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Reviews

Airway assessment based on a three column model of direct laryngoscopy

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SUMMARY

Airway assessment has remained a problematic area, largely due to the low sensitivities, specificities and/or positive predictive values of most bedside tests. In this paper, a structured overview of the common preoperative airway assessment tests is presented, based on a model for direct laryngoscopy that has been previously described. This model is composed of three columns: anterior, middle and posterior. The anterior column tests are classified into the assessment of volume and compliance of the submandibular space, the range of movement of the temporomandibular joints and the flexibility of the stylohyoid ligament. Reductions in volume of the anterior column may be absolute or relative. An absolute reduction may occur with shortening of either the incisor-hyoid distance, the temporomandibular joint-incisor distance or the temporomandibular joint-temporomandibular joint distance. A relative reduction may be seen with either prominent upper front incisors or large tongues. Testing of the middle column includes a history and physical examination of the upper respiratory system, imaging of the airway (such as X-ray, computed tomography scans and/or magnetic resonance imaging scans) and nasopharyngoscopy. The posterior column may be assessed by the range of movement of the neck, especially the range of extension of the occipito-atlanto-axial complex.

By integrating common tests of the anterior, middle and posterior columns within this three-column model, the practitioner may be better positioned to understand the complexity of direct laryngoscopy in both normal and difficult airway scenarios.

Key Words: anaesthesia, airway assessment, laryngoscopy, difficult airway, prediction

Predicting a difficult airway remains problematic for anaesthetists, intensivists and emergency physicians alike. Despite the difficulties in predicting difficult intubation, there remains a need to assess the airway knowing that inaccuracies exist[1]. Many factors contribute to difficult laryngoscopy, including limited mouth-opening, short mandibular distance and limited cervical spine movement. Though previous studies[2-10] focusing on these contributory or associated factors have added significantly to this field, a reliable assessment has remained elusive[9]. Difficulties in airway assessment are compounded by inter-observer variability[11], inaccuracies in measured airway variables at the bedside, and the plethora of airway devices, each having a different impact on the airway. All of these variables may lead to unexpected difficult laryngoscopy. Experienced clinicians try to predict potential problems. A variety of different factors have been linked to difficult airways (Table 1). It is vital to understand how these factors cause difficult laryngoscopy and, more importantly, to understand their inter-relationship.

In the author's view, previous work critically evaluating individual airway tests has often failed to address the inter-relationship of these factors within an individual. This paper does not attempt to add another combination of airway tests or repeat previously published analyses in this area. It does, however, describe one approach to link commonly used airway assessment tests in a structured manner. This paper provides recommendations that are based on rational argument rather than outcomes per se.

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The basis for this approach is a model recently described by the author as the "model of direct laryngoscopy and tracheal intubation"[12], which provides an anatomical classification of difficult airways. Measurements used to predict difficult airway may, therefore, be classified into one of the three columns described in this model: the anterior, middle and the posterior columns.

ASSESSMENT OF THE ANTERIOR COLUMN

This assessment may be classified as follows (Figure 1):

- Volume of the submandibular space;
- Compliance of the submandibular tissues;
- Tethering of the inverted triangular pyramid (anterior column) at one or more of its apices:
  - One or both temporomandibular joints (TMJ): TMJ dysfunction leading to limited mouth-opening and/or failure to protrude the mandible in front of the maxillary teeth;
  - Hyoid: calcification of the stylohyoid ligament has been postulated to cause difficult laryngoscopy but the evidence is conflicting.

Volume of the submandibular space

Absolute reduction in volume

The volume of the anterior column is assessed by measuring the three sides of the inverted triangular pyramid (TMJ-incisor, incisor-hyoid and TMJ-TMJ). A reduction in one or more of these distances leads

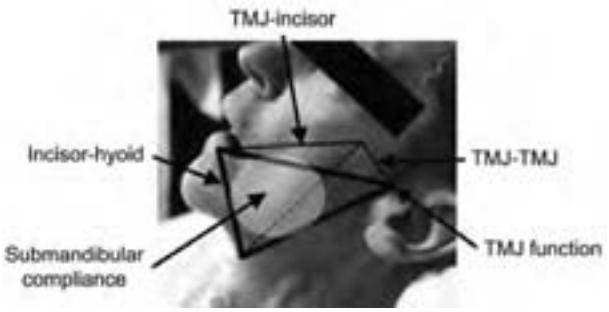

FIGURE 1: Factors for airway assessment during physical examination of the anterior column: 1) three dimensions of the inverted triangular pyramid (TMJ-incisor, TMJ-TMJ and incisor-hyoid), 2) the function of the TMJ and its ability to sublux leading to mouth-opening and mandibular prognathism during laryngoscopy and 3) compliance of the submandibular tissues. TMJ=temporomandibular joint, incisor=lower front incisors.

TABLE 1
A summary of some notable factors that influence laryngoscopy

Preoperative examination	Acceptable endpoints	Significance of endpoints
Length of upper incisors	Qualitative – normal/short incisors	Long incisors cause laryngoscope blade to enter mouth in cephalad direction
Involuntary: maxillary teeth anterior to mandibular teeth	No overriding of maxillary teeth anterior to the mandibular teeth	Overriding maxillary teeth cause laryngoscope blade to enter mouth in a more cephalad direction
Voluntary: protrusion of mandibular teeth anterior to the maxillary teeth	Anterior protrusion of the mandibular teeth relative to the maxillary teeth	Test of TMJ function; means good mouth-opening and jaw will protrude anteriorly with laryngoscope
Inter-incisor distance	>3 cm	2 cm flange on blade can be easily inserted between teeth
Mandibular space length (thyromental distance)	5 cm or 3 average-sized fingerbreadths	Larynx is relatively posterior to other upper airway structures
Submandibular tissue compliance	Qualitative – palpation of normal resilience/softness	Compliance of the tissues determines if tongue fits into space
Oropharyngeal class (modified Mallampati)	Class I/II	Tongue is small in relation to size of oropharyngeal cavity
Narrowness of palate	Should not appear very narrow and/or highly arched	A narrow palate decreases the oropharyngeal volume and room for laryngoscope blade
Length of neck	Qualitative only (a quantitative index is not yet available)	A short neck decreases the ability to align the upper airway axes
Thickness of neck	Semi-quantitative – neck circumference is used as an indicator but fails to differentiate between amount of fat and/or muscle in neck which may be significant in obese and non-obese patients	A thick neck decreases the ability to align the upper airway axes

Adapted from the American Society of Anesthesiologists Task Force on Difficult Airway Management: Practice guidelines for management of the difficult airway[13]. TMJ=temporomandibular joint.

to a small anatomical space into which the submandibular tissues must be compressed. This in turn leads to difficult laryngoscopy. A reduction in the TMJ-incisor distance correlates with a small mandibular length or retrognathia. A reduction in the incisor-hyoid distance is related to a small thyromental distance. Finally, the reduced TMJ-TMJ distance is associated with a narrow palate, which in turn leads to difficult laryngoscopy.

Relative reduction in volume

A relative reduction may occur with either: 1) large tongue volume relative to the volume of the bony limits of the anterior column or 2) prominent top incisors requiring more mandibular protrusion during direct laryngoscopy. A large tongue relative to the size of the triangular pyramid will usually be associated with a Mallampati III/IV. This in turn produces a difficult laryngoscopy due to problems displacing sufficient glottic tissue anteriorly. The commonest example of tongue enlargement is that occurring in late pregnancy[14] and an extreme example is the macroglossia that occurs in acromegaly.

Prominent upper front incisors are also associated with difficult laryngoscopy. This is due to: 1) cephalad insertion of the laryngoscope blade into the mouth so that the line of sight is more vertical, and 2) similar to short mandibular distance (or 'absolute' retrognathia) (Figure 2A), a 'relative' retrognathia (Figure 2B) is produced because prominent upper front incisors require greater protrusion of the mandible to get anterior to the maxillary teeth. This extra subluxation at the TMJs may provide the straight line of vision required for successful laryngoscopy. The corollary of prominent maxillary incisors is when maxillary incisors are missing and the patient has a top denture plate. In this situation, less mandibular protrusion is necessary to provide a line of sight during laryngoscopy.

Compliance of the submandibular tissues

Assessment of the submandibular compliance remains largely qualitative. A history of conditions that predispose to low compliance states should be sought. These conditions include previous radiotherapy to the submandibular area, neck masses, haemorrhage or infection of the submandibular space and severe burns of the neck and jaw. Currently, no objective measurement of submandibular compliance as part of airway assessment has been reported. Tissue compliance measurements are, however, used for objective measurement of soft tissue consistency in many other neurological, lymphostatic and venous disorders. Currently, handheld computerised soft tissue stiffness meters are available, which measure the soft tissue stiffness in the form of the instantaneous force by which the tissue resists the constant deformation produced by a cylindrical intender[15]. Such measurements may prove advantageous as part of routine submandibular compliance assessment, but require further investigation.

Tethering of the inverted triangular pyramid (anterior column)

Tethering of the anterior column may occur with either dysfunction of the TMJs or calcification of

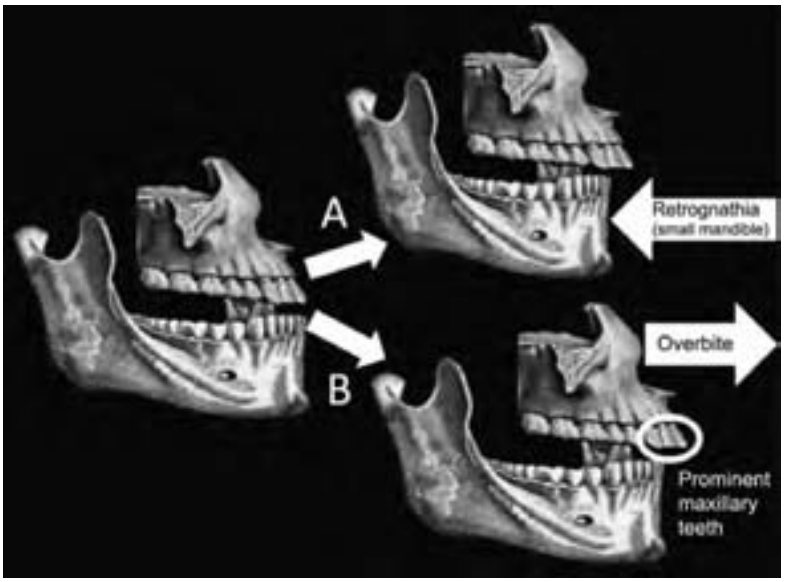

FIGURE 2: Low volume of the submandibular area may be created by shortening of the mandible (retrognathia) producing an 'absolute' reduction of the space (A). Alternatively, overbite or prominent maxillary teeth create a 'relative' volume reduction by requiring a greater distance for the mandible to protrude (B).

the stylohyoid ligament. The TMJ has two functions, hinge movement and subluxation or gliding movement on the maxilla[16]. Consequently, TMJ dysfunction may be evident by limited mouth-opening and/or an inability to protrude the mandible in front of the maxilla. There are several causes of TMJ dysfunction both intrinsic and extrinsic to the joint. Examples of intrinsic conditions include bony fractures disrupting the joint surface, while extrinsic conditions include masseter spasm and burn contractures.

Calcification of either one or both stylohyoid ligaments has been associated with difficult laryngoscopy[17-19]. This rare condition has also, however, been associated with normal laryngoscopy[20] in a case report and further information is required to understand this problem.

ASSESSMENT OF THE MIDDLE COLUMN

Assessment of the middle column or airway passage for conditions such as laryngeal tumours and lingual tonsillar hypertrophy follows a well-established process including: 1) an adequate history and physical examination, 2) imaging of the airway passage and 3) nasopharygoscopy. Unfortunately, each of these factors, except for recent laryngoscopy grading during anaesthesia, involve an awake patient, and therefore the correlation with laryngoscopy grading during anaesthesia is problematic.

Imaging of the airway conduit may involve X-ray, computed tomography scanning or magnetic resonance imaging scanning. These modalities evaluate with differing levels of accuracy and spatial resolution. The advantages and disadvantages of each should be considered when choosing the appropriate modality for the patient's condition. Fibreoptic nasopharyngoscopy under local anaesthesia, commonly performed by an ear, nose and throat specialist, may be considered an easier alternative, possibly cheaper and more readily available than imaging. Though ear, nose and throat surgeons share a close relationship with anaesthetists in airway management, they may not be aware of the various devices and manoeuvres that can be used by anaesthetists in difficult airway management[21]. In addition, fibreoptic pharyngoscopy is performed in the sitting or semi-reclining position instead of the sniffing position frequently used by anaesthetists[21]. It is therefore possible that the results of the examination may not correlate with some of the important aspects of the functional anatomy pertaining to difficult airway management in anaesthesia.

A clinically relevant assessment of the middle column remains problematic for the anaesthetist and continues to demand a high degree of expertise when the airway proves difficult to manage, before and after anaesthesia is induced. The changes in the tone of the airway musculature and airway maintenance are difficult to predict in an anaesthetised patient.

ASSESSMENT OF THE POSTERIOR COLUMN

The posterior column is assessed by measuring the range of movement of the cervical spine and the ability of the patient to achieve a 'sniffing' position. Bannister and Macbeth[22] refined Magill's description of a sniffing position by proposing a need to align the oral, pharyngeal and laryngeal axes when the head is placed in a number of positions. Horton[23] further developed the optimal sniffing position by determining "ideal angles" for upper and lower cervical flexion as 15° and 35°, respectively (Figure 3).

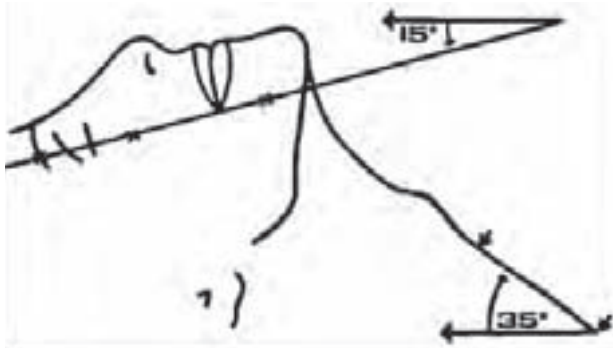

FIGURE 3: The standard intubating position. The supraorbital, infraorbital and mental foramina are labeled x and shown to be in line at an angle of 15° of declination. The line of neck flexion is defined by two points: the upper is the cricoid and the lower is level with the lowermost depth palpable in the sternal notch[23].

These ideal angles have been endorsed by Benumof[24]. He extended this principle to severely obese patients who frequently require elevation of the shoulders and neck region as well as additional elevation of the head to achieve an optimal position. Some authors have described this as the "ramped"[25] or "stacked"[26] position in contrast to the 'sniffing position', which they achieved by elevating the head by 7 cm[25]. The latter degree of elevation in obese patients results in a position more closely aligned with the neutral rather than the sniffing position, with the head position below the anterior chest wall. The ramped position is produced by aligning the external auditory meatus with the sternal notch[27].

This will result in flattening of the primary and secondary curves similar to normal weight patients and essentially achieves a true sniffing position in obese patients.

Difficulty in achieving an appropriate sniffing position for laryngoscopy also occurs with short, thick-necked patients (Figure 4).

Therefore, the assessment of neck mobility must focus on the ability of the patient to assume the sniffing position relevant to their body habitus. Further research into these patients' head position in relation to the antero-posterior diameter of their chest is required comparing patients with normal build, those with short, thick necks and the morbidly obese.

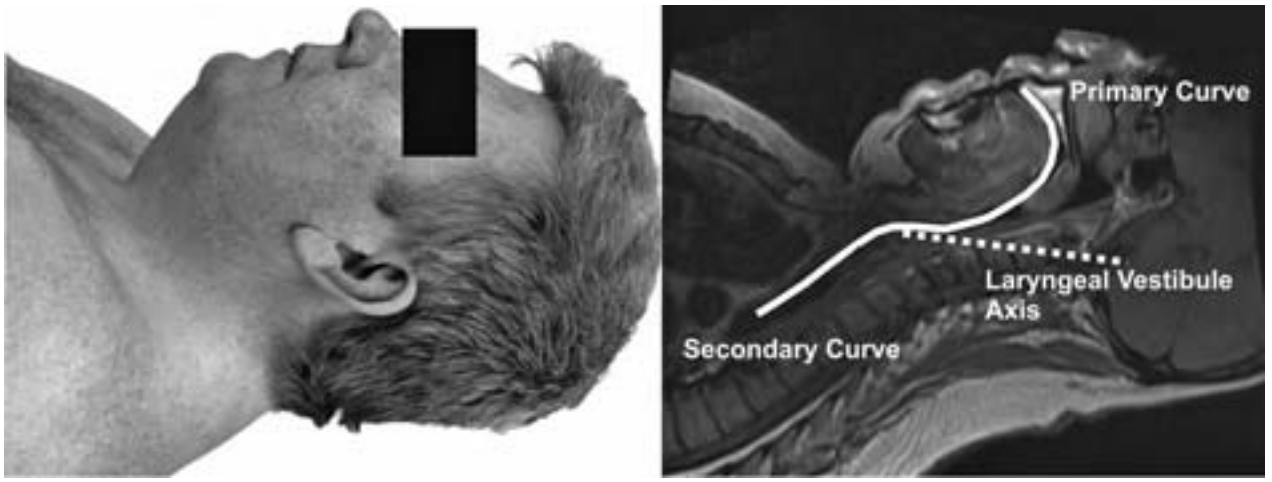

FIGURE 4: Magnetic resonance imaging of a patient on left with a short, thick neck positioned on one pillow. Note the laryngeal vestibule axis is upsloping. Further ramping of the head and neck position is required before laryngoscopy is attempted. (Consent for publication of the photograph and magnetic resonance imaging scan was obtained from the patient.)

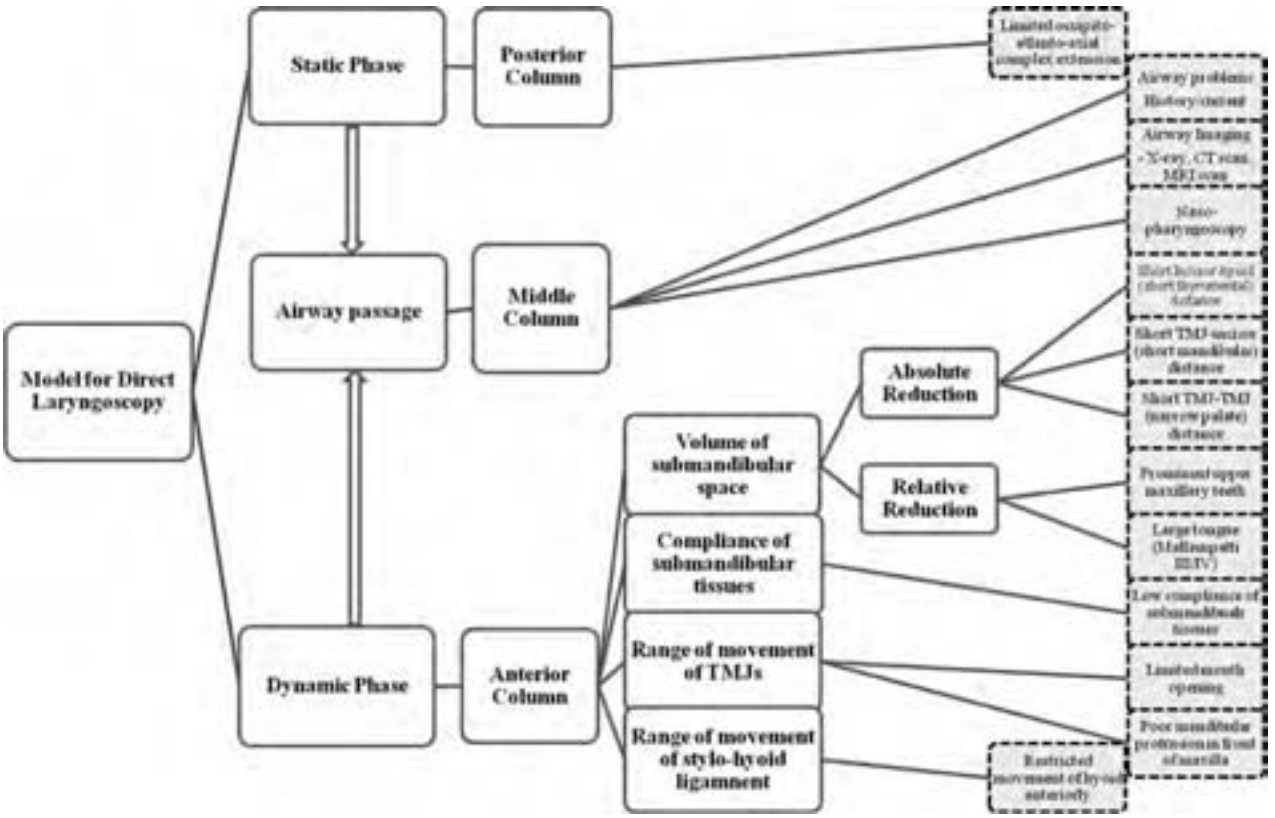

FIGURE 5: Integrated assessment of all three columns using the proposed 'model for direct laryngoscopy'. (Elements of the model in clear boxes; airway assessments in shaded boxes.) TMJ=temporomandibular joint, incisor=lower front mandibular incisors.

COMBINING THE ANTERIOR, MIDDLE AND POSTERIOR COLUMNS IN AIRWAY ASSESSMENT

Airway assessment studies have shown that the more individual tests performed, the better the correlation with difficult airway prediction[6,9,28]. Importantly, when anterior, middle and posterior columns test are all included in the assessment, the correlation with difficult intubation is closest[6,9,10]. The proposed 'model for direct laryngoscopy' may be used to provide a basis for a structured airway assessment. The relationship of individual pre-intubation tests to the static and dynamic phases of direct laryngoscopy is shown in Figure 5.

CONCLUSION

This article attempts to provide an approach to the integrated use of various tests that have been used to predict difficult laryngoscopy, using a previously described model for airway assessment. By integrating common tests reflecting the anterior, middle and posterior columns within the model, the practitioner may be better positioned to understand the complexity of direct laryngoscopy in both normal and difficult airway scenarios.

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