Comparison of polyvinyl chloride, curved reinforced, and straight reinforced endotracheal tubes for tracheal intubation through Airtraq™ laryngoscope in anesthetized patients

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Abstract

Background and Aims: The Airtraq™ video laryngoscope facilitates tracheal intubations in patients with difficult airway or cervical spine immobilization. However, curved reinforced tracheal tube and straight reinforced tracheal tubes are useful where neck of the patient is likely to be moved or flexed or if patient is in prone position, wherein nonreinforced endotracheal tube (ETT) might get kinked and/or compressed. We compared intubation success rate of curved and straight reinforced tracheal tubes with polyvinyl chloride (PVC) tracheal tube using Airtraq™ laryngoscope in paralyzed and anesthetized patients.

Material and Methods: Totally, 120 patients underwent random allocation to one of the three groups using computer-generated randomization table. Patients were intubated with appropriate size and type of ETT using Airtraq™ after obtaining optimal glottis view. Experienced anesthesiologist performed endotracheal intubation and unblinded observer noted down success and ease of intubation.

Results: Patients intubated with PVC tube (100%) had higher rates of successful intubation and shorter intubation time (4 s), in comparison to intubation with curved reinforced (92.5%) and straight reinforced tubes (SRTs) (85%) using Airtraq™ laryngoscope (AL). However, there was no statistical difference in the incidence of airway trauma among all the three groups.

Conclusions: PVC tracheal tube is significantly superior to both curved and SRTs for intubation using AL.

Keywords: Airtraq™ laryngoscope, airway management, intubation

Introduction

The Airtraq™ (Prodol Ltd., Vizcaya, Spain) is an indirect video laryngoscope facilitates tracheal intubations in patients with normal and difficult airways.[1-3] It provides glottis view without the need for alignment of oral, pharyngeal, and laryngeal axes. This is due to the exaggerated curvature of the blade and series of lenses, prisms, and mirrors that transfer the image from illuminated tip to proximal viewfinder.[1]

The Airtraq™ laryngoscope (AL) is a better alternative to conventional Macintosh laryngoscope for routine airway management and in difficult airway scenarios.[4-8] The AL has been successfully used in difficult airway management including morbidly obese and patients needing cervical spine stabilization.[9-14] Most commonly, we choose polyvinyl chloride (PVC) tubes for AL-assisted intubation. The manufacturers recommend the use of appropriate sized endotracheal tube...
(ETT) for AL-assisted intubation, but there are no specific recommendations on appropriate type of ETT to be used. Cost effectiveness and comparable success rates are the main reasons for choosing PVC tubes. However, there are cases where use of curved reinforced or straight reinforced tracheal tubes is more useful. These tubes may be used where the neck of the patient is likely to be moved or flexed or when the patient is in prone position.

Most of the clinical trials conducted previously have used Portex® PVC tracheal tubes (Smiths Healthcare Manufacturing S.A., California, USA) for intubation using AL. In the previous studies, it was found that the intubation success rate with the use of curved reinforced tube (CRT) through AL is better compared to straight reinforced tube (SRT).[15]

In another study, intubation success rate was found to be better with the use of PVC tube through AL than SRT.[16] In the latter, ETT of different sizes and types were used for intubation using AL of two different sizes laryngoscope blades, alternatively. Hence, lack of standardization in size of ETT and laryngoscope blade could have resulted in higher failure rate with use of CRT. Moreover, there is no study mentioned in literature, to the best of our knowledge, which compares ease of intubation with the use of standard PVC tube, CRT, and SRT through AL.

In this prospective, randomized study, primary objective was to compare the intubation success rate and ease of intubation of Rusch® curved reinforced tracheal tube (Teleflex Medical Sdn., Kamunting, Malaysia) and Portex® straight reinforced tracheal tube (Smiths Healthcare Manufacturing S.A., California, USA) with standard PVC ETT through AL in anesthetized and paralyzed patients. Secondary objective of the study was to compare straight tube and CRT with standard PVC tube in terms of duration of intubation, number of attempts at intubation, number of optimization maneuvers, and airway trauma.

**Material and Methods**

Approval for the conduct of study was obtained from the Departmental Dissertation Committee and Institutional Ethics Committee. The sample size was estimated based on the intubation success rate. Based on results obtained from pilot study, allowing for an α-error of 0.05 and β-error of 0.2 (power of 80%) with a minimum difference of 20% in terms of intubation success rate, sample size of 34 patients for each group was calculated. Totally, 120 patients scheduled for elective surgery under general anesthesia requiring endotracheal intubation, aging between 18 and 60 years, of either gender, with body mass index (BMI) of 17.5-30 kg/m², belonging to American Society of Anesthesiologists Physical Status I and II, and modified Mallampati Classes I and II were included in the study. Patients with anticipated difficult airway and risk of gastric regurgitation (inadequate fasting, pregnancy, morbid obesity, emergency surgeries requiring rapid sequence induction of anesthesia, history suggestive of acid peptic disease) were excluded from the study. Patients were randomly allocated to one of the three groups using computer-generated random number table. Group allocation was concealed using sealed envelopes which were opened only by the anesthesiologist who was supposed to do the endotracheal intubation on the patient using AL, just before shifting patient into the operation room (OR). The three groups were group PVC: Patients intubated with PVC tube, group CRT: Patients intubated with CRT, and group SRT: Patients intubated with SRT. AL blade is available in two different sizes: Larger AL was used to intubate males with ETT of 8.0 mm internal diameter (ID) size and smaller AL was used to intubate females with ETT of 7.0 mm ID size, according to manufacturer’s recommendation.[11]

Anesthesiology residents performed preanesthetic evaluation, obtained written informed consent, recorded the parameters during the procedure, and were not blinded to group allocation of the patient. Anesthesiology consultant, who was not blinded, performed the endotracheal intubation. The operator had an experience of using Airtraq™ in at least 50 patients before commencing the study.

Inside the OR, standard monitors (electrocardiogram, noninvasive arterial pressure, pulse oximetry) were connected and baseline vitals were recorded. After securing the intravenous (IV) access, IV fentanyl 2 µg/kg and glycopyrrolate 0.2 mg were given. Preoxygenation was performed with 100% oxygen supplementation for 3 min. Anesthesia was induced with titrated dose of IV propofol 2.5-3 mg/kg, taking loss of verbal contact as the endpoint of anesthetic induction. Following induction, ability to bag-mask ventilation was checked and IV vecuronium 0.1 mg/kg was given for muscle relaxation. Anesthetic depth was maintained using 2% isoflurane in 100% oxygen for 3 min. When complete relaxation was confirmed (train-of-four count was 0 on ulnar nerve stimulation), patients were placed in sniffing position. AL preloaded with appropriate ETT (as per group allocation), was inserted into mouth in the midline, over center of the tongue (inventor’s technique). Once the glottis view was optimized, tube was passed through the glottis and cuff was inflated. If it was not possible to direct the ETT toward the glottis, optimization maneuvers were attempted. Optimization maneuvers, which included rotation and/or vertical lift of AL blade, were used.
only to direct the ETT into the glottis after obtaining an optimal glottis view. Number of attempts to pass the ETT through the glottis after obtaining an optimal glottis view was noted down. A failed intubation was defined when the trachea was not intubated after three attempts to pass the ETT through the glottis or it took more than 120 s to intubate the trachea successfully or drop in oxygen saturation to <93% during intubation attempt. In case of failed intubation, trachea was intubated with PVC tube using conventional laryngoscopy.

Percentage of glottic opening (POGO), representing the linear span extending from the anterior commissure to interarytenoid notch of vocal cords, was done for all the patients where glottis was visualized. Intubation was attempted only if an optimal glottis view, with POGO score of ≥75% was obtained. Time for intubation was defined as time in seconds taken from obtaining an optimal glottis view to visual confirmation of ETT passing through glottis. Airway trauma was defined as the presence of blood on AL blade after removal of the blade from mouth of patient or presence of blood on ETT tip after extubation.

All the statistical analysis in our study was performed with a commercially available statistical package (SPSS version 16.0 for Windows; SPSS Inc., Chicago, IL, USA). Age of patients was presented as median value (interquartile range) and was analyzed using the Kruskal-Wallis rank sum test. BMI of the patients and the best possible glottis view obtained were presented in mean ± standard deviation and were analyzed using one-way ANOVA test. Gender distribution of patients in each group was analyzed using Chi-square test. The intubation success rate and the incidence of airway trauma were compared using the Chi-square test. The intubation success rate and the incidence of airway trauma in the three groups were compared using Chi-square test. The time for successful intubation was analyzed using one-way ANOVA test. Post hoc analysis using Fischer’s exact test for intergroup analysis in statistically significant one-second difference does not produce a clinically significant difference. Percentage of glottic opening (POGO), representing the linear span extending from the anterior commissure to interarytenoid notch of vocal cords, was measured in all the patients where glottis visualization was possible. The time intervals between the three groups for intubation was statistically significant; one-second difference does not produce a clinically significant difference. Table 3 shows number of attempts for successful intubation. Success rate of intubation in first attempt was higher in group PVC. We found that the three groups were comparable with respect to the incidence of airway trauma. Table 5 enumerates the reasons for failed intubation. Post hoc analysis using Fischer’s exact test for intergroup analysis in statistically significant comparison between three groups of successful intubation, number of attempts for successful intubation, and number of optimization maneuvers required for successful intubation was found to be insignificant. As intergroup analysis was done between three groups, significant $P$ value was considered to be $<0.016$. Post hoc analysis using Mann-Whitney U-test for intergroup analysis of duration of intubation in three groups was found insignificant.

### Results

Table 1 demonstrates the demographic data of the patients included in each group. There was a comparable distribution of patients in all groups, with respect to age, BMI, and gender. All the three groups were comparable with respect to the best possible glottis view obtained. This shows that there was insignificant difference in the best view of glottis between the three groups that could have influenced the success rate of intubation. Table 2 depicts the rate of success of intubation in each group. In cases of unsuccessful intubation, it was constantly hinging the arytenoids in two patients in CRT and four patients in SRT groups, and it was directed toward the esophagus in one of the patients in CRT and four of the patients in SRT groups. Though the comparison of time intervals between the three groups for intubation was statistically significant, one-second difference does not produce a clinically significant difference.

### Discussion

AL is an important rescue device for failed intubation attempt using conventional direct laryngoscopy in difficult airway scenarios. It has been widely used in both adult and

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**Table 1: Demographic data**

| Parameters | Group PVC ($n = 40$) | Group CRT ($n = 40$) | Group SRT ($n = 40$) | $P$ |
|------------|----------------------|----------------------|----------------------|-----|
| Age (year) median (IQR) | 42 (31.8-54.8) | 42.5 (28.6-55.3) | 37 (27.3-52.0) | 0.264 |
| BMI (kg/m²) (mean±SD) | 23.0±3.6 | 23.9±2.7 | 23.3±3.0 | 0.452 |
| Gender (male/female) | 25/15 | 24/16 | 26/14 | 0.899 |

*PVC = Polyvinyl chloride, CRT = Curved reinforced tube, SRT = Straight reinforced tube, SD = Standard deviation, IQR = Interquartile range, BMI = Body mass index*
pediatric airway managements. In this study, we compared the CRT and SRT with PVC tube for intubation using AL in anesthetized and paralyzed patients. Our aim of the study was to find out whether PVC tube with a reasonably stiffer and preformed curvature has influence on the success of intubation with AL when compared to CRT which has lesser preformed curvature and SRT which has no curvature and is more flexible. The results of our study emphasized on angle formed by emerging ETT with the tip of AL guiding channel as a major determinant of successful intubation using Airtraq™ [Figure 1]. As the direction of ETT cannot be manipulated by operator, alignment of AL tip in front of glottis is essential for successful intubation. PVC tube being stiffer, with a curvature of 130°, takes a more anterior course toward glottis after emerging from the tip of AL [Figures 1 and 2]. This was attributed to the smaller angle formed by PVC tube with tip of AL [Figure 1] whereas CRT and SRT take a more posterior course, away from the glottis, toward the arytenoids or the esophagus after emerging from the tip of AL [Figures 1 and 2]. This was attributed to the greater angle formed by CRT and SRT with tip of AL [Figure 1]. It is nearly impossible to manipulate and guide a highly flexible reinforced tube into the glottis through the fixed channel of AL. Optimization maneuvers such as rotation and/or vertical lift of AL blade might assist smooth passage of reinforced tubes into the glottis. Ali et al. used a rigid stylet introduced into the ETT giving it a preformed curved shape and rigidity. The tube along with the stylet was then inserted in the conduit meant for the ETT in the Airtraq in the midline centralizing the glottis of the patient. After the confirmation of correct placement of ETT, stylet and AL blade were then removed. We believe that use of stylet might produce more trauma to the soft tissue of airway and there is a remote possibility of ETT tip hinging over the anterior commissure of vocal cords due to excess curvature and rigidity of the ETT. Hence, the use of stylet to ease the intubation of reinforced tube through AL requires further investigation and research, and no conclusion can be derived out of a single case report.

While designing the study, several precautions were taken to nullify the effects of possible confounding factors. Meticulous attention was given to the randomization and recording of parameters. The AL was inserted by anesthesiologists who were familiar with the use of same, using PVC tubes. This ensured that the operator using Airtraq™ was at the plateau of learning curve. Contrary to this, most of the operators had no experience of using AL with CRT or SRT. The operators had a formal training in more than twenty dummies before placing them in patients, thereby avoiding placing the PVC group at an advantage over the CRT and SRT groups. Patient safety was ensured by allowing only 120 s for achieving successful

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### Table 2: Rate of successful intubation

| Successful intubation | Group PVC (n = 40) (%) | Group CRT (n = 40) (%) | Group SRT (n = 40) (%) | P value |
|-----------------------|-----------------------|-----------------------|-----------------------|---------|
| Yes                   | 40 (100)              | 37 (92.5)             | 34 (85)               | 0.041   |
| No                    | 0 (0)                 | 3 (7.5)               | 6 (15)                |         |

PVC = Polyvinyl chloride, CRT = Curved reinforced tube, SRT = Straight reinforced tube

### Table 3: Number of attempts at endotracheal intubation

| Attempts | Group PVC (n = 40) (%) | Group CRT (n = 40) (%) | Group SRT (n = 40) (%) | P value |
|----------|-----------------------|-----------------------|-----------------------|---------|
| 1        | 35 (87.5)             | 27 (67.5)             | 26 (65)               | 0.038   |
| 2        | 3 (7.5)               | 9 (22.5)              | 5 (12.5)              |         |
| 3        | 2 (5)                 | 1 (2.5)               | 3 (7.5)               |         |
| Failed intubation | 0 (0)                 | 3 (7.5)               | 6 (15)                |         |

PVC = Polyvinyl chloride, CRT = Curved reinforced tube, SRT = Straight reinforced tube

### Table 4: Number of optimization maneuvers required to aid endotracheal intubation

| Number of manoeuvres required | Group PVC (n = 40) (%) | Group CRT (n = 40) (%) | Group SRT (n = 40) (%) | P value |
|-----------------------------|-----------------------|-----------------------|-----------------------|---------|
| 0                           | 35 (87.5)             | 27 (67.5)             | 26 (65)               | 0.038*  |
| ≥1                          | 5 (12.5)              | 10 (25)               | 8 (20)                |         |

Unsuccessful intubation even with two maneuvers

*P < 0.05 is statistically significant. PVC = Polyvinyl chloride, CRT = Curved reinforced tube, SRT = Straight reinforced tube

### Table 5: Reasons for failure to intubate

| Failed intubation | Group CRT (n = 40) | Group SRT (n = 40) |
|-------------------|--------------------|--------------------|
| Hinging at anterior commissure | 0                  | 0                  |
| Hinging at arytenoids    | 2                  | 2                  |
| ETT tip directed toward esophagus | 1                  | 4                  |

CRT = Curved reinforced tube, SRT = Straight reinforced tube, ETT = Endotracheal tube

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Figure 1: Different angles formed between the polyvinyl chloride tube (angle a), straight reinforced tube (angle b) as well as curved reinforced tube (angle c) and the tip of Airtraq™ laryngoscope blade (Prodol Meditec S.A., Vizcaya, Spain)
intubation during which only three attempts were allowed to pass the ETT through the glottis.

In a study conducted by Dimitriou et al., rate of successful intubation was 100% for polyvinyl tracheal tubes, 78.5% for wire reinforced tubes and 75.4% for SRTs. In our study, we achieved same success rate for PVC tubes. There was higher success rate in case of CRTs (92.5% vs. 78.5%) and SRTs (85% vs. 75.4%). In the preliminary study conducted by Hirabayashi et al., AL loaded with PVC tube was used in 20 patients undergoing surgery under general anesthesia. All patients were intubated successfully in the first attempt. A study conducted by Minonishi et al. compared SRT and CRT for success of intubation with airway scope, a device similar to AL. In their study, rate of successful intubation was 100% with CRT and 83% with SRT. [15]

In our study, time taken from obtaining an optimal glottis view to visual confirmation of ETT passing the vocal cords was assessed. Though the duration was statistically significant, one-second difference does not produce a clinically significant difference. In our study, we have calculated the time taken from obtaining optimal glottis view to visual confirmation of ETT passing the vocal cords. In a similar study done previously, the time elapsed from inserting the blade between the teeth until the ETT crossed the vocal cords as evidenced by visual confirmation by the anesthesiologist was considered as duration of intubation. In this present study, time to insert AL in mouth of the patient and obtaining an optimal glottis view was excluded from time for intubation, considering it to be similar in all the three groups because it will not change depending upon the type of ETT used for intubation through AL. In a previous study, duration of intubation in group PVC tube was 13 (12-14.7) s as compared to group wire reinforced group 20 (16-23.5) s and group reinforced tube 19 (16-23) s, which was highly statistically significant. In a similar methodology used by another study, where airway scope was used, the time from laryngeal view to tracheal intubation was longer in straight group than the curved group (11.1 ± 5.2 s vs. 6.3 ± 4.7 s), which was again statistically significant.

In our study, the rate of successful intubation in the first attempt in group PVC was significantly better. In a study conducted previously, the rate of successful intubation in the first attempt was higher in case of group PVC which was 100%, 89.6% in case of wire reinforced tube, and 96.5% in case of straight tube. For statistical analysis, they included only those cases who were successfully intubated. Another study conducted with airway scope video laryngoscope found that the number of insertion attempts was greater in straight group than in the curved group (2.4 ± 1.4 vs. 1.2 ± 0.5). In our study, there was statistical and clinical difference in terms of number of attempts at successful intubation.

In our study, optimization maneuvers (rotation and/or vertical lift of AL blade) required to direct the ETT into the glottis after obtaining optimal glottis view were recorded.

Blood stain on the AL blade during the time of intubation or blood on the tip of the ETT during the time of extubation was considered marker of soft tissue trauma. In a previously done study, a higher incidence of airway trauma was recorded with use of reinforced tubes. Incidence of airway trauma in group wire reinforced was 26.6%, in group straight reinforced was 25.4%, and in group PVC was 1.02%. In our study, there was no statistically significant difference in incidence of airway trauma among the three groups.

There are some limitations to our study. The study was conducted in patients with modified Mallampati Classes I and II. Results may not be reflected similarly in patients with higher Mallampati Classes or patients with cervical spine immobilization, the cases in which Airtraq™ is most useful. Second, the results of our study need not apply to anesthesiologists who are less experienced in use of AL.

**Conclusion**

Patients intubated with PVC tube have higher rates of successful intubation in comparison to intubation with SRT and CRT using AL. Patients intubated with CRT and SRT needed more frequent application of optimization maneuvers and more attempts at successful intubation, in comparison to PVC tube using AL. To conclude, we found that PVC tube is superior to both CRT and SRT for intubation using AL.
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Conflicts of interest
There are no conflicts of interest.

References

1. Pedra A, inventor; Guangzhou Intmed Medical Appliance For Prodol Meditec (Spain), assignee. Airtraq® Optical Laryngoscope. United States Patent US Patent number 6843, 79. 2007 February.
2. Maharaj CH, O’Croinin D, Curley G, Harte BH, Laffey JG. A comparison of tracheal intubation using the Airtraq™ or the Macintosh laryngoscope in routine airway management: A randomised, controlled clinical trial. Anaesthesia 2006;61:1093-9.
3. Maharaj CH, Costello JF, Harte BH, Laffey JG. Evaluation of the Airtraq™ and Macintosh laryngoscopes in patients at increased risk for difficult tracheal intubation. Anaesthesia 2008;63:182-8.
4. Ford PN, Hamer C, Medakkar S. Use of the Airtraq™ in the difficult airway. Eur J Anaesthesiol 2007;24:730-1.
5. Norman A, Date A. Use of the Airtraq™ laryngoscope for anticipated difficult laryngoscopy. Anaesthesia 2007;62:533-4.
6. Maharaj CH, Higgins BD, Harte BH, Laffey JG. Evaluation of intubation using the Airtraq™ or Macintosh laryngoscopy by anaesthetists in easy and simulated difficult laryngoscopy — A manikin study. Anaesthesia 2006;61:469-77.
7. Maharaj CH, Costello JF, McDonnell JG, Harte BH, Laffey JG. The Airtraq™ as a rescue airway device following failed direct laryngoscopy: A case series. Anaesthesia 2007;62:598-601.
8. Malin E, Montblanc JD, Yninéb Y, Marret E, Bonnet E. Performance of the Airtraq™ laryngoscope after failed conventional tracheal intubation: A case series. Acta Anaesthesiol Scand 2009;53:858-63.
9. Dhonneur G, Ndoko S, Amathieu R, Housseini LE, Poncelet C, Tual L. Tracheal intubation using the Airtraq™ in morbid obese patients undergoing emergency cesarean delivery. Anesthesiology 2007;106:629-30.
10. Ndoko SK, Amathieu R, Tual L, Polliand C, Kamoun W, El Housseini L, et al. Tracheal intubation of morbidly obese patients: A randomized trial comparing performance of Macintosh and Airtraq™ laryngoscopes. Br J Anaesth 2008;100:263-8.
11. Dhonneur G, Ndoko SK, Amathieu R, Attias A, Housseini LE, Polliand C, et al. A comparison of two techniques for inserting the Airtraq™ laryngoscope in morbidly obese patients. Anaesthesia 2007;62:774-7.
12. Uakridthikarn T, Asampinawat T, Wanasuwannakul T, Yoosamran B. Awake intubation with Airtraq™ laryngoscope in a morbidly obese patient. J Med Assoc Thai 2008;91:564-7.
13. Maharaj CH, Buckley E, Harte BH, Laffey JG. Endotracheal intubation in patients with cervical spine immobilization: A comparison of Macintosh and Airtraq™ laryngoscopes. Anesthesiology 2007;107:53-9.
14. Durga P, Yendrapati C, Kaniti G, Padhy N, Anne KK, Ramachandran G. Effect of rigid cervical collar on tracheal intubation using Airtraq™. Indian J Anaesth 2014;58:416-22.
15. Minonishi T, Kinoshita H, Tange K, Hatakeyama N, Matsuda N, Azma T, et al. Tracheal intubation with the AirwayScope™ videolaryngoscope using straight vs curved reinforced tubes. Can J Anaesth 2010;57:92-3.
16. Dimitriou VK, Zogogiannis ID, Douma AK, Pentilas ND, Liotiri DG, Wachtel MS, et al. Comparison of standard polyvinyl chloride tracheal tubes and straight reinforced tracheal tubes for tracheal intubation through different sizes of the Airtraq™ laryngoscope in anesthetized and paralyzed patients: A randomized prospective study. Anesthesiology 2009;111:1265-70.
17. Ali QE, Siddiqui OA, Amir SH, Chaudhri TR. Using stylet in Airtraq optical laryngoscope for armored tube intubation: A new experience. J Anaesthesiol Clin Pharmacol 2013;29:124.
18. Hirabayashi Y, Otsuka Y, Taira K, Shinohara T, Kikuchi Y, Shimada N, et al. Airtraq™ optical laryngoscope. Masui 2008;57:1026-30.