Original Article

A comparative study to evaluate the cervical spine movements during laryngoscopy using Macintosh and Airtraq laryngoscopes

Kiranpreet Kaur, Rameez Raja, Prashant Kumar, Roop Singh[1], Sumedha Vashishth, Harshil D. Singh[2], Mamta Bhardwaj, Suresh K. Singhal

Departments of Anaesthesiology and Critical Care, [1]Orthopaedics, Pt. B.D. Sharma PGIMS, Rohtak, Haryana, [2]Department of Computer Science, IIIT UNA, Himachal Pradesh, India

Abstract

Background and Aim: Intubation with Macintosh requires flexing the lower cervical spine and extending the atlanto-occipital joint to create a "line of sight." Primary aim of study was to compare the extent of cervical spine movement during laryngoscopy using conventional Macintosh laryngoscope and Airtraq.

Material and Methods: A total of 25 patients of either sex between the age group of 18 and 60 years, having American Society of Anesthesiologists (ASA) physical status of Grade-I and Grade-II, scheduled for elective surgery under image control requiring general anesthesia and intubation were enrolled. A baseline image of the lateral cervical spine including the first four cervical vertebrae was taken by an image intensifier. After administration of general anesthesia, laryngoscopy was first performed using a Macintosh laryngoscope and a second X-ray image of the lateral cervical spine was taken. The second laryngoscopy using a Airtraq laryngoscope was done and the third image of the lateral cervical spine was taken. Angles between occiput and $C_{1;}$ C_1 and $C_{2;}$ C_2 and $C_{3;}$ C_3 and $C_{4;}$ and occiput and C_4 were calculated. Atlanto-occipital distance (AOD) was calculated as the distance between occiput and C_1.

Results: Macintosh showed greater cervical movement as compared with Airtraq but a significant difference in the movement was observed at C_2–C_3 and C_0–C_4. Baseline mean AOD was 2.21 ± 1.25 mm, after Macintosh and Airtraq laryngoscopy was found to be 1.13 ± 0.60 and 1.6 ± 0.78 mm, respectively, and was found to be significant ($P < 0.05$).

Conclusion: We conclude that Airtraq allows intubation with less movement of the upper cervical spine makes Airtraq preferred equipment for intubation in patients with a potential cervical spine injury.

Keywords: Cervical vertebrae, general anesthesia, intubation, laryngoscope, laryngoscopy, spine

Introduction

Direct laryngoscopy (DL) is the most commonly employed means of facilitating tracheal intubation.[1,2] For optimal visualization of the glottis, some degree of movement of the cervical spine is required. The sniffing position is considered the standard head position for optimal glottic exposure during DL. This position provides alignment of the oral, pharyngeal, and laryngeal axes in a straight line of vision from the mouth to the vocal cords for intubation. Sniffing position requires the lower cervical spine to be flexed, the upper cervical spine and atlanto-occipital joint to be extended. The proper position involves 35° flexion of the neck on the torso and head extended

Address for correspondence: Dr. Sumedha Vashishth,
Assistant Professor, Department of Anaesthesiology, Pt.B.D. Sharma PGIMS, Rohtak - 124 001, Haryana, India.
E-mail: summivashishth@gmail.com

Access this article online

Quick Response Code:

Website: https://journals.lww.com/joacp

DOI: 10.4103/joacp.joacp_89_22

How to cite this article: Kaur K, Raja R, Kumar P, Singh R, Vashishth S, Singh HD, *et al*. A comparative study to evaluate the cervical spine movements during laryngoscopy using Macintosh and Airtraq laryngoscopes. J Anaesthesiol Clin Pharmacol 2024;40:101-7.

Submitted: 08-Mar-2022 **Revised:** 29-May-2022
Accepted: 03-Jul-2022 **Published:** 29-Jul-2023

at the atlanto-occipital joint to produce a 15° angle between the facial plane and the horizontal plane.[3]

There is a cervical spine extension during direct laryngoscopy, which is most evident at the atlanto-axial and the occipito-atlantal joints. First, most extension created by DL occurs at the OAA complex and the subaxial cervical segments are only minimally displaced. Second, OAA extension enhances the mouth opening ability. Finally, the alignment of the pharyngeal axis with the axis of the mouth is the main factor for improving laryngoscopic view, and depends entirely on the degree of the OAA extension. Thus, greater OAA extension can produce a good laryngeal view during laryngoscopy.[4]

Direct laryngoscopy with Macintosh laryngoscope remains the most popular device to facilitate orotracheal intubation in the majority of patients. The cervical spine movement is greatest with Macintosh laryngoscope.[5] Use of Macintosh blade is not of much use in patients, who require cervical spine immobilization as in patients with cervical trauma. Excessive spine movement with laryngoscopy may be dangerous in patients because of the possibility of causing new neurological deficits.[6] Direct laryngoscopy using a conventional blade may be difficult if spine movement is limited because of arthritis, disk disease, other spine abnormalities, or a small gap between the occiput and the spinous process of the atlas. Alternative airway management techniques may be employed in situations where cervical spine movement is limited. But with the development of specialized videolaryngoscopes, scenarios have changed.[7]

The Airtraq optical laryngoscope is a new rigid laryngoscope designed to facilitate tracheal intubation in patients with both normal and difficult airways.[8] Airtraq has an exaggerated blade curvature, an internal arrangement of optical lenses, and a mechanism to prevent fogging of the distal lens. A high-quality view of the glottis is provided without the need to align the oral, pharyngeal, and tracheal axes. This configuration enables intubation with reduced cervical spine movement. For this reason, in patients with cervical spine immobilization, the Airtraq has been observed to have advantages compared with the Macintosh laryngoscope and proved to have a beneficial role in patients with cervical spine injury. The Airtraq provides a "non-line-of-sight" view of glottis.[7,9] We did a study with a null hypothesis that there is no difference in required cervical spine movements for intubation using Macintosh laryngoscope and Airtraq. The primary aim of the study was to compare the extent of cervical spine movement during laryngoscopy using the conventional Macintosh laryngoscope and Airtraq. The secondary aim was to assess complications between the two laryngoscopy methods, if any,

Material and Methods

The prospective longitudinal crossover study received ethical approval (IEC/Th/19/Anst02) from Institutional Ethical Committee Pt B D S, PGIMS UHS, Rohtak, Haryana, India on December 19, 2018 and registration with the trial registry (CTRI/2020/05/024961). Informed consent from all the participants was obtained. The study was done in accordance with the Ethical Principles for Medical Research Involving Human Subjects, outlined in the Helsinki Declaration of 1975 (revised 2013). A total of 25 adult patients of either sex between the age group of 18 and 60 years, having a physical status of Grade-I and Grade-II according to the American Society of Anesthesiologists, scheduled for elective surgery under image control requiring general anesthesia and intubation were enrolled in the study. Cervical spine injury, rheumatoid arthritis, scoliosis/spinal deformity, anticipated difficult intubation, aspiration risk, pregnancy, BMI $>30\ k \cdot gm^{-2}$ were excluded from the study.

All patients were examined preoperatively and all required investigations were carried out. In the operating room, standard monitoring consisting of electrocardiogram (ECG), pulse oximetry SPO_2, and noninvasive arterial blood pressure was established. Baseline readings of all parameters were recorded. Baseline image of a lateral view of the cervical spine including the first four cervical vertebrae was taken by an image intensifier.

All the patients received general anesthesia with thiopentone 5 $mg{\cdot}kg^{-1}$, fentanyl 2 $\mu g{\cdot}kg^{-1}$ and vecuronium bromide 0.1 $mg{\cdot}kg^{-1}$ intravenously. Intermittent positive pressure ventilation was done for 3 min. Sheet of 4 cm height was placed underneath the occiput. Laryngoscopy was first performed in the sniffing position using a Macintosh laryngoscope and a second X-ray image of the lateral cervical spine was taken. Patients were ventilated again for another four to five breaths with 100% oxygen using a bag and mask. A second laryngoscopy using a Airtraq laryngoscope was done and a third image of the lateral cervical spine was taken. Images during both the laryngoscopies were taken only after obtaining best laryngoscopic view. All the patients were intubated after the second laryngoscopy with an appropriate size tracheal tube to secure the airway. Anesthesia was continued with sevoflurane in MAC value of 1 and nitrous oxide and oxygen in the ratio of 50:50.

Analysis of radiological images: Reference lines were drawn [Figures 1-3].

C_0 (McGregor line): The reference of the occiput—defined as line drawn between posterior margin of hard

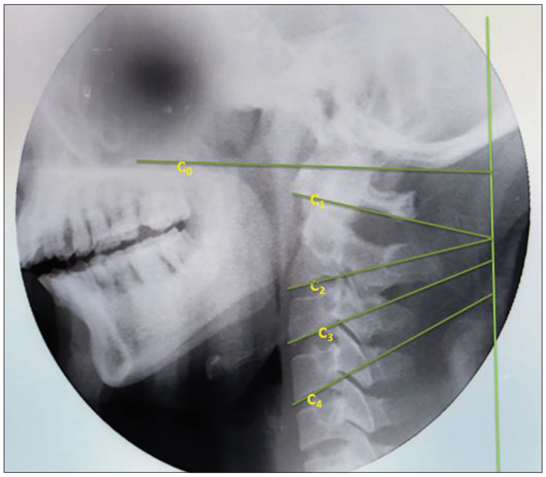

Figure 1: Tangents for measuring angle of cervical spine

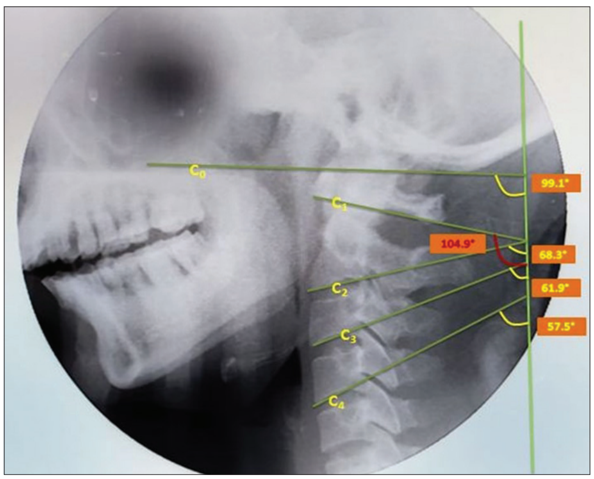

Figure 2: Baseline tangents and its angle measurement

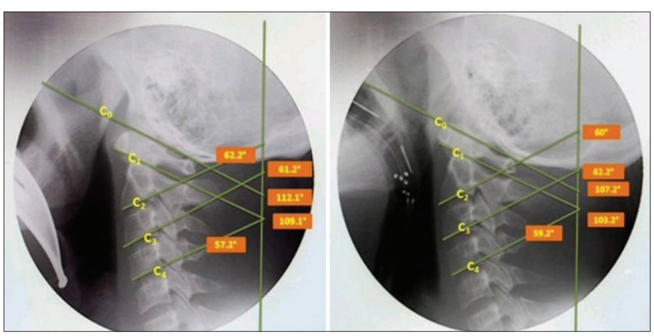

Figure 3: Tangents and angle calculation after Macintosh laryngoscopy (left) and Airtraq laryngoscopy (right)

palate and opisthion. **C_1 reference:** The line between the anterior and posterior arches of the atlas. **C_2 reference:** It is a tangent through the anterior and posterior basal plates of the C_2 vertebral body. **C3 reference:** Tangent through anterior and posterior basal plates of C_3 vertebral body. C_4 reference: Tangent through anterior and posterior basal plates of C_4 vertebral body. C0, C1, C2, C3, and C4 angles were measured with respect to common reference lines using the software. The angles between the adjacent levels were calculated based on the difference between the angles. Angle between occiput and C_1 (C_0–C_1); angle between C1 and C2 (C1–C2); angle between C2 and C3 (C2–C3); angle between C3 and C4 (C3–C4); and angle between occiput and C_4 (C_0–C_4) were calculated. Positive angles denote neck extension and negative angle denote neck flexion. Atlanto-occipital distance (AOD) was calculated in mm as the distance between the occiput and C_1 [Figure 4].

Anterior deviation of spine following the use of Macintosh and Airtraq was calculated in millimeters using radiological images. To calculate the anterior deviation tangents were drawn from C_1 to C_4 [Figure 4]. LC1: length of vertical line drawn from the common line to the edge of the anterior arch of atlas. LC2: length of vertical line drawn from the common line to the anterior and superior edge of vertebral body at C2 level. LC3: length of vertical line drawn from the common line to the anterior and superior edge of vertebral body at C_3 level. LC4: length of vertical line drawn from the common line to the anterior and superior edge of vertebral body at C_4 level. Finally, anterior deviation with both the laryngoscopies was calculated using the formula:

Anterior deviation = (Length of tangents from common reference line during laryngoscopy) – (length of tangents at baseline).

Statistical test

Sample size

A previous study using a similar protocol indicated that the mean cervical spine movement with Macintosh was 7.2° with an SD of 5.8° at C_0–C_1.[10] Considering that there was a minimum difference of 20% in mean cervical spine movement change between the two techniques, thus 18 observations per technique provided 90% power at an α level of 0.05. Considering some drop rate in the subjects, 25 patients were included during the study period.

Statistical testing was conducted with the Statistical Package for the Social Sciences (SPSS) 17.0. Continuous variables will be presented as means ± SD or median if the data is unevenly distributed. Categorical variables were expressed as frequencies and percentages. The comparison of continuous variables between the groups was performed using Student's *t* test. Nominal categorical data between the groups were compared using Chi-squared test or Fisher's exact test as appropriate. Non-normal distribution continuous variables were compared using Mann–Whitney *U* test. For all statistical tests, a *P* value less than 0.05 was taken to indicate a significant difference

Results

The mean age of the patients enrolled in the study was 31.32 ± 10.37 years. The majority of patients (44%) were in the age group of 21–30 years. In the study, 19 (76%) patients were males and six (24%) patients were females. The mean weight and height of the patients was 68.52 ± 9.29 kg and 171.36 ± 2.94, respectively. Mean BMI was found to be 21.87 ± 2.53 kg · m^{-2}.

Analysis of radiographs

Table 1 shows the mean of angle measured from C_0 to C_4. *P* values were found to be significant for C_0 and C_1 when baseline X-ray was compared with X-ray with Macintosh and Airtraq. The difference in the angles, i.e. (C_0– C_1; C_1– C_2; C_2– C_3; C_3– C_4; C_0– C_4) is shown in Table 2. At C_2– C_3 and C_0– C_4, significant differences in movement were found when Macintosh was compared with Airtraq. Baseline mean AOD was 2.21 ± 1.25 mm, after Macintosh and Airtraq laryngoscopy it was found to be 1.13 ± 0.60 and 1.6 ± 0.78 mm, respectively [Figure 5], this decrease was found to be significant ($P < 0.05$).

The anterior deviation caused by both the laryngoscopes was calculated from C_1 to C_4 and is depicted in Figure 6. Macintosh results in more anterior deviation compared with Airtraq. When anterior deviation caused by both the laryngoscopes was statistically compared, this difference was found to be statistically highly significant from C_1 to C_4 ($P < 0.001$).

Discussion

During direct laryngoscopy using Macintosh laryngoscope, force applied by the blade causes movement of the cervical spine to align the oral, pharyngeal, and laryngeal axes.[11,12] Videolaryngoscopes like Airtraq provide indirect exposure, magnified and high-resolution images of the airway through a nonlinear view, and less movement of the cervical spine.[5] The Airtraq has been reported to have advantages over Macintosh in limiting the cervical spine movement as demonstrated by previous studies. Hence, the present study was conducted to compare the cervical spine movement caused by Macintosh and Airtraq laryngoscopes.

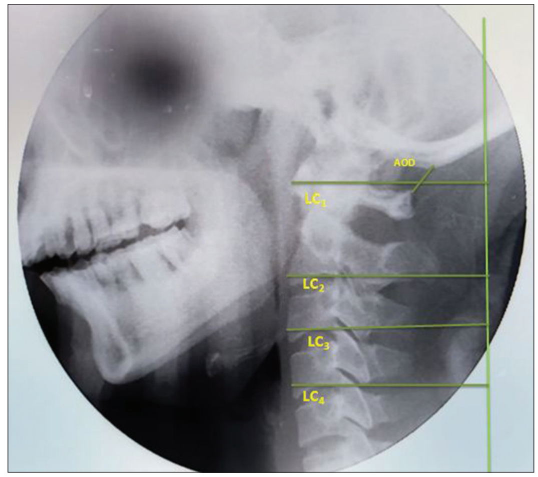

Figure 4: Atlanto-occipital distance and tangents for anterior deviation

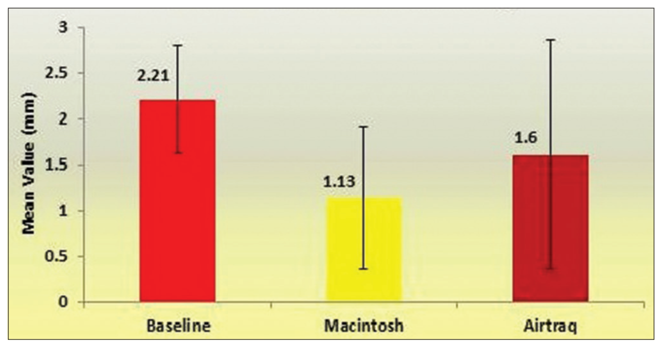

Figure 5: Comparison of Atlanto-occipital distance between Macintosh and Airtraq

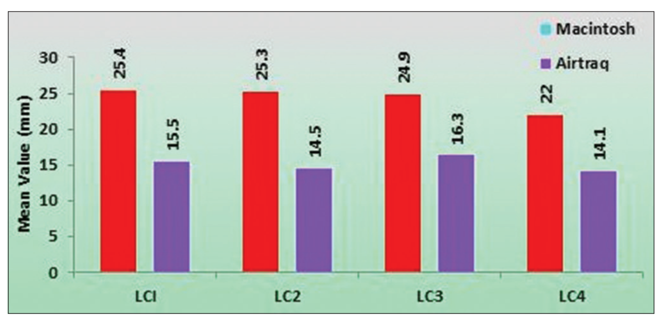

Figure 6: Comparison of anterior deviation between Macintosh and Airtraq

Table 1: Angle measurement from C0 to C4

Angle Measurement (°)	Mean±SD			*P*	M V/s C	A V/s C	M V/s A
	Baseline (C)	Macintosh (M)	Airtraq (A)				
C_0	95.3±7.45	118.35±5.8	112.27±4.1	<0.001*	<0.001*	<0.001*	0.002*
C_1	102.03±6.6	113.59±6.1	108.04±3.9	<0.001*	<0.001*	0.001*	0.003*
C_2	74.32±7.49	74.31±11.06	70.43±7.39	0.205	1.000	0.269	0.272
C_3	71.02±8.12	69.28±10.54	70.01±8.18	0.792	0.776	0.917	0.957
C_4	72.36±8.54	68.72±11.39	69.85±9.72	0.419	0.402	0.647	0.914

**P*<0.05

Table 2: Difference between the adjacent angles

Angle difference (degree)	Mean±SD			P	M V/s C	A V/s C	M V/s A
	Baseline (C)	Macintosh (M)	Airtraq (A)				
$(C_0–C_1)$	−6.728±4.43	4.76±3.30	4.228±2.05	<0.001*	<0.001*	<0.001*	0.845
$(C_1–C_2)$	27.71±10.08	39.28±8.29	37.61±7.94	<0.001*	<0.001*	<0.001*	0.782
$(C_2–C_3)$	3.303±2.2	5.024±3.99	0.424±3.02	<0.001*	0.139	0.005*	<0.001*
$(C_3–C_4)$	−1.344±4.77	0.568±3.27	0.156±5.99	0.339	0.343	0.515	0.951
$(C_0–C_4)$	22.94±9.17	49.63±9.95	42.42±10.8	<0.001*	<0.001*	<0.001*	0.035*

*$P<0.05$

Angle measurement was done in the present study, after drawing tangents at different levels from Occiput to C_4, with respect to the common reference line [Figure 1]. The mean angle measured in the current study was less following Airtraq (C_0 = 112.27°; C_1 = 108.04°; C_2 = 70.43° C3 = 70.01°) as compared with Macintosh laryngoscopy (C_0 = 118.35°; C_1 = 113.59°; C_2 = 74.31°, C3 = 69.28°), and was found to be significant at C_0 (P < 0.002) and C_1 (P < 0.003). (Angle calculation is shown in Figure 2, which is illustration of one of the patient).

The difference in the angles ($C_0–C_1$; $C_1–C_2$; $C_2–C_3$; $C_3–C_4$; and $C_0–C_4$) was further calculated. The negative value shows flexion and the positive value depicts extension. The current study demonstrated radiographically that laryngoscopy using the Airtraq involves less movement of the cervical spine as compared with conventional Macintosh laryngoscopy at all cervical levels from C_1 to C_4, but a significant difference in the movement was observed at $C_2–C_3$ (5.024°–Macintosh; 0.424°– Airtraq; P < 0.001), and $C_0–C_4$ (49.63 ± 9.95°–Macintosh; 42.42 ± 10.8°–Airtraq; P < 0.0035), whereas the nonsignificant difference was observed at $C_0–C_1$, $C_1–C_2$, and $C_3–C_4$ levels.

Hirabayashi *et al.*[5] found a significant decrease in the cervical spine movement at $C_3–C_4$ and $C_0–C_4$. Their observations were similar to the present study, except for significant reduction extension at $C_3–C_4$. Turkstra *et al.*[13] observed a significant reduction in the cervical spine movements with the Airtraq at $C_0–C_1$ (12 ± 6°– Macintosh; 6 ± 5°–Airtraq) and $C_2–C_3$ segment (4 ± 5° –Macintosh; 1 ± 4°– Airtraq). Significant cervical extension between the occiput and C_4 ($C_0–C_4$) and $C_2–C_3$ was observed in current study. Hirabayashi *et al.*[12] on comparing Airway scope with Macintosh found more significant extension at $C_0–C_1$, $C_1–C_2$, and, $C_3–C_4$ motion segments (P < 0.05). They concluded that the airway scope required less extension at the cranial end of the cervical spine.

Contrasting results as compared with the current study were observed by Erden *et al.*[9] with no statistically significant difference in the cervical spine movement during intubation using Airtraq and direct laryngoscopy. In comparison with the current study, Bhardwaj *et al.*[10] observed that cervical spine movement is significantly reduced at $C_0–C_1$ and $C_1–C_2$ levels when videolaryngoscope (Truview) was compared with Macintosh laryngoscope. They observed that the Truview laryngoscope produced less extension of the cervical spine at $C_0–C_1$ and at $C_1–C_2$.

All the investigators and the present study concluded that videolaryngoscope involves less movement at the upper cervical spine. Exaggerated movement carries the potential risk of increasing neurological damage during intubation.[10,12-14] Uzun *et al.*[15] and Panjabi *et al.*[16] defined the instability limits as rotation of >20° in the sagittal plane. If movement exceeds this limit of physiological motion, spinal instability is likely to occur. Therefore, the reduction in movement at $C_0–C_1$ and $C_1–C_2$ is clinically important. While using Airtraq laryngoscope, epiglottic lifting with the tip of the blade is hardly required. Moreover, minimal upward traction is required to provide an excellent view of the glottic opening, without aligning the oral, pharyngeal, and laryngeal axis as compared with conventional Macintosh laryngoscopy, thus resulting in limited head manipulation.[9,12]

The distance between the occiput and C_1 (AOD) was measured. AOD was significantly less (P < 0.05) with Macintosh (1.13 ± 0.60 mm), when compared both with Airtraq laryngoscope (1.6 ± 0.78 mm) and baseline (2.21 ± 1.25 mm). Similar reduction in AOD was observed by Hirabayashi (Baseline 12.5 mm, Airtraq 9.4 mm, and Macintosh 7.8 mm) and Bhardwaj *et al.* (Baseline 6.4 ± 3.3 mm, Truview 3.8 ± 1.9 mm, and Macintosh 2.6 ± 1.6 mm). AOD was reduced in both Airtraq and Macintosh laryngoscopies but more reduction was observed in Macintosh.[4,10] The sniffing position traditionally used for tracheal intubation involves near full extension of atlanto-occipital joints, resulting in further reduction in the space. Airtraq, to some extent, helps in resolving this problem of reduction of AOD by limiting extension.

The anterior deviation of the cervical spine using Macintosh and Airtraq was studied in the present study. The deviation during tracheal intubation was less with Airtraq when compared with Macintosh laryngoscope. The mean anterior deviation with Macintosh was 25.4 ± 5.2, 25.3 ± 5.4, 24.9 ± 5.1, and 22.0 ± 5.6 mm at C_1, C_2, C_3, and C_4 levels, respectively, whereas deviation ranged between 14 and 16 mm after use of Airtraq laryngoscope ($P < 0.001$). A comparable pattern in anterior deviation was observed by Hirabayashi *et al*.[5] (Macintosh-39, 42, 43, and, 42 mm at C_1, C_2, C_3, and C_4 levels, respectively; Airtraq-26, 28, 27, and 25 mm deviation at C_1, C_2, C_3, and C_4 levels, respectively). The reduced anterior deviation signifies that when patients were intubated with Airtraq, they were subjected to less force during the procedure and the smaller ventral lifting force cause less pressure on cervical vertebrae. Thus, intubation with the Airtraq seems more suitable than the Macintosh laryngoscopy, especially in those patients in whom the neck extension is to be avoided.

Conclusion

We conclude that Airtraq allows intubation with less movement of the upper cervical spine, especially at C_2-C_3 and C_0-C_4 levels. Simultaneously result in less decrease in AOD and minimal anterior deviation of the spine. These reduced movements during laryngoscopy; makes Airtraq preferred equipment for intubation in patients with a potential cervical spine injury or patients with cervical instability and may be beneficial to reducing cervical spine movements.

Limitations

1. Person doing the intubation could not be blinded to the type of laryngoscope.
2. We studied only healthy adult patients undergoing elective procedures, which did not represent the cervical spine injury.
3. This study was carried out by experienced users, and results may differ in hands of less experienced users.
4. Airtraq is a disposable product that can be used in a limited number of patients and can increase hospital cost.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Author's contributions

Study planning, data collection, interpretation of results, and initial writing of the manuscript -Author 2 (initials). Study planning, data collection, interpretation of results, data analysis, and final writing of the manuscript - Author 3 (initials). Conception of the original project, study planning, interpretation of results, and final writing and approval of the manuscript.

1. K.K.: Study planning, data collection, interpretation of results, and initial writing of the manuscript
2. R.R.: Data collection and initial writing of the manuscript
3. P.K.: Conception of the original project and study planning
4. R.S.: Data collection and interpretation of results
5. S.V.: Data analysis and final writing of the manuscript.
6. H.D.S.: Data collection and interpretation of results
7. M.B.: Data analysis and final writing of the manuscript.
8. S.K.S.: Final writing and approval of the manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Schälte G, Scheid U, Rex S, Coburn M, Fiedler B, Rossaint R, *et al*. The use of the Airtraq® optical laryngoscope for routine tracheal intubation in high-risk cardio-surgical patients. BMC Res Notes 2011;4:1-7. doi: 10.1186/1756-0500-4-425.
2. Sawin PD, Todd MM, Traynelis VC, Farrell SB, Nader A, Sato Y, *et al*. Cervical spine motion with direct laryngoscopy and orotracheal intubation: An *in vivo* cinefluoroscopic study of subjects without cervical abnormality. J Am Soc Anesthesiol 1996;85:26-36.
3. Takenaka I, Aoyama K, Iwagaki T, Ishimura H, Kadoya T. The sniffing position provides greater occipitoatlanto-axial angulation than simple head extension: A radiological study. Can J Anesth 2007;54:129-33.
4. Saracoglu KT, Eti Z, Gogus FY. Airtraq optical laryngoscope: Advantages and disadvantages. Middle East J Anaesthesiol 2013;22:135-41.
5. Hirabayashi Y, Fujita A, Seo N, Sugimoto H. A comparison of cervical spine movement during laryngoscopy using the Airtraq® or Macintosh laryngoscopes. Anaesthesia 2008;63:635-40.
6. MacIntyre PA, McLeod AD, Hurley R, Peacock C. Cervical spine movements during laryngoscopyComparison of the Macintosh and McCoy laryngoscope blades. Anaesthesia 1999;54:413-8.
7. Hastings RH, Vigil AC, Hanna R, Yang BY, Sartoris DJ. Cervical spine movement during laryngoscopy with the Bullard, Macintosh, and Miller laryngoscopes. J Am Soc Anesthesiol 1995;82:859-69.
8. Bhandari G, Shahi KS, Asad M, Bhakuni R. Airtraq® versus Macintosh laryngoscope: A comparative study in tracheal intubation. Anesth Essays Res 2013;7:232-6.
9. Erden IA, Pamuk AG, UZUN Ş, Geyik S, Cekirge S, Aypar U. Cervical spine movement during intubation using the Airtraq® and direct laryngoscopy. Turk J Med Sci 2010;40:299-304.
10. Bhardwaj N, Jain K, Rao M, Mandal AK. Assessment of cervical spine movement during laryngoscopy with Macintosh and Truview laryngoscopes. J Anaesthesiol Clin Pharmacol 2013;29:308-12.
11. LeGrand SA, Hindman BJ, Dexter F, Weeks JB, Todd MM. Craniocervical motion during direct laryngoscopy and orotracheal intubation with the macintosh and miller blades: An *in vivo* cinefluoroscopic study. J Am Soc Anesthesiol 2007;107:884-91.

12. Hirabayashi Y, Fujita A, Seo N, Sugimoto H. Cervical spine movement during laryngoscopy using the Airway Scope compared with the Macintosh laryngoscope. Anaesthesia 2007;62:1050-5.
13. Turkstra TP, Pelz DM, Jones PM. Cervical spine motion: A fluoroscopic comparison of the AirTraq laryngoscope versusthe macintosh laryngoscope. J Am Soc Anesthesiol 2009;111:97-101.
14. Hindman BJ, Santoni BG, Puttlitz CM, From RP, Todd MM. Laryngoscope force and cervical spine motion during intubation with Macintosh and Airtraq laryngoscopes. Surv Anesthesiol 2015;59:71-2.
15. Uzun S, Erden IA, Pamuk AG, Yavuz K, Cekirge S, Aypar Ü. Comparison of Flexiblade™ and Macintosh laryngoscopes: Cervical extension angles during orotracheal intubation. Anaesthesia 2010;65:692-6.
16. Panjabi MM, Thibodeau LL, Crisco JJ 3rd, White AA 3rd. What constitutes spinal instability? Clin Neurosurg 1988;34:313-39.