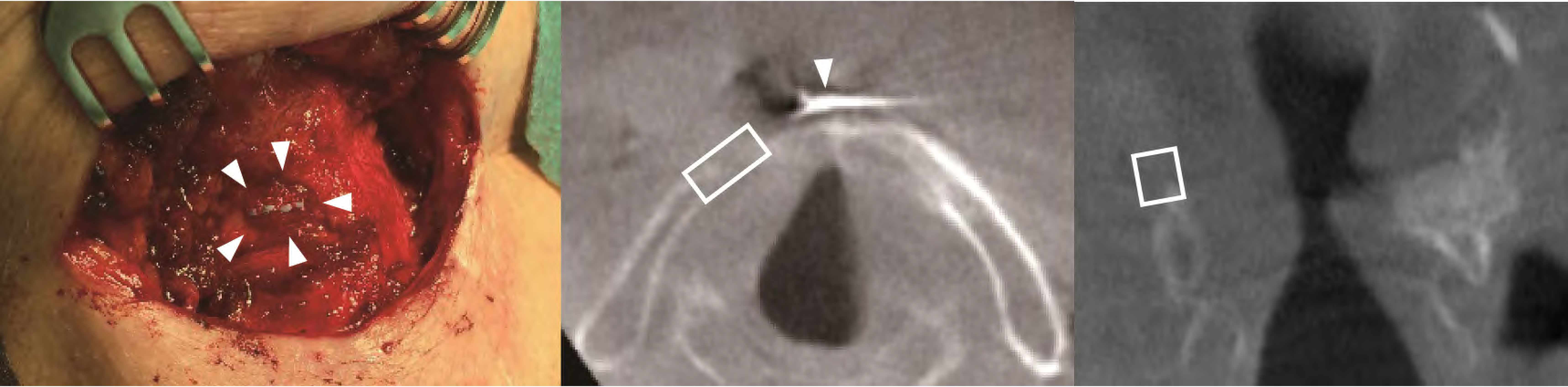
Fig 5. Visualization quality of CBCT. Based on the assessment of rater 1, visual quality of each structure of interest is ranked, and then sorted by negative and positive motion artifact (A).

Within the motion artifact-negative group, patients were sub-grouped to < 50 or ≥ 50 years of age (B). The Y-axis of each graph indicates the number of cases. TC: Thyroid cartilage, AC: arytenoid cartilage

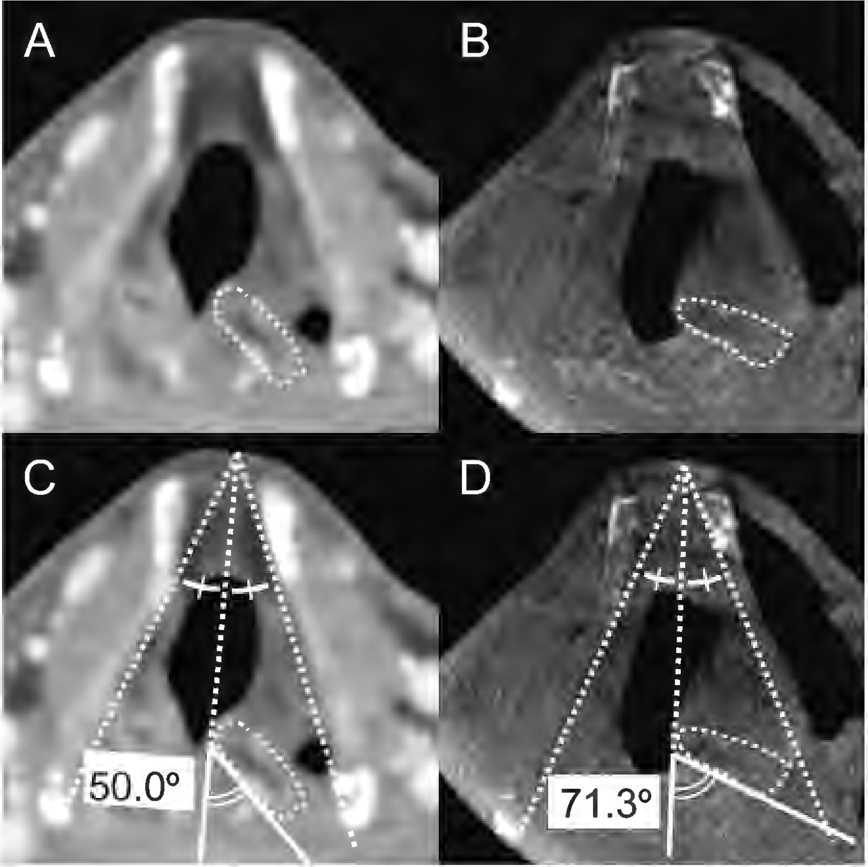
Case	Age	Gender	Disease	Surgery	Pre-Operative			Post-Operative			CBCT visualization (rater 1)					CBCT visualization (rater 2)				
					VHI-10	MPT (second)	MFR (mL/sec)	VHI-10	MPT (second)	MFR (mL/sec)	Motion artifact	Glottis	Thyroid cartilage	Arytenoid cartilage	Implant	Motion artifact	Glottis	Thyroid cartilage	Arytenoid cartilage	Implant
1	26	M	Lt. UVFP	AA	-	-	-	-	-	-	-	good	good	poor	good*	-	good	good	poor	good*
2	23	M	Lt. UVFP	I	34	7	415	-	9	372	-	good	fair	poor	good	-	good	fair	poor	good
3	36	F	Rt. UVFP	I	28	11	239	-	13	155	-	good	fair	fair	fair	-	good	fair	fair	fair
4	42	F	Rt. UVFP	I	34	6	403	11	12	162	-	good	good	good	fair	-	good	good	good	fair
5	51	M	Lt. UVFP	I, AA	-	21	162	0	10	264	-	good	good	good	poor	-	good	good	good	poor
6	55	M	Lt. UVFP	AA	25	2	1501	16	12	199	-	good	good	fair	-	-	good	good	fair	-
7	59	M	Lt. UVFP	AA	34	3	549	10	28	109	-	good	good	good	-	-	good	good	good	-
8	60	M	Lt. UVFP	I, AA	31	2	1269	8	28	127	-	good	good	good	poor	-	good	good	good	poor
9	61	F	Lt. UVFP	I	-	4	621	-	10	-	-	good	good	good	fair	-	good	good	good	fair
10	62	M	Lt. UVFP	I, AA	15	2	894	6	5	354	-	good	good	good	poor	-	good	good	good	poor
11	64	M	Lt. UVFP	I, AA, IV	35	3	928	0	26	146	-	good	good	fair	poor	-	good	good	fair	poor
12	65	M	Lt. UVFP	I, AA	34	1	1242	3	16	257	-	good	good	fair	poor	-	good	good	fair	poor
13	67	F	Rt. UVFP	I	21	8	248	0	11	178	-	good	good	good	poor	-	good	good	good	poor
14	70	F	Lt. UVFP	I	16	5	393	16	7	330	-	good	good	good	fair	-	good	good	good	fair
15	71	M	Rt. UVFP	I	19	3	1674	14	6	440	-	good	good	good	fair	-	good	good	good	fair
16	72	M	Rt. UVFP	AA	33	2	1283	21	12	268	-	good	good	good	good*	-	good	good	good	good*
17	73	M	Rt. UVFP	I, AA, IV	22	3	704	8	12	254	-	good	good	good	fair	-	good	good	good	fair
18	81	F	Lt. UVFP	I	16	11	180	15	11	267	-	good	good	good	fair	-	good	good	good	fair
19	82	M	Lt. UVFP	AA	23	2	1259	2	6	248	-	good	good	fair	-	-	good	good	fair	-
20	46	M	Lt. UVFP	I, AA	33	8	189	6	13	101	+	poor	fair	poor	poor	+	poor	fair	poor	poor
21	51	M	Lt. UVFP	I	-	6	511	23	12	249	+	fair	fair	fair	good	+	fair	fair	fair	good
22	62	M	Lt. UVFP	I	-	1	894	15	2	936	+	poor	fair	poor	poor	+	poor	fair	poor	poor
23	67	M	Lt. UVFP	I	27	10	395	12	10	265	+	fair	fair	poor	good	+	fair	fair	poor	good
24	77	F	Lt. UVFP	I, AA, IV	27	3	797	13	11	154	+	poor	poor	poor	poor	+	poor	poor	poor	poor
25	79	F	Lt. UVFP	I	25	3	475	4	5	178	+	poor	fair	poor	poor	+	poor	fair	poor	poor
26	79	F	Lt. UVFP	I, AA	22	3	441	15	5	422	+	fair	fair	poor	poor	+	fair	fair	poor	poor

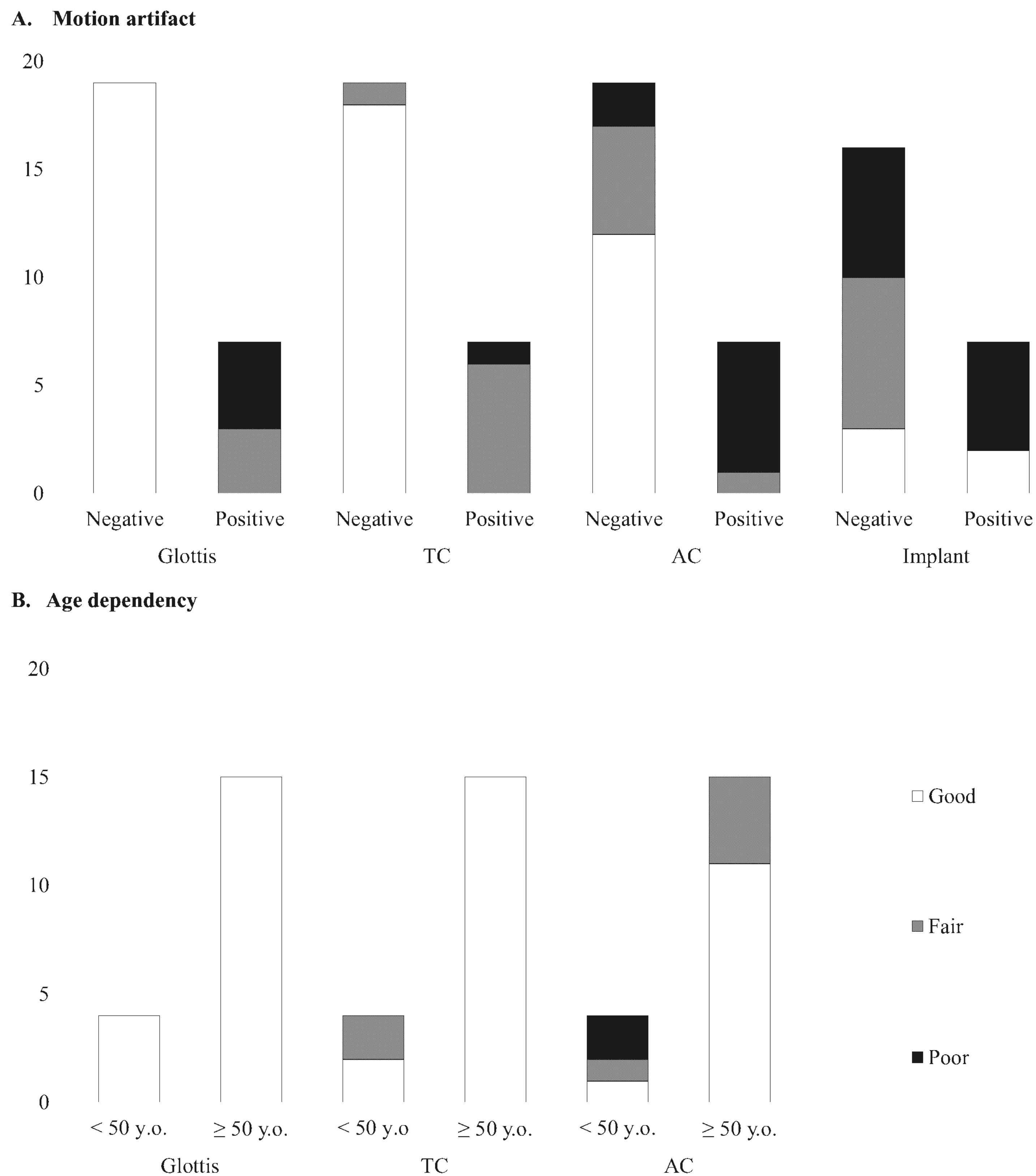
Table 1 : Patient Demographics: All cases underwent surgery under local anesthesia except for case 1 who underwent simultaneous phonomicrosurgery to improve the vocal fold scarring. A patient was counted twice for initial (case 22) and revision (case 10) surgery. Cases 1, 2, 16, 18, 21 and 23 underwent laryngoplasty as revision surgery. The pre-operative phonation of Case 5 was ventricular dysphonia. Visualization grade was estimated by two independent raters.*Implants were leftovers of privious surgery. UVFP: unilateral vocal fold paralysis, AA: arytenoid adduction.


A
B
C




A
B
Vestibular Fold
Ventricle
Vocal Fold
C
D


A
B
C
D
50.0°
71.3°


A. Motion artifact
20
15
10
5
0
Negative
Positive
Negative
Positive
Negative
Positive
Negative
Positive
Glottis
TC
AC
Implant
B. Age dependency
20
15
10
5
0
< 50 y.o.
≥ 50 y.o.
< 50 y.o
≥ 50 y.o.
< 50 y.o.
≥ 50 y.o.
Glottis
TC
AC
Good
Fair
Poor