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A comparison of airway dimensions, measured by acoustic reflectometry and ultrasound before and after general anaesthesia

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Short Title: Postoperative changes in airway dimensions

Presentation: This study was presented in part at the Japanese Society of Anesthesiologists 59th Annual Meeting, Kobe, Japan, June 6–9, 2012.

Summary

Changes in airway dimensions can occur during general anaesthesia and surgery for a variety of reasons. This study explored factors associated with postoperative changes in airway dimensions. Patient airway volume was measured by acoustic reflectometory and neck muscle diameter by ultrasound echography in the pre- and post-anaesthetic periods in a total of 281 patients. Neck circumference was also assessed during these periods. A significant decrease in median (IQR [range]) total airway volume (from 63.8 (51.8–75.7 [14.7–103]) to 45.9 (33.5–57.2 [6.4–96.3]) ml, $p<0.0001$) and a significant increase in muscle diameter (from 4.25 (3.31–5.60 [2.17–8.95]) to 5.77 (4.73–7.28 [2.83–1.25]) mm, $p<0.0001$) and neck circumference (from 34.0 (32.5–37.0 [29.5–49.0]) to 35.0 (33.5–38.0 [30.5–50.5]) cm, $p<0.0001$) were observed. It may be possible that changes in airway volume and neck circumference were influenced by surgical duration or perioperative fluid management (rs (95%CI) = -0.31(-0.24 – -0.01), p=0.0301, -0.17(-0.23 – -0.06), p=0.0038, 0.23(0.12 – 0.34), $p<0.0001$, and 0.16(0.05 – 0.27), p=0.0062, respectively). The intraoral space can significantly decrease and neck thickness increase after general anaesthesia, and might increase the risk of difficult laryngoscopy and intubation if airway management is required after extubation following general anaesthesia.

Several studies have reported airway changes in patients during labour and delivery [1-4]. Possible causes include airway oedema, which can be augmented by excessive use of crystalloid fluids and prolonged Valsalva, as described in previous case reports [5]. During general anaesthesia and surgery, patients are similarly exposed to increases in central venous and intracapillary pressure due to positive pressure ventilation, which can alter the Starling equation and exacerbate mucosal oedema by fluid overload in the presence of decreased oncotic pressure [6]. Besides, there are other reasons such as trauma from airway devices or instrumentation and loss of muscle tone which can influence airway dimensions. Therefore, changes in airway dimensions can occur during general anaesthesia and surgery as well as during labour and delivery. Studies have also suggested that fluid displacement can effect upper airway patency while recumbent as a result of leg accumulation during the daytime in certain disease states with fluid overload [7,8].

Occasionally, reintubation is required after general anaesthesia because of unanticipated postoperative respiratory failure. In such a situation, laryngoscopy and intubation may be more difficult because of the aforementioned postoperative changes in airway dimensions. Most anaesthetists have probably experienced this and yet characteristics of postoperative changes in airway dimensions have not been extensively investigated.

It has been reported that oral and pharyngeal volumes measured by acoustic reflection technology and ultrasound quantification of anterior neck soft tissue may be useful in distinguishing and predicting difficult airways [3,9-12]. Increased neck circumference has also been postulated as a marker of difficult airway management [13,14]. It is possible that airway oedema decreases airway volume and increases the amount of soft tissue in the neck. Moreover, postoperative changes in airway dimensions may be enhanced by specific factors such as patient positioning (especially the prone or Trendelenburg positions), obesity, and pneumoperitoneum during laparoscopic procedures.

This observational cohort study was initially conducted to investigate whether airway dimensions evaluated by acoustic reflection, ultrasound quantification, and neck circumference measurement are affected by general anaesthesia and surgery. In addition, preoperative and/or intraoperative parameters influencing these changes were explored. Specifically, we focused this retrospective investigation on preoperative obesity, patient position during surgery, and pneumoperitoneum during laparoscopy.

Methods

This observational cohort study was registered with the University Hospital Medical Information Network Clinical Trials Registry (UMIN R000008413) and approved by the Nara Medical University Hospital (Japan) institutional review board. Four hundred and fifty five consecutive patients (>18 years old) who underwent orthopaedic and gynaecologic procedures under general anaesthesia administered by one of our authors between July 2011 and November 2013 at Nara Medical University Hospital were initially enrolled. Patients who were pregnant or had upper airway pathology, cervical spine fractures, were not fasted, had hiatus hernia, gastroesophageal reflux, a history of difficult laryngoscopy or intubation, symptomatic congestive heart failure, or renal disease and patients undergoing gynaecological laparotomy were excluded. Patients unable to understand instructions were also excluded because oral and pharyngeal volumes measured by acoustic reflection technology are an active physical test.

Methods of anaesthetic induction and maintenance and tracheal intubation were not standardised for each patient. Usually, general anaesthesia was induced with intravenous propofol (1–2.5 $mg.kg^{-1}$) and fentanyl (1–2 $\mu g.kg^{-1}$) or remifentanil (0.2-0.3 $\mu g.kg^{-1}.min^{-1}$). Tracheal intubation was facilitated using rocuronium (0.6-0.9 $mg.kg^{-1}$) with laryngoscopy. Anaesthesia was maintained with sevoflurane (1.5-2%) and 40% oxygen and air mixture, or propofol (6-10 $mg.kg^{-1}.h^{-1}$). Fentanyl (1-2 $\mu g.kg^{-1}.h^{-1}$) or remifentanil (0.1-0.2$\mu g.kg^{-1}.min^{-1}$) were used for analgesia. Rocuronium (0.2-0.3 $mg.kg^{-1}.h^{-1}$) was used for muscle relaxation and sugammadex (2-4 $mg.kg^{-1}$) was used for its reversal. Fluid management was also at the discretion of the attending anaesthetist. Usually, 500-1000 ml of colloid (6% hydroxyethyl starch) was infused in the first one hour followed by 2-4 $ml.kg^{-1}.h^{-1}$ of crystalloid. Patients were fasted for at least 10 hours before anaesthesia induction. Objective airway assessments were conducted in the operating room, with patients in the supine position and the head placed in the neutral position with a 10-cm-high pillow. The first series of assessments were conducted just before anaesthesia induction. The second series of the same set of assessments were conducted 5 min after patients had a modified Aldrete score >9 following extubation [15]. Patient age, weight, height, gender, and body mass index (BMI) were noted (Table 1). Intraoperative variables, including surgical duration (first incision to final suture), fluid input, urine output, bleeding, and blood product transfusion were also recorded. Initially, the duration of anaesthesia was recorded; however, this parameter was excluded from later analyses because it is largely dependent on surgical duration; therefore, it is difficult to determine the exact interval on the basis of the National Health Insurance (Japan) definition, particularly for patients occupying the operating room for our study purposes.

Upper airway volume was assessed using an Acoustic Pharyngometer Eccovision™ device (Fig. 1) (Sleep Group Solutions, North Miami Beach, FL, USA) [3,9,10]. This comprises two microphones and one horndriver mounted on a 30-cm-long, 1.89-cm inner diameter wave tube with a microcomputer equipped with digital-to-analogue and analogue-to-digital converters and software for data processing. Acoustic waveforms were displayed on a computer screen. The system software also computes and displays values for oral volume, mean oral area, pharyngeal volume, mean pharyngeal area, total airway volume, and uvula and glottis distances from the incisor teeth. Patients breathed through the mouth using a respiratory mouthpiece without vocalizing through the wave tube. Data were acquired with the upper airway maintained in the supine position and the neck in the neutral position. Records of pharyngeal, oral cavity, and total airway volumes were used. Waveforms were stored on the equipment hard-disk drive and assigned numerical codes. Their volumes were later assessed by one of our authors who was blinded to the waveform origins. Fig. 2 shows representative acoustic waveforms obtained by the Acoustic Pharyngometer Eccovision™ in the pre- and postoperative periods in the supine position.

Ultrasound quantification of anterior neck tissue was performed using a linear transducer with an ultrasound system (L12-3 and CX50, Philips Electronics Japan, Tokyo, Japan) at a frequency of 5.0 MHz. Originally, Ezri and colleagues measured the distance from the skin to the anterior aspect of the trachea in obese patients [11]. However, it may be very difficult to determine this distance in those of normal body mass index (BMI) and, therefore, we measured the diameter of the sternothyroid muscle at the level of the vocal cords. The amount of anterior neck tissue was quantified by averaging the diameter of the sternothyroid muscle obtained 15 mm to the left and right of the central axis. To subsequently measure the identical muscle area, a black mark was made on the neck at the transducer application point. Ultrasound images (Fig. 3) were also stored on the equipment hard-disk drive and given numerical codes, and their diameters were later measured by one of our authors who was blinded to the image origin.

Neck circumference was measured at the thyroid cartilage. Three black marks were made on the neck as a reference for subsequent measurements of the same area. After obtaining two sets of assessments, the change index (%) of each study component was calculated using the following formula:

100* (post-anaesthetic – pre-anaesthetic value) /pre-anaesthetic value

Given the observational nature of this study, no formal sample size calculations were made. According to the Kolmogorov-Smirnov test, most variables were judged to be not normally distributed. Therefore, data are presented as median (IQR [range]) instead of mean (SD) where appropriate. The Wilcoxon's signed rank test was used to compare pre- and post-anaesthetic values for individual airway assessments using acoustic reflectometery and ultrasound as well as neck circumferences. To determine whether change indices correlated with age, height, BMI, surgical duration, or intraoperative fluid balance, Spearman's rank correlation coefficient analysis was used.

To investigate whether postoperative changes in airway dimensions were affected by preoperative obesity, patient position (particularly the prone position) during anaesthesia, or pneumoperitoneum during laparoscopy, patients were divided into the following subgroups: obese (BMI $\geq$ 30 kg.m^{-2}) and nonobese, prone and nonprone, or pneumoperitoneum and nonpneumoperitoneum. BMI $\geq$ 30 kg.m^{-2} was considered as obese based on The International Classification of adult BMI [16]. Subgroups were categorised in this way to prevent interaction with each other. Obese and nonobese patients were patients who underwent general anaesthesia without prone positioning nor pneumoperitoneum. Prone and nonprone patients were nonobese and underwent general anaesthesia without pneumoperitoneum, while pneumoperitoneum and nonpneumoperitoneum participants were nonobese patients who underwent general anaesthesia without prone positioning. Comparisons of change indices between groups were made using the Mann-Whitney test. After exclusion of these strong factors, correlations between change indices and intraoperative factors (surgical duration and intraoperative fluid balance) were examined in nonobese patients who underwent general anaesthesia without prone positioning or pneumoperitoneum. A p-value of <0.05 was considered statistically significant for all analyses. Statview version 5 software (SAS Institute Inc., Cary, NC, USA) and Stats Direct version 3 software (StatsDirect Ltd., Altrincham, Cheshire, UK) were used for statistical calculations.

Results

According to the exclusion criteria, 72 patients were excluded from 455 patients. Of eligible 383 patients, informed consent was obtained from 320 patients during the study period. Five refused to undergo airway assessments in the operation room and 34 could not complete all assessments accurately. Eventually, 281 patients completed the study protocol. Seventy four were obese (BMI > 30 kg/m^2). Laparoscopic surgery was performed in 86 patients. Orthopaedic surgery in the prone position was performed in 34 patients. Median (IQR [range]) oral (from 48.4 (37.3 – 57.7 [11.7 – 93.8]) to 35.4 (25.5 – 44.4 [4.6 – 76.5]) ml, p<0.0001), pharyngeal (from 14.6 (9.6 – 19.9 [2.6 – 38.3]) to 9.5 (6.1 – 13.5[1.7 – 27.8]) ml, p<0.0001), and total airway volumes (from 63.8 (51.8–75.7 [14.7–103]) to 45.9 (33.5–57.2 [6.4–96.3]) ml, p<0.0001) significantly decreased in the post-anaesthetic period (Fig. 4). Conversely, the diameter of the sternothyroid muscle (from 4.25 (3.31–5.60 [2.17–8.95]) to 5.77 (4.73–7.28 [2.83–1.25]) mm, p<0.0001) and neck circumference (from 34.0 (32.5–37.0 [29.5–49.0]) to 35.0 (33.5–38.0 [30.5–50.5]) cm, p<0.0001) significantly increased in the post-anaesthetic period (Fig. 5). A post-hoc power calculation using neck circumference data, which showed the smallest change index, was conducted. We arbitrarily assumed that difference of mean from zero = 1.2 and standard deviation = 3.6 according to raw data. Based on the formula for normal theory and assuming a type I error protection of 0.01 and a power of 0.95, 163 patients were required, which demonstrates that our sample size was sufficient to see the changes in parameters.

However, changes in airway dimensions revealed by these assessments did not correlate with most perioperative factors, including age, height, BMI, surgical duration, and intraoperative fluid balance (Table 2). Nevertheless, changes in total airway volume only very weakly correlated with surgical duration and intraoperative fluid balance (rs (95%CI) = -0.31(-0.24 – -0.01), p=0.0301, and -0.17(-0.23 – -0.06), p=0.0038, respectively; Table 2).

Changes in neck circumference also only weakly correlated with height, surgical duration, and intraoperative fluid balance (rs (95%CI) = -0.14(-0.26 – -0.03), 0.23(0.12 – 0.34), p<0.0001, and 0.16(0.05 – 0.27), p=0.0062, respectively; Table 2).

Regarding subgroup analyses, only the change index of sternothyroid muscle diameter after general anaesthesia was significantly affected by the prone position (p = 0.0498). Other changes in airway dimensions were not affected by any of these factors (Table 3). After excluding obesity, prone positioning, and laparoscopic surgery, the relationship between change indices and intraoperative factors, including surgical duration and intraoperative fluid balance, was further evaluated (n = 121; Table 4). Again, no apparent correlations were identified with most intraoperative factors (Table 4). However, changes in neck circumference weakly correlated with surgical duration and intraoperative fluid balance (rs (95%CI) = 0.24(0.07 – 0.40), p=0.0078, and 0.25(0.08 – 0.41), p=0.0038, respectively; Table 4).

Discussion

As anticipated, changes in airway dimensions were observed after general anaesthesia and surgery, including a decrease in oral and pharyngeal volumes measured by acoustic reflection technology, an increase in sternothyroid muscle diameter evaluated by ultrasound, and an increase in neck circumference. Considering the increased neck thickness, it is possible that the primary cause of decreased airway space resulted from oedema. Although surgical duration and perioperative fluid management correlated weakly with these changes, there was no strong associative factor. In any case, the simultaneous decrease in intraoral space and increase in neck thickness after general anaesthesia suggest that postoperative airway management (if necessary) is likely to be more difficult.

In Figure 2, it is evident that airway and oral space is decreased in the post-anaesthetic period. Interestingly, the post-anaesthetic waveform was very similar to that seen in unexpected failed intubation, in which unclear anatomical segments in the pharyngeal region have been reported by previous investigators [9]. However, we did not confirm whether patients with this wave pattern had difficult airways because none required airway management immediately after anaesthesia. In this context, it may be interesting to find the different airway volume change patterns in the oral and pharyngeal regions in this study. The tongue volume might also be increased by oedema formation.

These changes in airway dimensions are attributed to systemic fluid retention during the perioperative period [17,18], which may signify extravascular fluid accumulation [19]. In addition, it has been suggested that rostral fluid displacement can occur even in supine patients who are predisposed to fluid retention [7,8]. This suggests that fluid shift into the neck could increase upper airway collapsibility during general anaesthesia with lying supine. A previous study suggested that perioperative fluid retention may be associated with not only surgical tissue manipulation but also anaesthesia [19]. This same study implied that mechanical ventilation has little to do with perioperative fluid retention. Although it may be natural for clinicians to believe that surgical duration may impact fluid retention, it has not been demonstrated in major thoracic surgery [20], perhaps because intensity of surgical insults masks the effects of surgical duration on fluid retention. Patients in the current study underwent relatively minor surgery; therefore, surgical and anaesthesia duration could have affected the degree of fluid retention, resulting in a weak correlation between surgical duration and changes in airway dimensions. However, a previous report showed no correlation between changes in airway dimensions during labour and the duration of labour or fluids administered during labour [3]. Our results show weak correlations between changes in airway dimensions and intraoperative fluid balance as well as surgical duration. Therefore, such changes in airway dimensions may not be explained simply by these parameters.

After confirming the presence of postoperative changes in airway dimensions, we conducted subgroup analyses focusing on preoperative obesity, prone positioning, and pneumoperitoneum. Although still a matter of debate, it has been suggested that difficult laryngoscopy and intubation are more common in obese patients than in patients of normal weight [21,22]. Obese patients usually require higher positive airway pressure during mechanical ventilation, which can change airway dimensions. Reintubation after extubation following general anaesthesia in obese patients can be more difficult than preoperatively. Although obesity *per se* may not be a substantial cause of difficult laryngoscopy [13,23], other associated factors such as large neck circumference or sleep apnoea syndrome are frequently observed in obese patients [13,24]. Therefore, it is possible that the degree of preoperative difficult laryngoscopy and intubation in a certain population of obese patients may substantially increase in severity immediately following general anaesthesia. However, obesity itself does not seem to effect postoperative changes in airway dimensions.

During laparoscopic surgery, lung and chest wall mechanical impedances increase with increasing abdominal pressure, resulting in increased intrathoracic pressure [25,26]. These changes induce an increase in central venous pressure, which may result in increasing intraocular pressure [26]. Therefore, postoperative changes in airway dimensions may be augmented during laparoscopic procedures. Moreover, the effects of pneumoperitoneum on respiratory system compliance have been reported to be modified by head-up or -down postures [27]. We expected that changes in airway dimensions in our gynaecological patients undergoing laparoscopy would be more affected because of the head-down posture. However, our results suggest that pneumoperitoneum does not seem to augment changes in airway dimensions.

It has been demonstrated that dynamic lung compliance is affected by patient positioning [27]. When a patient is placed in the prone position, the abdomen is compressed, and the internal organs push the diaphragm in a cephalad direction [28]. The increased venous system pressure in conjunction with the weight of the patient's trunk decreases the diameter of the chest wall, limits movement, and increases thoracic pressure. Thoracic pressure elevation further increases venous pressure by decreasing left ventricular compliance [29]. Severe postoperative macroglossia after posterior fossa surgery in the prone position with additional factors has been reported [30]. Although postoperative changes in airway dimensions may also be affected by patient positioning, we did not find any change with prone positioning. As mentioned, mechanical ventilation is not associated with increased extravascular fluid during general anaesthesia [19]. Obesity, pneumoperitoneum, and prone positioning strongly affect mechanical ventilation conditions, initially considered as primary factors associated with changes in airway dimensions due to oedema during surgery under general anaesthesia.

This study has certain limitations. First, this was not a completely blinded investigation and could, therefore, be affected by observer bias. However, it was not possible to blind this study for obvious reasons and, therefore, to decrease further bias, several measurements were performed using a blinded analytical approach after data collection. Secondly, it is possible that acoustic reflectometery can be affected by the degree of awareness because it is important to avoid nasal breathing, as the opening of the oropharyngeal space would increase the calculated volume; therefore, we may have underestimated it in the post-anaesthetic period. To address this, recording was only completed after patients fulfilled standardised criteria following extubation. Even with these criteria, it is still difficult to completely exclude any influence of residual anaesthesia. Thirdly, sample sizes were relatively small in the subgroup analyses. To determine factors affecting the airway during general anaesthesia, controlled prospective studies with larger populations should be undertaken in the future. Lastly, it was not confirmed whether observed changes in airway dimensions directly contributed to difficult laryngoscopy and intubation because it would have been unethical to perform such manoeuvres. However, it is not unreasonable to suppose that the decrease in intraoral space and increase in neck thickness could make airway management more difficult after general anaesthesia and surgery relative to the original status.

In conclusion, postoperative changes in airway dimensions were confirmed by a decrease in intraoral space and increase in neck thickness using acoustic reflection technology, ultrasound, and manual measurements. We were unable to clarify the specific mechanisms for this phenomenon; however, it is suggested that some of these changes may be influenced by surgical duration or perioperative fluid management, which can induce oedema. Therefore, it seems that oedema formation in the airway during general anaesthesia plays a pivotal role. It should be noted that the risk of difficult laryngoscopy and intubation can increase when airway management is required after extubation following general anaesthesia. This may particularly be the case in patients with pre-existing factors associated with a difficult airway.

Acknowledgement

The authors would like to thank Enago (www.enago.jp) for the English language review.

Competing interests

No external funding and no competing interests declared.

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Table 1. Patient characteristics.

Age (year)	54 (38-47 [18-86])
Height (cm)	158 (152-164 [140-187)
Weight (kg)	56 (50-64 [40-105])
Body mass index (kg.m^{-2})	22.6 (20.6-25.1 [15.5-38.4])
Surgical duration (min)	137 (105-188 [16-496])
Fluid input (ml)	1750 (1375-2425 [350-5150])
Urine output (ml)	258 (125-450 [0-1720])
Transfusion (ml)	0 (0-100 [0-1600])
Bleeding (ml)	30 (0-431 [0-2550])
Fluid balance (ml)	1370 (1024-1766 [0-2942])
Male/Female (n)	65/216
Supine/Lateral/Prone Position (n)	78/83/34
Laparoscopic surgery (n)	86

Values are median (IQR [range]) or number (proportion)

Table 2. Correlation analysis of change index of airway assessments with age, height, body mass index (BMI), surgical duration, and intraoperative fluid balance (n=281),

	Age	Height	BMI	Surgical duration	Fluid balance
Neck circumference					
Correlation coefficient	-0.03	-0.14	0.10	0.23	0.16
95%CI	-0.15 – 0.09	-0.26 – -0.03	-0.02 – 0.22	0.12 – 0.34	0.05 – 0.27
P value	0.5903	0.016	0.0902	0.0002	0.0062
Total airway volume					
Correlation coefficient	0.04	0.08	-0.04	-0.13	-0.17
95%CI	-0.08 – 0.16	-0.04 – 0.19	-0.16 – 0.07	-0.24 – -0.01	-0.28 – -0.06
P value	0.0.4938	0.2085	0.4493	0.0301	0.0038
Sternothyroid muscle diameter					
Correlation coefficient	-0.04	0.07	0.01	0.02	0.05
95%CI	-0.16 – -0.07	-0.05 – 0.18	-0.11 – 0.13	-0.10 – 0.13	-0.06 – -0.17
P value	0.425	0.2583	0.8695	0.7648	0.3765

Table 3. Comparisons of change indices (%) of airway assessments between the subgroups.

	Neck circumference	Sternothyroid muscle	Total airway volume
Obesity or not			
Obese (n=40)	3.0 (1.4 – 4.4[-7.9 – 11])	33 (14 – 55[-15 – 103])	-23 (-38 – -13[-80 – 18])
Non-obese (n=121)	3.2 (1.6 – 4.8[-5.1 – 8.6])	30 (19 – 45[-29 – 154])	-27 (-36 — -16[-85 – 44])
P value	0.4294	0.6670	0.3271
Prone position or not			
Prone (n=20)	3.8 (2.8 – 5.5[-4.1 – 9.5])	45 (21 – 68[7 – 133])	-21 (-36 — -7.6[-64 – 12])
Non-prone (n=121)	3.2 (1.6 – 4.8[-5.1 – 8.6])	30 (19 – 45[-29 – 154])	-27 (-36 — -16[-85 – 44])
P value	0.2349	0.0498	0.3123
Pneumoperitoneum or not			
Pneumoperitoneum (n=66)	3.7 (1.6 – 6.2[-4.3 – 10])	32 (20 – 52[-23 – 112])	-25 (-34 – -14[-63 – 13])
Non-pneumoperitoneum (n=121)	3.2 (1.6 – 4.8[-5.1 – 8.6])	30 (19 – 45[-29 – 154])	-27 (-36 — -16[-85 – 44])
P value	0.1973	0.5776	0.4718

Values are median (IQR [range]).

Table 4. Correlation analysis of change index of airway assessments with surgical duration, and intraoperative fluid balance after excluding obesity, prone position and laparoscopic surgery (n=121)

	Surgical duration	Fluid balance
Neck circumference		
Correlation coefficient	0.24	0.25
95%CI	0.07 – 0.40	0.08 – 0.41
P value	0.0078	0.0052
Total airway volume		
Correlation coefficient	-0.08	-0.16
95%CI	-0.25 – 0.10	-0.33 – 0.02
P value	0.3964	0.0828
Sternothyroid muscle diameter		
Correlation coefficient	-0.07	-0.05
95%CI	-0.25 – 0.11	-0.22 – 0.13
P value	0.4263	0.6222

Captions for Figures

Fig. 1. Acoustic Pharyngometer Eccovision^{TM} device

Fig. 2. Representative acoustic waveforms obtained by Acoustic Pharyngometer EccovisionTM in the pre- and post-anaesthetic periods in the supine position

The X-axis shows the distance from the incisor teeth. The Y-axis shows airway cross-sectional area. Airway space, particularly pharyngeal space, is usually smaller in the supine position than in the sitting position because of the influence of gravity on airway patency. Results reveal that the airway space was decreased in the post-anaesthetic period.

Pre, pre-anaesthetic waveform; Post, post-anaesthetic waveform; A, teeth; B, oropharyngeal junction; C, glottis; A–B, oral space; B–C, pharyngeal space

Fig. 3. Representative ultrasound echographic image of the sternothyroid muscle in the pre- and post-anaesthetic periods

The diameter of the sternothyroid muscle obtained 15 mm to the left and right of the central axis is measured. As shown, the sternothyroid muscle diameter increased in the post-anaesthetic period.

Fig. 4. Pre- and post-anaesthetic values for total airway, oral, and pharyngeal volumes and their change indices

The graphs demonstrate a significant decrease after anaesthesia in all parameters.

Horizontal line, median; box, IQR; whiskers, 10th and 90th percentiles.

Fig. 5. Pre- and post-anaesthetic values for neck circumference and sternothyroid muscle diameter and their change indices

As shown, these values significantly increased after anaesthesia.

Horizontal line, median; box, IQR; whiskers, 10th and 90th percentiles.

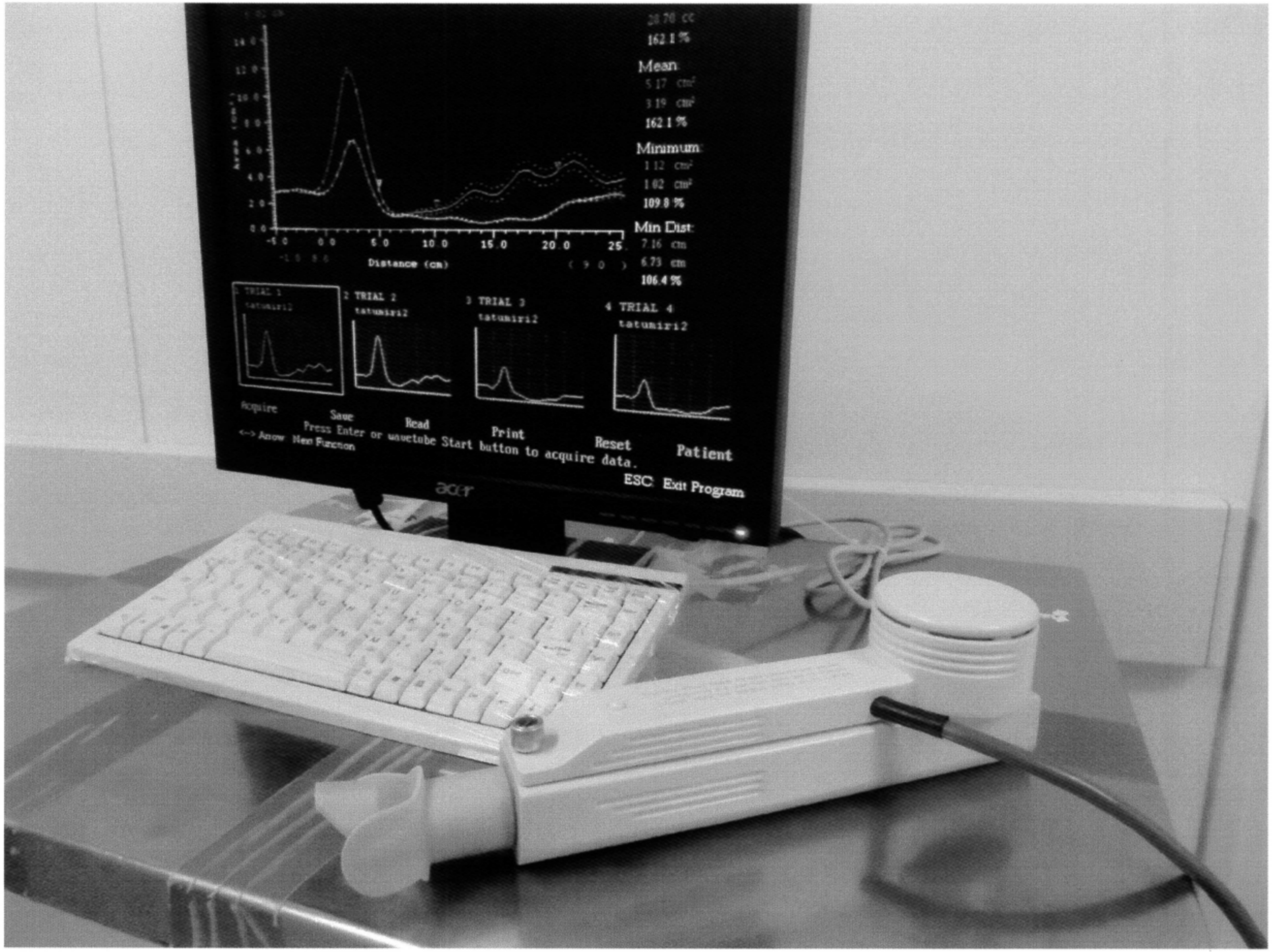

Mean
Minimum
Min Dist
Distance (cm)
2 TRIAL 2
3 TRIAL 3
4 TRIAL 4
Save
Read
Print
Reset
Patient
Press Enter or wavetube Start button to acquire data.
ESC: Exit Program

Figure 1

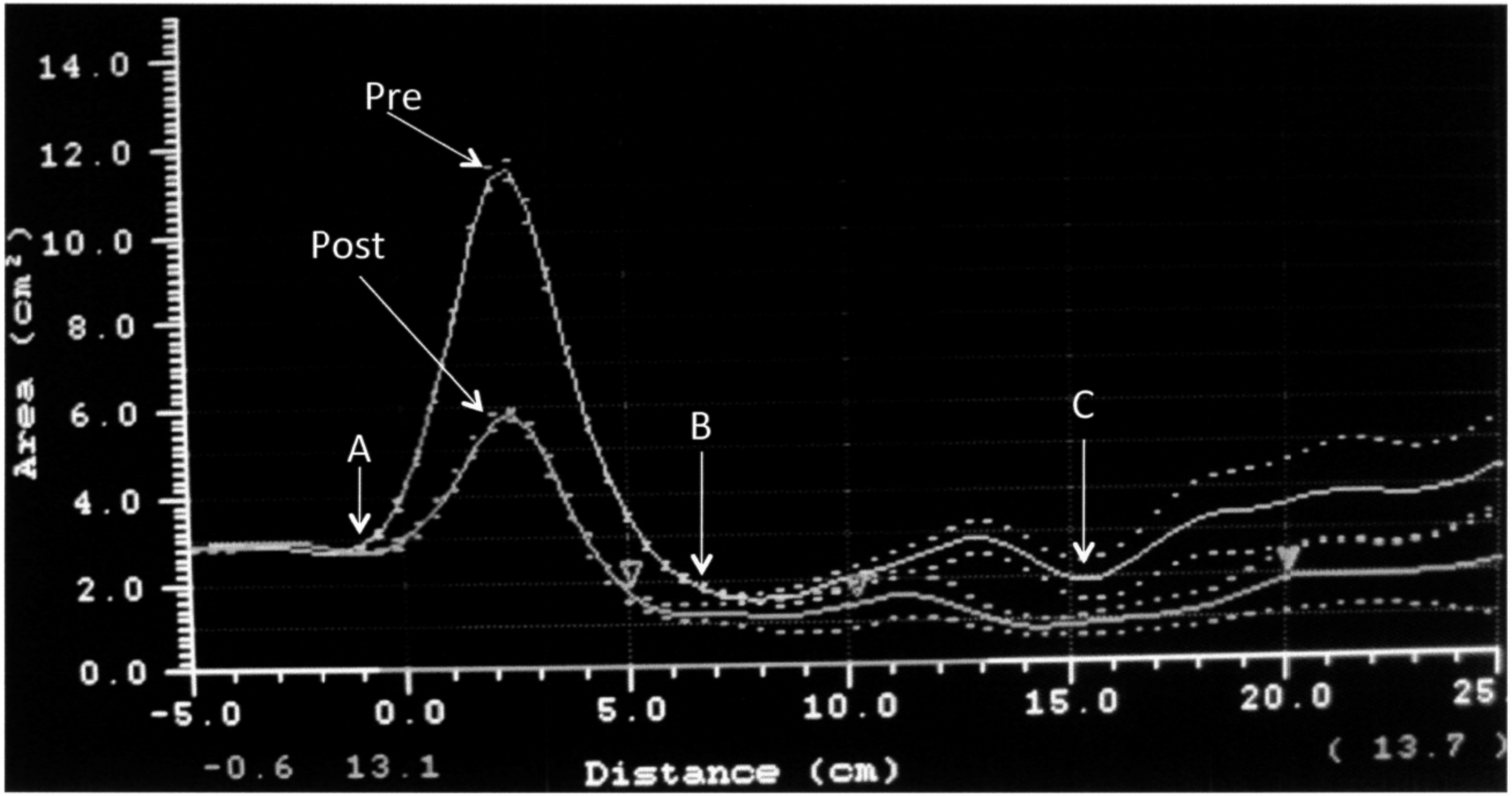

Pre
Post
A
B
C
Area (cm²)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-5.0
0.0
5.0
10.0
15.0
20.0
25
-0.6
13.1
Distance (cm)
(13.7)

Figure 2

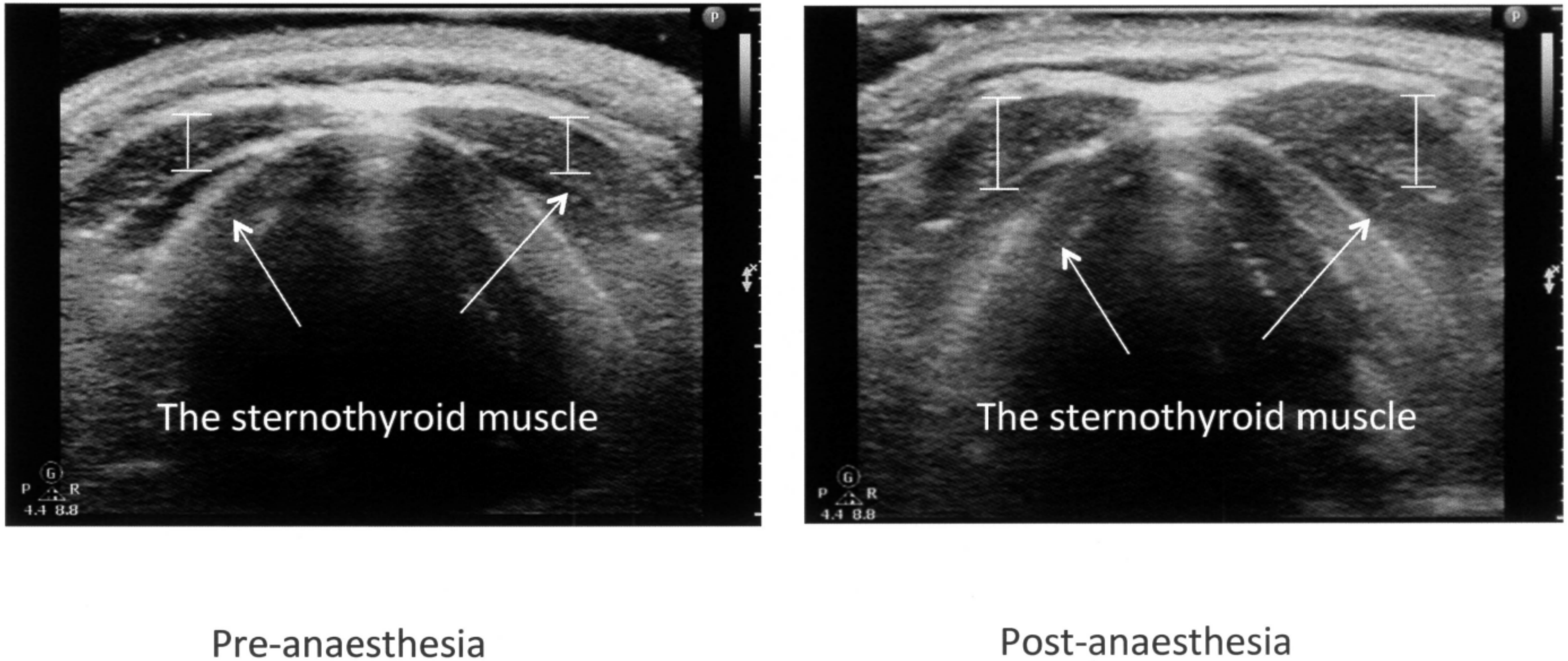

The sternothyroid muscle
P R
4.4 8.8
Pre-anaesthesia
The sternothyroid muscle
P R
4.4 8.8
Post-anaesthesia

Figure 3

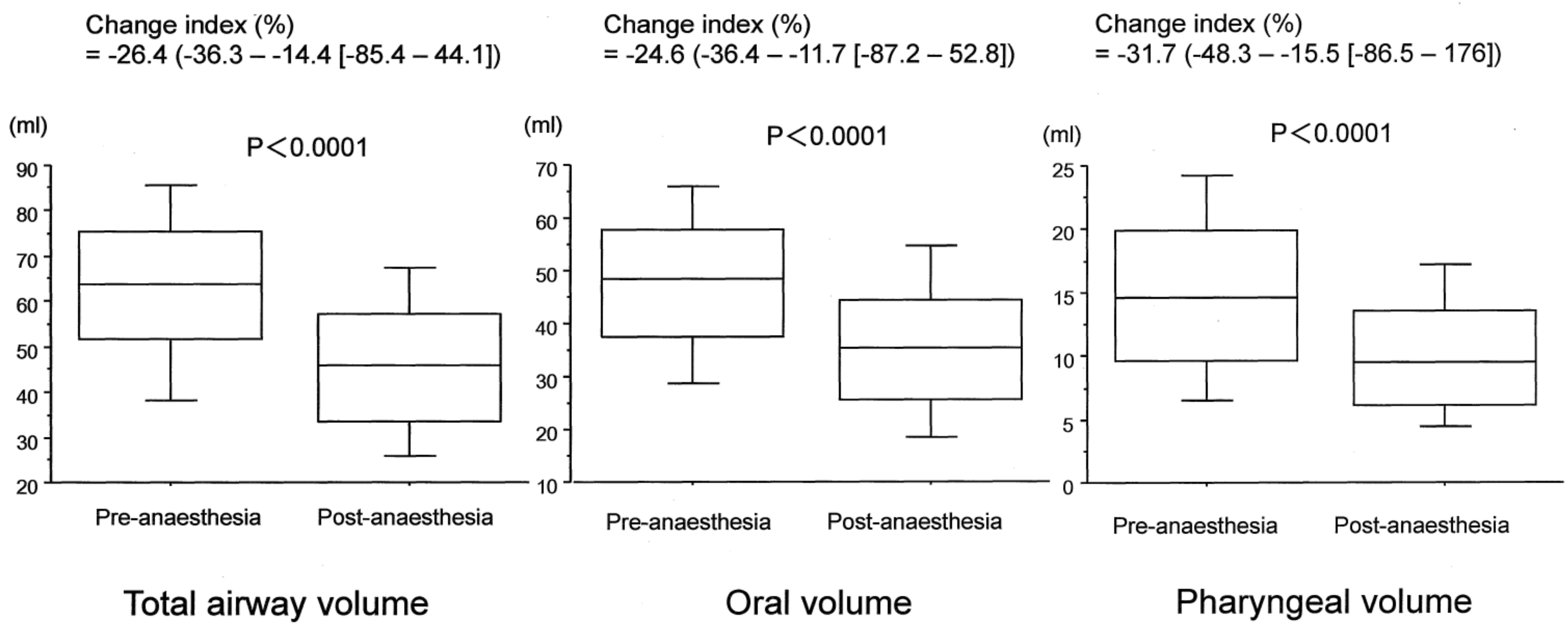
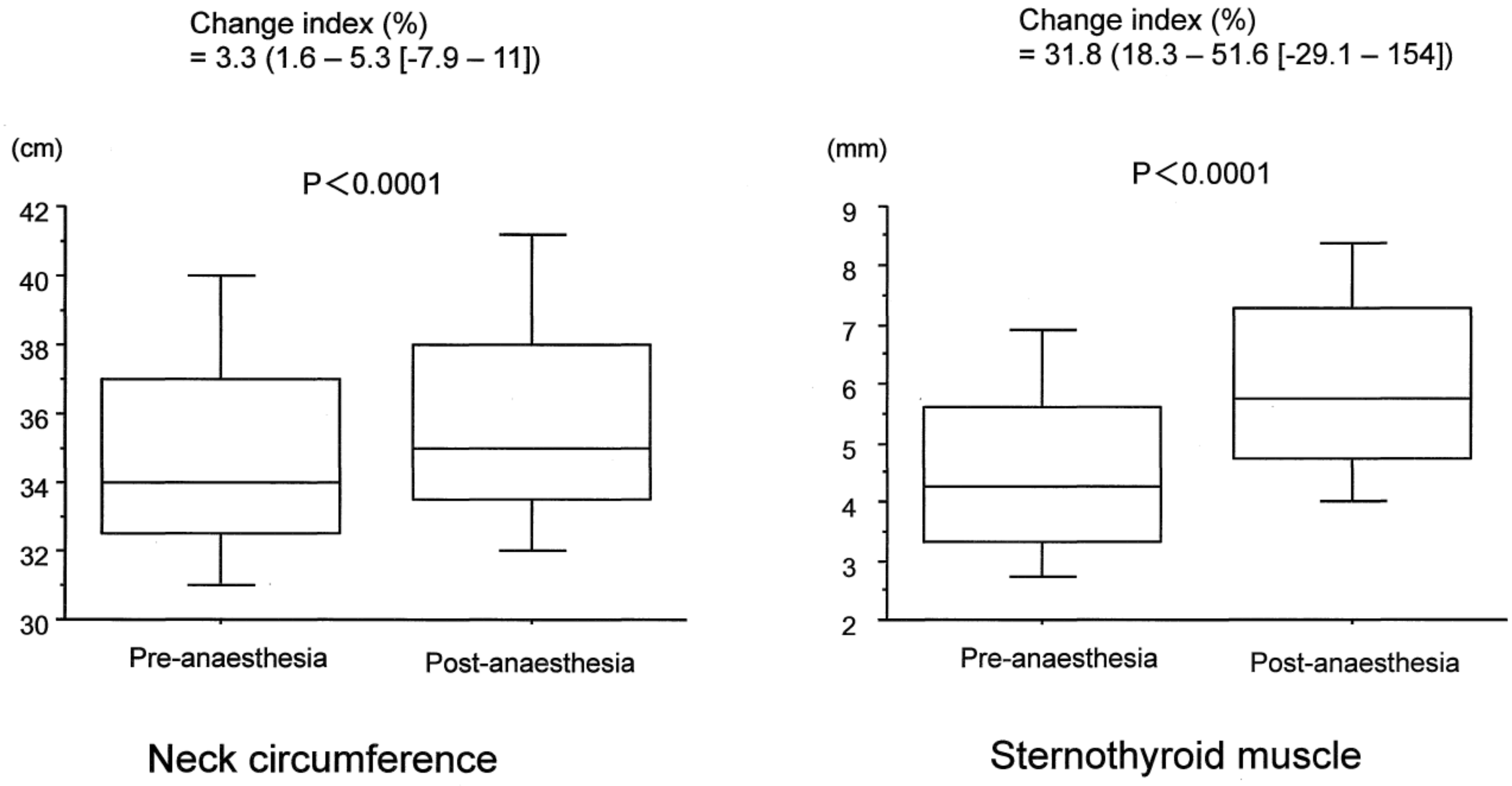

Change index (%)
= -26.4 (-36.3 – -14.4 [-85.4 – 44.1])
(ml)
P<0.0001
90
80
70
60
50
40
30
20
Pre-anaesthesia
Post-anaesthesia
Total airway volume
Change index (%)
= -24.6 (-36.4 – -11.7 [-87.2 – 52.8])
(ml)
P<0.0001
70
60
50
40
30
20
10
Pre-anaesthesia
Post-anaesthesia
Oral volume
Change index (%)
= -31.7 (-48.3 – -15.5 [-86.5 – 176])
(ml)
P<0.0001
25
20
15
10
5
0
Pre-anaesthesia
Post-anaesthesia
Pharyngeal volume

Figure 4



Change index (%)
= 3.3 (1.6 – 5.3 [-7.9 – 11])
(cm)
P<0.0001
42
40
38
36
34
32
30
Pre-anaesthesia
Post-anaesthesia
Neck circumference
Change index (%)
= 31.8 (18.3 – 51.6 [-29.1 – 154])
(mm)
P<0.0001
9
8
7
6
5
4
3
2
Pre-anaesthesia
Post-anaesthesia
Sternothyroid muscle

Figure 5