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FACTOR ANALYSIS IN DIFFICULT TRACHEAL INTUBATION: LARYNGOSCOPY-INDUCED AIRWAY OBSTRUCTION

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SUMMARY

We have studied eight patients with a history of difficult tracheal intubation, using x-ray laryngoscopy and local anaesthesia, a curved Macintosh blade and a standard intubating position. The view obtained was better than recorded previously during general anaesthesia in two patients, and in a third the x-ray showed that positioning the blade tip beneath the epiglottis would have improved vision, suggesting that reproducibility of the assessment may not be consistent. The "ease of intubation" and "complementary" angles may be helpful in the assessment of such patients. A "peardrop" effect is described whereby during laryngoscopy, the epiglottis became pressed against the posterior pharyngeal wall as a result of tongue compression. In the absence of muscle paralysis, removal of the blade caused immediate correction. However, during anaesthesia with neuromuscular block it is suggested that this not only occurs more readily but, may not correct when the blade is removed. Iatrogenic airway obstruction during moderately difficult tracheal intubation may be common and should be anticipated.

KEY WORDS

Anatomy: cervical vertebrae, hyoid, mandible, larynx. Intubation, tracheal: complications.

We have proposed previously a standard intubating position to investigate patients presenting difficulties with tracheal intubation [1] and have shown that x-ray laryngoscopy is useful in demonstrating the relevance of soft tissue effects [2]. In normal volunteers, successful laryngoscopy with a curved laryngoscope blade depends largely on appropriate positioning of the tip of the blade so as to move the hyoid forward and elevate the epiglottis. In a preliminary report in which patients with a history of difficult laryngoscopy were studied [3], two mechanisms were suggested to be responsible for the difficulty. The blade tip could be positioned correctly with respect to the hyoid but forward movement constrained, for example by calcified stylohyoid ligaments. Alternatively, despite appropriate advancement of the blade tip, approximation to the hyoid may be prevented by the tongue. In both circumstances the usual mechanism for elevating the epiglottis is rendered ineffective and laryngeal exposure compromised. This paper reports further analysis of such patients.

PATIENTS AND METHODS

After local Ethics Committee approval, eight patients (three female; mean age 53 (SD 19) yr) with a recent (within 12 months before the study) history of difficulty with tracheal intubation consented to take part in the study. An anaesthetist of senior registrar or consultant status had decided originally that the patients presented difficulty at laryngoscopy. No patient was pregnant.

Physical characteristics were recorded, including dental impressions and mandibular translation (obtained by biting into dental wax). Neck length was measured as the vertical distance from the sternal notch to the middle of the external

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auditory meatus with the subject erect and the head in a neutral position. Neck circumference was the minimum value. Ramus length was the vertical distance from the condyle to the angle of the jaw. Maxilla and mandible lengths were the antero–posterior distances from the front of the upper incisors to the posterior border of the condyles, and the tip of the symphysis menti to the condyles, respectively.

The x-ray laryngoscopy technique and the subsequent analyses were as reported previously [4]. The laryngoscopy grading used was as follows: E0 = *severe*, no part of glottis seen; E1 = *moderate*, epiglottis seen, immobilized on pharyngeal wall; E2 = *intermediate*, epiglottis partly elevated, and no clear indication of glottic midline; E3 = *minimal*, epiglottis partly elevated, glottic midline position obvious (because interarytenoid groove obvious); E4 = *not difficult*, posterior commissure or cords seen.

For analysis of the x-rays, the points shown in figure 1 were used. As far as possible, the variables investigated were midline angles. The cervical spine was described as "bowed" if any of the upper cervical vertebrae protruded forward of a line at 35° (the standard neck flexion angle) to the front of C6. From our earlier study in normal volunteers, expected values for normal length ratios and angles were derived as shown in table I. Abnormality was described in terms of the appropriate 2 and 3 SD from the mean for the volunteers.

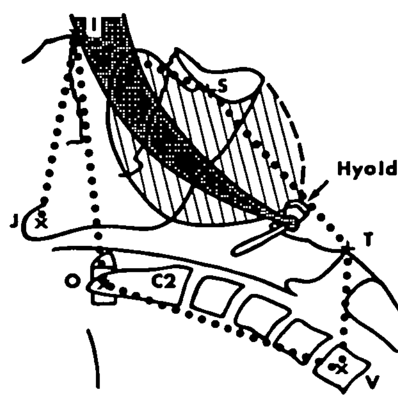

FIG. 1. Points for analysis of x-rays (joined by dotted lines): I = tip of upper incisors; O = central point of the anterior half of the vertebral foramen of atlas; V = central point on the body of C6; T = most anterior–inferior position of the airway behind the thyroid cartilage and above the vocal cords; S = mid-point on the inner surface of the mandibular symphysis (from the tip of the lower incisors to the lower border of the mandible); J = radiological mid-point between the centres of the two condyles. The diagram shows the expected position of the laryngoscope blade (stippled) relative to the tongue (cross-hatched). Note that the blade is completely around the tongue reaching to just behind the body of the hyoid. The main bulk of the tongue is pushed forward between the mandible and hyoid and the dashed line represents the anterior delineation of the tongue.

RESULTS

Table II summarizes the x-ray and clinical abnormalities. From the original descriptions, difficulty of intubation was equivalent to grade E1–E2 in each patient. At x-ray laryngoscopy the posterior commissure was seen in two patients. One was asthmatic and the previous anaesthetic had been complicated by bronchospasm during induction. Unilateral stylohyoid ligament calcification was present in the other patient and x-ray showed that rotation of the hyoid forward away from the immobilized side had revealed the larynx. Patient No. 6 was graded E2 at x-ray laryngoscopy, but an "eyeline" from the upper incisors tangential to the blade indicated that, had the blade been positioned behind the epiglottis, the glottic midline should have been seen (E3). The two patients with "short neck" indices had narrowing of C5 and C5 + C6 vertebrae, respectively, and the "bull neck" index was consistent with the clinical appearances.

The midline angles in figure 1 were determined from the x-rays. In the polygon VOIST, only the angles VOI and IST were different from those of normal subjects ($P < 0.01$ and $P < 0.002$, respectively). The spread of normal values suggested the difference was fortuitous in the case of angle VOI, but in the triangle IST, the angle SIT was not only different from the normal ($P < 0.001$), but also appeared to be a sensitive index of degree of difficulty (table II). For this reason it was called the "Ease of Intubation (EoI)" angle. The angle ITS was different also from normal ($P < 0.01$) and was considered an independent, "complementary" angle.

No significant difference in translation movements of the mandible was found compared with normal individuals. The "face line" and "tracheal alignments" [4] confirmed that approximation to the standard position was achieved in each patient.

"Peardrop" phenomenon

In all four cases of greatest difficulty in this study (E1 grade laryngoscopy) a mechanism (fig. 2) was apparent which suggests that airway

TABLE I. *Definitions for abnormality. Angular reference points as shown in figure 1; other measurements are described in the text. Height refers to overall body height. Values are 2 and 3 SD from the mean values in normal volunteers [4]. Asterisks are for purposes of reference in table II*

Character	Components	Defining angle/ratio 2 SD(*)	3 SD(**)
Bull neck	Height/neck circumference	<4.4	<4.1
Short neck	Height/neck length	>10	>11
Long ramus	Height/vertical height of ramus	<25	<21
Long maxilla	Height/effective length maxilla	<18	<16
Mandible/ maxilla	Relative lengths	<1.0	<0.9
Angle SIT	"Ease of intubation" angle (EoI)	<12°	<9°
Angle ITS	"Complementary" angle (Com)	<9°	<6°
Angle JIT	Condyle/incisor/trachea angle	>68°	>72°

TABLE II. *X-ray features, neck and jaw characteristics. Laryngoscopy gradings are defined in the text. SHC = Calcification of stylohyoid ligaments. In patient No. 7 the ramus extended beyond the film so JIT could not be measured. Abnormal indices are defined in table I (beyond the appropriate 2 SD (*) and 3 SD (**) limits)*

Patient No.	(M/F)	Grade	EoI°	Com°	X-ray features	Soft tissues	Jaw comment
1	F	E4	19.0	12.0	SHC—but hyoid could rotate forward	—	—
2	M	E1	3.5**	2.0**	—	Bull neck**	Long maxilla**; long ramus* Short mandible/maxilla* Large JIT*
3	M	E1	1.0**	0.5**	Narrowed C5 body	Short neck**	Large JIT**
4	M	E1	6.5**	5.0**	Hypertrophic anterior osteophytes, C3–C5	—	Symphysis hypertrophic (protruded inwards)
5	M	E4	16.5	13.5	—	—	—
6	F	E3	12*	10	Blade below epiglottis and arytenoids visible	—	—
7	M	E1	1.0**	0.5**	Narrowed C5+C6 bodies	Short neck*	Long maxilla**; long ramus*
8	F	E2	10.5*	8.0**	SHC—immobilized hyoid. Vertebrae bowed forward	—	—

obstruction during laryngoscopy is almost inevitable in such patients. Compression of part of the tongue occurred, forcing the tip of the blade further posteriorly than might otherwise be expected.

Figure 2 shows that the tongue is in contact with the posterior pharyngeal wall and has its lower margins extending along the greater horns of the hyoid. Where the space for the tongue is limited, the laryngoscope blade inevitably encroaches upon it. The tongue is pushed into the pharynx and against the mandibular symphysis as the blade is advanced. When the handle is pulled forward, the limitations imposed by the symphysis result in further downward force on the tongue. The hyoid and thyroid cartilage limit downward movement and the trapped anterior tongue becomes moulded into a "peardrop" shape.

The forces within the tongue are transmitted in all directions at its lower part and as a result the epiglottis is pressed against the posterior pharyngeal wall. In effect, the anterior movement of the laryngoscope handle results in a backwards force exerted at the blade tip. This is in keeping with the clinical observation that under such circumstances it may be difficult to lift the epiglottis off the posterior pharyngeal wall, even with a bougie positioned directly beneath it.

Where the epiglottis is not fixed against the pharyngeal wall, an intermediate "partial peardrop" effect may be seen (fig. 3). Here the blade displaces the tongue, but not sufficiently to make contact with the hyoid, so the view is compromised. The backwards force on the epiglottis is less than with the complete peardrop effect. In the case represented in figure 3, the arytenoids

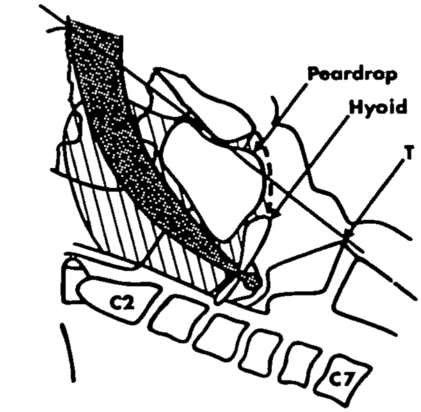

FIG. 2. The "peardrop" phenomenon. The laryngoscope blade tip is pressing against the epiglottis which is folded down against the posterior pharyngeal wall. A line is superimposed from the tip of the upper incisors (point I in figure 1) to the anterior airway point T. The blade tip is well back from the hyoid body. By comparison with figure 1, the tongue is relatively large and the area involved in the peardrop effect is shown unmarked.

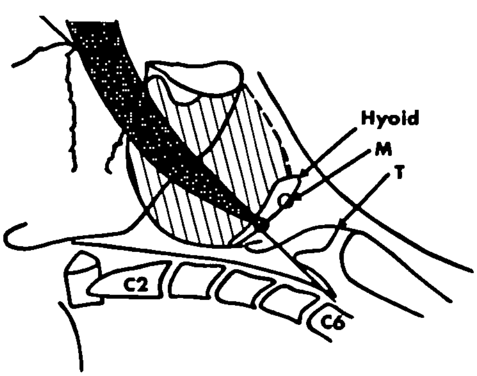

FIG. 3. "Partial peardrop" effect. The blade is not completely around the tongue. T is the anterior airway point as before, and M is an indication of where the blade tip might be expected to be located under normal circumstances. An eyeline is shown from the incisors along the under surface of the laryngoscope blade.

and larynx are shown displaced forward from the posterior pharyngeal wall. This implies that the laryngoscopic view depends on the degree of movement of the soft tissues, the actual position of the blade tip and the direction of application of the various forces involved. This intermediate stage was not seen in any of the present group of patients, so its further significance is discussed in the accompanying paper on patients with a history of difficult laryngoscopy during pregnancy [5].

DISCUSSION

The principal finding of this study is that the generally favoured curved laryngoscope blade is of limited usefulness in patients in whom laryngoscopy is of moderate difficulty and in certain circumstances may be in part responsible for some of the difficulty encountered. This observation could have important implications for future developments in laryngoscopy.

The "peardrop phenomenon" seen with x-ray laryngoscopy is caused by compression of the tongue and postero–inferior displacement results in airway obstruction on insertion of the laryngoscope. In awake, non-paralysed subjects the obstruction is corrected on removal of the laryngoscope. This suggests that local analgesia may be more appropriate in difficult cases as the tongue may be less liable to such effects when not paralysed. Under general anaesthesia with neuromuscular block it should not only occur more easily because of reduced muscle tone, but the obstruction is unlikely to clear on removal of the blade (as when assisting ventilation during a prolonged attempt at intubation).

Although the obvious action to deal with this problem is to pull the tongue forward again into the mouth, this may be difficult, for the reasons causing the problem with laryngoscopy (large tongue for the space available, limited mouth opening, or both). Other measures may also be affected. The introduction of a laryngeal mask, for example, might imitate the action of the laryngoscope blade and also tend to produce a "peardrop" effect itself. Where laryngoscopy precedes placement of such a mask, its effectiveness or otherwise may depend on whether or not the tongue remains mostly in the pharynx as a result of the laryngoscopy.

All the patients in this study were originally deemed difficult by an anaesthetist of at least senior registrar status. The finding of much better laryngoscopic vision during the investigation in two, and a suggestion that placing the blade below the epiglottis would have improved the view in a third subject, implies that reproducibility for this assessment should be questioned. It could be inferred that the inconsistency seen with senior practitioners would be worse when less experienced anaesthetists were involved. This must cast some doubt on the validity of studies aimed at predicting difficulty where there is no independent confirmation other than a single laryngoscopic assessment. In the present study, inconsistencies occurred only when there was a single documented laryngoscopy beforehand.

Perhaps one of the main limitations of assessment by laryngoscopy is its subjective nature, and hence it is proposed that the criteria defined in table I may be used as the basis for an "objective supplementary assessment". Cormack and Lehane [6] suggested that E0 grade laryngoscopy (epiglottis not seen) was unlikely to occur in the absence of obvious anatomical abnormality. The present work confirms this assertion, since all four E1 grade patients had multiple abnormalities when assessed by objective assessment criteria.

An objective assessment might be useful in a patient in whom difficulty with laryngoscopy is reported. The angular measurements require x-ray laryngoscopy under local anaesthesia, but the other measurements may be made with the minimum of equipment. The indices themselves were derived from only 10 normal volunteers and must be treated with caution at the present time. Certain problems associated with difficulty at laryngoscopy (such as limited mouth opening) were not encountered in this study. The list of assessments is obviously not exhaustive, but the principle that each index is independent of the others, takes relative size into account and is defined by the appropriate 2 and 3 SD from a mean in a normal range, should be considered a basis for further studies.

The present study was retrospective and is thus of limited value in predicting difficulty at laryngoscopy in unselected patients. Wilson and colleagues [7] and Bellhouse and Doré [8] sought to predict difficulty with tracheal intubation from simple tests suitable for routine clinical use. The "ease of intubation" angle seems to be a sensitive index of difficulty and is comparable to a similar measurement in Bellhouse and Doré's paper (the V16/V19 factor). Four of the five risk factors in Wilson and colleagues' paper (head and neck movement, jaw movement, receding mandible and buck teeth) could be seen to affect this angle directly, suggesting it may be of potential use in prospective screening. A further study showed that, as well as varying with head and neck posture, EoI showed a maximum value when the patient was placed in the proposed standard intubating position [9].

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