Laboratory Investigations

Does experience influence the forces exerted on maxillary incisors during laryngoscopy? A manikin study using the Macintosh laryngoscope

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The influence of the level of experience of the laryngoscopist on the duration of laryngoscopy, the forces exerted on the tongue and on the maxillary incisors during laryngoscopy, were investigated. Five groups (anaesthetists, residents in anaesthesia, nurse anaesthetists, surgeons and medical students), each consisting of 15 individuals, participated in the study. An intubation manikin was used with a laryngoscope modified so that the forces applied during laryngoscopy could be measured. The mean duration of laryngoscopy in these groups was 23.4 sec, 17.6 sec, 27.1 sec, 26.8 sec and 42.7 sec, respectively. The maximally applied forces on the tongue were 71.7 N, 60.5 N, 65.9 N, 74.2 N and 69.7 N, respectively. The maximally applied forces on the maxillary incisors were 49.9 N, 36.3 N, 41.1 N, 58.3 N and 53.9 N, respectively. These results indicate the level of experience has a significant influence on the duration of laryngoscopy but seems to have little influence on the forces applied to the tongue and the maxillary incisors.

Cette étude recherche l'influence du degré d'expérience du laryngoscopiste sur la durée de la laryngoscopie, sur la force exercée sur la langue et sur les incisives maxillaires au cours de la laryngoscopie. Cinq groupes de 15 personnes chacun participent à l'étude: anesthésistes, résidents en anesthésie, infirmières anesthésistes, chirurgiens et étudiants en médecine. Un mannequin de pratique est utilisé avec un laryngoscope modifié pour mesurer la force appliquée. La durée moyenne de la laryngoscopie est respectivement de 23,4 sec, 17,6 sec, 27,1 sec, 26,8 sec et 42,7 sec. La force maximale exercée sur la langue est de 71,7 N, 60,5 N, 65,9 N, 74,2 N et 69,7 N respectivement. La force maximale exercée sur les incisives est de 49,9 N, 36,3 N, 41,1 N, 58,3 N et 53,9 N, respectivement. Ces résultats montrent que le degré d'expérience a une influence significative sur la durée de la laryngoscopie, mais peu d'influence sur la force exercée sur la langue et les incisives.

Keywords
ANAESTHETIC TECHNIQUES: laryngoscopy;
EQUIPMENT: laryngoscopes;
INTUBATION, TRACHEAL: technique;
LARYNX: laryngoscopy.

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According to current opinion,[1,2] force should not be exerted on the maxillary incisors during laryngoscopy using the Macintosh laryngoscope, particularly in patients in whom it is considered that the trachea is "easy to intubate." With more difficult cases, application of force to the teeth is sometimes inevitable and, therefore, jus-

tified.[3] However, we have observed that the application of force on the maxillary incisors during routine tracheal intubation is common, and its magnitude is often considerable.[4]

As the routine application of force on the teeth is considered to be in contradiction to accepted professional standards, and is sometimes even referred to as "typical for the careless and unskillful,"[1] the question arises whether experienced intubators differ from the inexperienced.

The purpose of this study was to investigate the influence of the level of experience on the forces applied during laryngoscopy, on the duration of laryngoscopy, the best view obtained and the success of intubation. In addition, the effect of re-larygoscopy on these variables was investigated. Because many patient-related factors influence the forces applied during laryngoscopy,[5,6] an intubation manikin was used to represent a "standard patient," allowing simple comparisons between groups and avoiding ethical problems.

Methods

During a three-day period, 150 laryngoscopies performed in an intubation manikin were studied. The procedures were performed by 75 study participants who were divided into five groups (15 per group) of different levels of experience. Group 1 were staff anaesthetists; Group 2 were residents in anaesthesia (>two years experience or >300 tracheal intubations); Group 3 nurse anaesthetists; Group 4 consultants or senior residents in surgical fields with previous successful intubation experience in patients (referred to hereafter as surgeons), and Group 5 were medical students. Each participant performed two laryngoscopies; for each procedure a maximum of 60 sec was allowed. The second procedure was defined as re-laryngoscopy. All participants performed intubation with the same manikin (Adult Intubation Model, Laerdal, Stavanger, Norway) with a Portex 8.5 mm endotracheal tube. The head of the manikin was put in a sniffing position. As we wished to study only the effect of experience on handling of the laryngoscope and not on head positioning, the head was fixed in this position with screws. The forces applied during laryngoscopy were measured by means of a recent modification[4] to a previously described curved blade laryngoscope.[7] A combined moment and shear force sensor, based on the strain gauge technique, was built into this laryngoscope and positioned between the handle and the blade. This configuration of sensors allowed estimation of the forces applied on the tongue (Ft) and on the maxillary incisors (Fm), provided that the application points of these forces on the blade were known. The application points in the intubation manikin were determined by four investigators (MB, RvG, JW, CR) each performing seven laryngoscopies.

In addition to determining these forces, the mean and maximum values of the forces as well as their accompanying 95% confidence intervals can be determined. A detailed description of the principles of this measuring laryngoscope has been published recently.[4] An important feature of this laryngoscope is that it gives no indication to the intubator of the measurement. Before each measurement the instrument was calibrated. In all measurements the same No. 3 Macintosh laryngoscope blade (Penlon Ltd.) was used.

To avoid any influence on the way that laryngoscopy was carried out, the participants were not informed of the purpose of this study, nor were any comments made about the way laryngoscopy was performed. During laryngoscopy, no person other than the investigator and the study participant were present. During measurement the data were stored onto a memory card for later analysis, so that no-one was aware of the results.

The best view obtained during laryngoscopy was determined by the investigator by asking the intubator which (and how much) of the structures in the larynx-pharynx area of the manikin were identified. Subsequently, this view was graded according to Cormack and Lehane;[8] grade 1, most of the cords visible; grade 2, less than half of the cords visible; grade 3, only the epiglottis visible; and grade 4, not even the epiglottis visible. After each intubation (attempt) the investigator determined the position of the tube by looking at the transparent trachea at the back of the manikin which was not visible to the intubator. The presence of the tip of the tube in the trachea represented successful intubation.

Statistical analysis

To test for differences between groups in continuous variables, the Kruskal and Wallis test was used. If this test proved significant, pairwise comparisons of groups were done with the Mann-Whitney-Wilcoxon test. The chi-squared (trend) test was used to study the differences between participant groups in the best view obtained and the success of intubation. The influence of re-laryngoscopy on the laryngoscopic factors was studied using the paired t test. The influence of re-laryngoscopy on the best view obtained and the success of intubation were analysed using the Wilcoxon signed-rank test and McNemar's test, respectively. Logarithmic transformation to obtain approximate normal distribution was performed when appropriate. A P value <0.05 was considered statistically significant.

Results

The mean application point of the forces acting on the

TABLE I Laryngoscopic factors at first laryngoscopy

	Anaesthetists	*Residents*	*Nurses*	*Surgeons*	*Students*
tl (s)					
M	23.4	17.6	27.1	26.8	42.7*
SD	14.8	6.2	16.2	16.7	18.1
range	8–60	10–30	8–57	10–65	17–66
Ftmax (N)					
M	71.7	60.5	65.9	74.2	69.7
SD	25.1	20.6	25.6	30.1	26.3
range	38–115	40–114	25–122	26–153	24–114
Ftmean (N)					
M	31.7	30.3	29.8	31.1	27.4
SD	13.2	15.5	11.7	12.5	12.1
range	18–64	11–78	13–46	14–61	10–49
Fmmax (N)					
M	49.9	36.3	41.1	58.3	53.9
SD	25.2	29.2	27.4	36.1	35.6
range	10–100	8–123	9–92	7–127	3–109
Fmmean (N)					
M	19.6	15.0	13.8	18.9	14.6
SD	17.0	21.7	13.5	12.7	13.2
range	2–67	1–88	1–42	1–37	0–43

tl, duration of laryngoscopy; Ft, forces on the tongue; Fm, forces on the maxillary incisors; max, maximum value; mean, mean value; M, mean value; SD, standard deviation.
*Results in students different from results of all other groups.

maxillary incisors was 8.3 cm (SD 0.28; range 7.7–9.1) and on the tongue 2.1 cm (SD 0.62; range 1.4–3.3); from the tip of the blade.

Table I and II show the duration of laryngoscopy and the forces applied on the tongue and the maxillary incisors, recorded at the first and the second laryngoscopy attempts, respectively.

At first laryngoscopy, the global test indicated differences in the duration of laryngoscopy (tl_1). In medical students the duration of laryngoscopy was longer than in the four other groups ($P = 0.0005$), but differences between the other groups could not be demonstrated. In addition, there were no differences among groups concerning the forces on the tongue and on the maxillary incisors. When first laryngoscopies of all groups were considered, the maximal force exerted on the maxillary incisors was >20 N in 55 (73%) cases, >40 N in 40 (53%), >60 N in 28 (37%) and >80 N in 10 (13%) cases. For anaesthetists and residents in anaesthesia these values were 24 (80%), 14 (47%), 9 (30%) and 2 cases (7%), respectively. At second laryngoscopy, there was a decrease in duration of laryngoscopy (tl_2) ($P < 0.001$), as well as on the forces applied on the tongue and the teeth. When only those intubators who were successful both times were included, these results were similar except for the duration of laryngoscopy.

The best view obtained by medical students was worse than by other four groups; the differences between the other groups were not significant. However, there were differences between groups in best view obtained at first laryngoscopy ($P < 0.0001$) (Table III). The best view obtained improved at second laryngoscopy compared with the first, although this reached only borderline significance ($P = 0.05$).

The number of failed intubations at the first laryngoscopy was 15; two in the anaesthetists, 0 in the residents, three in the nurses, three in the surgeons and seven in the students. For the second laryngoscopy the number of failed intubations was 12; 1, 0, 4, 1 and 6, respectively. There were differences between groups in intubation success at first laryngoscopy ($P < 0.01$) but there was no difference between the number of intubation failures at first and second laryngoscopy. When the first intubation was successful, the chance of success in the second was 92%. However, when the first was not successful, the chance of success in the second was 53% ($P = 0.001$). There was a relationship between intubation success and best view obtained ($P < 0.0001$).

TABLE II Laryngoscopic factors at second laryngoscopy

	Anaesthetists	*Residents*	*Nurses*	*Surgeons*	*Students*
tl (s)					
Mean	14.0	15.6	22.5	16.1	31.5*
SD	5.6	7.5	13.7	15.6	18.2
range	8–26	7–33	9–62	7–70	13–63
Ftmax (N)					
Mean	58.7	54.4	61.4	67.7	55.9
SD	28.3	15.9	25.4	20.0	20.1
range	26–130	31–92	18–114	39–108	41–117
Ftmean (N)					
Mean	30.7	26.6	27.7	33.4	23.7
SD	14.2	11.6	13.0	12.4	7.9
range	15–62	13–51	10–55	22–70	18–43
Fmmax (N)					
Mean	39.5	29.31	42.1	47.7	35.4
SD	29.5	16.0	31.8	25.8	26.9
range	6–108	7–59	8–103	13–83	5–120
Fmmean (N)					
Mean	18.8	10.3	15.0	20.7	10.7
SD	17.3	7.5	16.0	15.5	11.4
range	1–66	1–21	1–45	1–51	1–43

tl, duration of laryngoscopy; Ft, forces on the tongue; Fm, forces on the maxillary incisors; max, maximum value; mean, mean value.
*Results from students different from results of all other groups.

TABLE III Best view obtained at first laryngoscopy

	*Best view obtained**			
	1	*2*	*3*	*4*
Anaesthetists	10	5	–	–
Residents	11	4	–	–
Nurses	6	7	2	–
Surgeons	7	6	1	1
Students	2	5	3	5

*1, most of the cords visible; 2, less than half of the cords visible; 3, only the epiglottis visible; 4, not even the epiglottis visible; Cormack and Lehane.[8]

Discussion

The results of this manikin study demonstrate that, in the majority of laryngoscopies, use of the Macintosh laryngoscope is associated with the application of considerable force to the maxillary incisors. This confirms the results of a previous study performed in patients in whom the tracheas were considered to be easy to intubate.[4] Both the incidence and the magnitude of the forces are remarkable, as both are in contrast to accepted views regarding the way laryngoscopy should be performed. Experience proved to have a substantial influence in reducing the duration of laryngoscopy, which is in agreement with previous reports.[5] In addition, increased experience facilitated attainment of the best view on the glottis and the intubation success, both of which proved to be closely related. In contrast, the level of experience had no influence on the forces applied to the tongue or to the maxillary incisors.

The influence of experience on the forces applied during laryngoscopy has been addressed in a recent study in which it was concluded that experience had no clear influence.[5] However, the instrument used in that study has not been validated and laryngoscopies during which force was exerted on the teeth were excluded. Should we now conclude that, as far as forces on the teeth are concerned, the experience of the intubator does not matter and, consequently, will have no influence on the (possible) resulting dental damage? We think not, and this opinion is based on the following. First, although the data indicate that the level of experience has little influence, it does not exclude that such an influence exists. Second, common sense leads us to assume that such a relationship does exist. In this respect it is interesting that, as far as differences between anaesthetists and residents are concerned, the results of this study indicate that the laryngoscopic factors are not influenced by the total number

TABLE IV Laryngoscopic factors in the manikin compared with patients

	Manikin	*Patients*		
			Bucx et al.[4]	
	*Present study**	*Bishop et al.*[5]†	*MI present*	*MI absent*
n	28	17	34	31
tl (s)	18.7	19	16.2	11.5
Ftmax (N)	64.3	43.2	56.8	33.5
Ftmean (N)	29.1	22.3	34.1	20.4
Fmmax (N)	40.4	-	49.1	21.0
Fmmean (N)	15.3	-	27.8	11.2

*Only the results of successful intubations by experienced intubators (i.e., anaesthetists and residents) are shown.
†The presence or absence of teeth was not stated in Bishop's study, measurements during which force was exerted on the teeth were excluded, only the results of experienced intubators are shown.
MI, maxillary incisors; tl, duration of laryngoscopy; Ft, forces on the tongue; Fm, forces on the maxillary incisors.

of laryngoscopies performed throughout a career. Third, the mechanisms leading to dental damage are complex and the sensor has technical limitations. Although teeth are able to withstand great forces in an axial direction, relatively small lateral forces can do great harm. Unfortunately, the measurement laryngoscope that was used enabled measurement only of the axial forces, which are not influenced by level of experience. However, experience might have an effect on the lateral forces. Therefore, to quantify all the essential force-related variables of laryngoscopy, a more sophisticated measuring laryngoscope than the one used in the present study is needed.

The results of this study do not support the contention that difficulty with laryngoscopy is associated with greater applied force, nor that intubation failure is the result of applying too little force.[9] However, this study was not designed to address these points and heterogeneity of the participating groups in this study might account for these results. As expected, the results demonstrate the favourable effect of re-laryngoscopy on the variables studied. The duration of laryngoscopy was decreased, as were the forces exerted on the tongue and the maxillary incisors. In addition, there was an improvement in the best view obtained and the number of successful intubations.

An important aspect of this study concerns the extent to which the intubation manikin used realistically mimics the clinical situation. Obviously, this question should only apply to the laryngoscopic factors measured in this study, as other characteristics of the manikin were not investigated. However, the measurements obtained with the manikin by experienced intubators in this study (i.e., anaesthetists and residents) proved to be comparable with measurements obtained by experienced intubators in patients[4,5] (Table IV). Therefore, it can be concluded that, within the limitations mentioned, this manikin is a reasonable representation of the situation in dentate patients. However, when no force is exerted on the maxillary incisors, the effort needed to perform laryngoscopy not only depends on the duration and the amount of force needed to lift the base of the tongue, but also on the magnitude of the moment to be exerted. In turn, the magnitude of this moment depends not only on the magnitude of the force to be exerted, but also on its application point on the blade. In the manikin used in this study, this application point was 2.1 cm, whereas in patients it is 3.9 cm from the tip of the blade.[4] As the distance from the central axis of the handle to the tip of the blade is 12.0 cm, the magnitude of the moment to be exerted in the manikin used in this study is approximately 22% greater than would be needed in dentate patients. Manufacturers of manikins should be made aware of these facts.

In conclusion, this manikin study demonstrated that, in the majority of laryngoscopies using the Macintosh laryngoscope, great forces are exerted on the maxillary incisors. This is comparable to the situation in patients. The experience of the intubator did not influence the incidence and magnitude of these forces. Re-laryngoscopy reduced the duration of laryngoscopy and the forces applied. The results of this study pose challenging questions concerning the validity of currently generally accepted basic knowledge on laryngoscopy, and stress the need for more rational methods in laryngoscope design and development.

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