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SPECIAL ARTICLE

A proposed model for direct laryngoscopy and tracheal intubation

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In 1913, Chevalier Jackson [1] described his method of laryngoscopy while his assistant Boyce supported the patient's head and neck in an elevated position ('Boyce-Jackson position'). Magill [2] in 1936 suggested the term the 'sniffing position', which has since gained wide acceptance as the best position for direct laryngoscopy. Later, Bannister and Macbeth [3] proposed the need for aligning the mouth, pharyngeal and laryngeal axes.

However, Adnet and workers [4–7] criticised the 'sniffing position' and found no significant improvement over simple extension of the head and neck, unless the patient was obese or had reduced neck mobility. Furthermore, previous studies have proven that it has been challenging to find a reliable pre-operative predictor for difficult laryngoscopy and tracheal intubation [8–11]. The problem arises from variations in investigators' assessments, as well as a variety of definitions for different aspects of difficult airway management [12, 13].

I attempt to reassess these issues, initially analysing how laryngoscopy succeeds in the 'normal' patient, and then proposing a new model describing the mechanism for successful direct laryngoscopy. Such a model aims to explain how extremes in the normal population, including particular pathological conditions, cause failures in the performance of direct laryngoscopy.

Dynamic phase of laryngoscopy

Separate from the static component of upper airway axes alignment, the dynamic phase of direct laryngoscopy is the second essential component to successful laryngoscopy. Boidin [14] argued that the hyoid formed the boundary between two parts of the airway – the pharynx and larynx. Anteroposterior shift of the hyoid leads to changes in the position of the epiglottis that may obstruct air flow within the airway. Further work by Horton and workers [15] showed that during laryngoscopy with a curved Macintosh blade in awake patients, the hyoid is drawn forward and downwards with a variable length of epiglottis.

If the hyoid is unusually low in the neck, leading to a long mandibulohyoid distance, a large portion of the tongue mass is situated in the hypopharynx rather than in the oral cavity [16,17]. Chou and Wu [18] postulated that, under general anaesthesia, this large hypopharyngeal tongue creates a narrowed air space and the epiglottis frequently falls against the posterior pharyngeal wall [16], resulting in difficult ventilation, difficult intubation and obstructive sleep apnoea [18]. The hypopharyngeal tongue leads to a reduction in the submandibular compliance, making tongue displacement difficult when lifting the laryngoscope blade.

A short mandibular ramus may lead to difficult laryngoscopy. First, the tongue will occupy more of the oral cavity and, consequently, there will be difficulty aligning the oral and pharyngeal axes during direct laryngoscopy. The short ramus may also lead to an increased mandibulohyoid distance and problems of a hypopharyngeal tongue, as mentioned above. It is therefore possible that the relationship of the three measurements (length of the mandibular ramus, mandibulohyoid distance, and the volume of the genioglossus muscle) are the contributing factors in difficult laryngoscopy. The thyromental distance is thus an oversimplification of a complex relationship between these anatomical structures, and therefore, understandably, will have a poor predictive value for difficult laryngoscopy [8].

A model of the head and neck for difficult intubation

A better understanding of difficult intubation may be achieved by the development of a clinically accurate model that is able to explain individual cases of difficult intubation and to predict when difficulties will occur. In addition, the model should be able to suggest the best intubation technique for the type of difficulty encountered, including the type of laryngoscope and appropriate additional intubation devices. The components of such a model for direct laryngoscopy are shown in Fig. 1.

Static positioning of the head and neck before laryngoscopy: the posterior complex

Traditionally, the static positioning of the head and neck involves the appropriate alignment of the pharyngeal axis with the line of vision (Fig. 2). The ability to position the patient's head and neck optimally in the sniffing position is governed by the ability to flex the lower cervical spine, and extend the occipito-atlanto-axial complex. Overall, this may be referred to as the posterior complex.

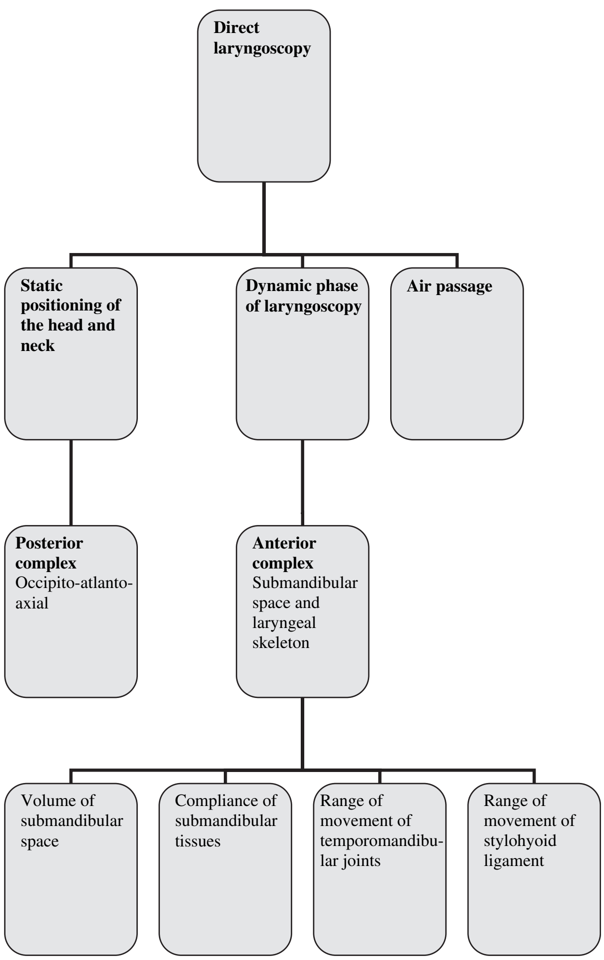

Figure 1 Components of the proposed model for direct laryngoscopy.

Popitz [19] described the occipito-atlanto-axial complex as having a range of extension of approximately 30°, limited in the normal patient by the anterior longitudinal ligament, the tectorial membrane and the ligamentum flavum. The atlanto-occipital distance is the major factor which limits extension of the head on the neck in many cases [20–23], with the range of extension of the atlanto-occipital joint alone being approximately 20° (with only 5° of flexion) [24]. This limited range of extension is therefore a significant factor in the static positioning of the patient, whether in the hyperextended or sniffing position for laryngoscopy. The distance between the spine at C1 and the occiput varies markedly within the normal population, and in a significant number of patients the spine of the atlas actually contacts the occiput in the neutral position. In these patients, extension of the head at this joint is impossible, and may only be achieved by some limited extension of the atlas and axis (although the main function is rotation, there is a limited range of extension – approximately 10° [24]), as well as bowing forward of the cervical spine and subaxial extension [25]. This may lead to the larynx being lifted anteriorly and out of the line of sight during laryngoscopy [21].

Clinical conditions that involve cervical spine abnormalities, especially involving the occiput-C1-C2 spine, will predictably lead to difficult laryngoscopy. Rigidity of the cervical spine may be due to previous surgical fusion, pathological conditions such as rheumatoid arthritis and ankylosing spondylosis, or external stabilisation forces caused by axial traction, manual inline stabilisation, halo-vest fixation, and hard (Philadelphia) cervical collars.

Dynamic phase of laryngoscopy: the anterior complex

This phase predominantly consists of a number of movements. Essentially the mouth is opened and the mandible is anteriorly displaced. The submandibular space is also anteriorly displaced, as well as shifted laterally and partially compressed. Factors affecting this displacement frequently involve abnormalities of the mandible–anterior neck area or anterior complex, which is mostly composed of the submandibular space and laryngeal skeleton.

The anterior complex of the neck may be considered an imaginary inverted triangular shaped pyramid (Fig. 3). The three apices of the base are formed by the two temporomandibular joints and the bottom front incisors. The sides of the pyramid drop down and intersect at the hyoid bone (the apex). The base of the pyramid is the cephalic surface of the tongue and oral mucosa of the floor of the mouth and extends along the two rami of

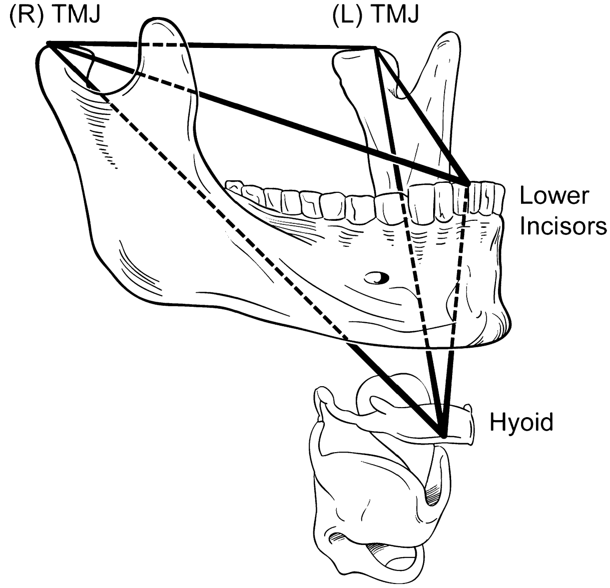

Figure 3 Submandibular space bounded by the two temporomandibular joints (TMJs), lower incisors and hyoid bone.

the mandible. The area below the hyoid is outside this pyramid, and is dominated by the laryngeal apparatus. The contents of this pyramid are composed of the submandibular space, subdivided by the mylohyoid muscle, which acts as a sling below the mandible, into the sublingual and submylohyoid spaces. The anterior muscular contents of the submandibular space are largely composed of the genioglossus muscle. Posteriorly are the hyoglossus, styloglossus and stylopharygeus muscles.

During the dynamic phase of direct laryngoscopy, the mandible is drawn forward and the muscle bulk of the submandibular space is compressed anterolaterally to provide a line of vision to the glottis. The ability of the anaesthetist to shift the submandibular tissues and the mandible anteriorly is dependent on the following:

Volume of the submandibular space

The contents of the submandibular space must be compressed sufficiently within its boundaries to accommodate the muscle bulk, so as to provide an enlargement in the airway that provides an adequate line of sight to intubate the trachea. Conditions such as Pierre Robin syndrome (including micrognathia) illustrate the problems of an inadequately developed mandible and a confined submandibular space which is unable to accommodate the submandibular contents during the dynamic phase of

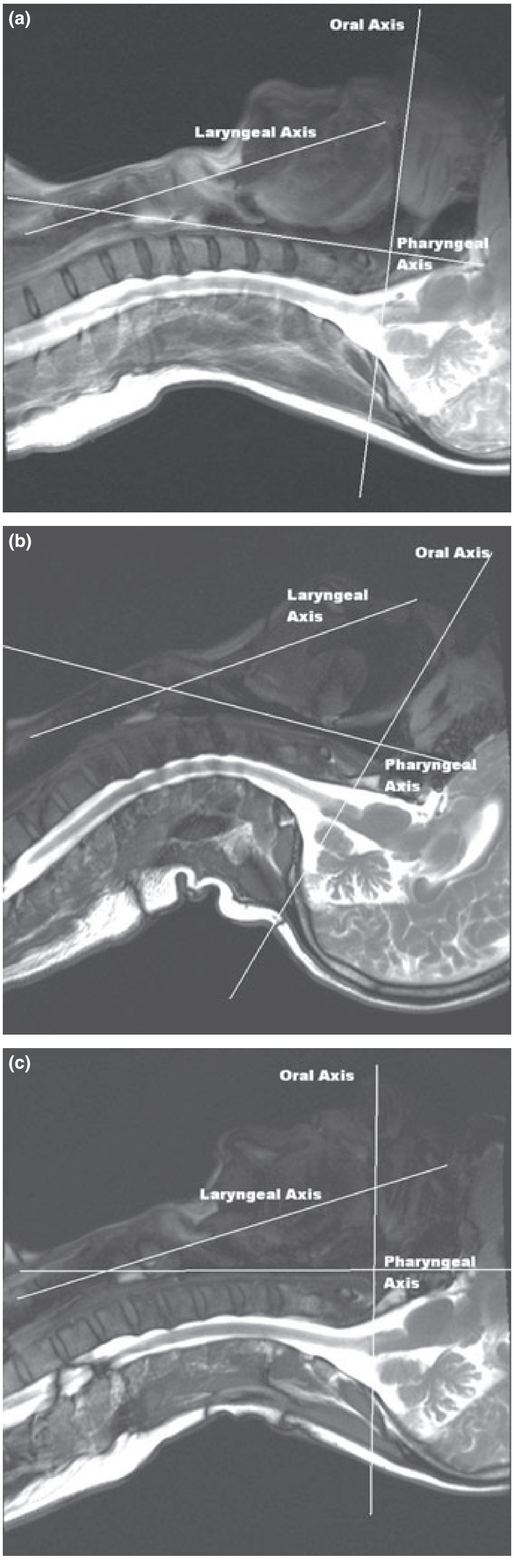

Figure 2 Magnetic resonance imaging scans of head and neck showing alignment of the oral, pharyngeal and laryngeal axes: (a) neutral position; (b) hyperextended position; (c) sniffing position.

laryngoscopy. Measurement of the thyromental distance is an indicator of the size of this space, but when the boundaries of the space are considered, it is understandable why this single measurement fails to provide a clear indication of the total volume of the submandibular space and therefore difficult laryngoscopy. Assessment of the volume of the submandibular space requires a combined measurement of each side of the pyramid – the mandibular length, the distance between the temperomandibular joints and the mandibulohyoid distance. This volume may be within the normal range but may prove to be insufficient in cases where the submandibular tissues are enlarged. Reclassification of patients with short thyromental distances into those with small and large submandibular spaces relative to the submandibular tissues is required, for application in this model.

Compliance of the submandibular tissues

A low compliance of the submandibular tissues will lead to difficult laryngoscopy, as these tissues will be unable to be compressed into the space required. A long mandibulohyoid distance leads to a hypoglossal tongue that is difficult to compress into the space. Other conditions that lead to an abnormally low compliance of the submandibular tissues and difficult laryngoscopy include infective causes such as Ludwig's angina, angioneurotic oedema of the tongue, burns to the skin of the neck, radiotherapy to the head and neck area, and tumours of the neck region.

Range of movement of the temporomandibular joints

Assessment of the temperomandibular joint should have the same importance as the assessment of the cervical spine before laryngoscopy [26]. Approximately the first 20 mm of mouth opening is largely a passive process involving relaxation of the masticatory muscles, except the suprahyoid and lateral pterygoids. The remaining 25 mm of opening is related to a forward translation movement of the superior disc [26]. This forward translation of the temperomandibular joint, with opening of the mouth and anterior mandibular advancement, improves the retropalatal [27–29] and velopharyngeal [28] airway, the first step during the dynamic phase of direct laryngoscopy.

Range of movement of the stylohyoid ligament

Calcification of the stylohyoid ligament has been described as a cause of difficult laryngoscopy [30–32]. However, a 19-year-old male who presented with complete bilateral calcification of the stylohyoid ligaments was reported to have a Cormack and Lehane grade 1 on direct laryngoscopy [33]. The authors stated that the patient had no other indicators, apart from the calcified stylohyoid ligaments, of difficult laryngoscopy. Based on one case report, it is impossible to draw any significant conclusions, although it may be possible that an isolated rigid stylohyoid ligament is insufficient to cause difficult laryngoscopy, and that it may need to be associated with other limiting factors to create difficulties.

Air passage

Encroachment upon the airway may occur with a wide variety of conditions including foreign bodies, infective conditions such as epiglottitis, peritonsillar and retropharyngeal abscess, papillomatosis of the larynx, thermal injuries and neoplastic conditions. The ability to perform successful laryngoscopy in each case will depend on the details of each condition and the degree of airway restriction.

The lateral pharyngeal walls are more 'compliant' [34] than the soft palate and tongue and, if redundant, may lead to obstruction of the airway and obstructive sleep apnoea. In obese patients, adipose tissue is deposited from the nasopharynx to the laryngopharynx [35], increasing the likelihood of collapse of the pharyngeal walls during laryngoscopy [36, 37]. If the patient is obese and does not have obstructive sleep apnoea or other indicators of difficult airway, then the body mass index alone is not associated with difficult laryngoscopy [38]. This is in keeping with the model, as the air passage is normal in patients with a high body mass index without the lateral wall adipose tissue deposits.

Conclusion

Direct laryngoscopy and tracheal intubation have been performed for almost 100 years and are now practised in many aspects of medical practice, including anaesthesia, intensive care and emergency medicine. At present, a number of aspects of difficult airway management remain unresolved:

- a reliable assessment tool that predicts difficult laryngoscopy/intubation and may be applied to anaesthesia in the peri-operative, intensive care and emergency medicine environments;
- an understanding of the mechanics of successful and difficult/failed direct laryngoscopy;
- an understanding of the mechanics of successful laryngoscopy and difficult/failed tracheal intubation;
- a method of predicting the appropriate airway device for a specific airway problem;
- the development of future airway devices for unresolved difficult airway management.

This paper suggests a new model of direct laryngoscopy/tracheal intubation to analyse direct laryngoscopy into static and dynamic phases and hence attempts to resolve these five issues.

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