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Functional features of anatomical structures affecting the process of endotracheal intubation

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Abstract

The study of the morphofunctional features of various structures of the head and the neck, as well as their congenital and acquired changes, enables a better understanding of conditions that influence performance of endotracheal intubation. Knowledge of the patient's individual anatomy enables one to forecast and to minimize incidence of intubation failure that might lead to adverse consequences, including dental trauma, damage to respiratory tract, hypoxic brain damage, and even death. As early as on the stage of collecting the patient's history, the anesthesiologist has to anticipate possible complications and identify the factors that might lead to complicated intubation and provision of anesthetic support.

This study analyzes the functional peculiarities of the anatomical structures influencing the process of endotracheal intubation, that are considered in the scales for the assessment of difficult airways and that cause complications for the visibility of the glottis. The article also dwells on various diseases that could cause difficult intubation of the trachea. The generalized results of these studies may be instrumental in the development of new methods and approaches towards the tracheal intubation procedure.

Keywords: endotracheal intubation, determination of patency of airways, head tilt, opening of the mouth, obstruction of airways.
Conflict of interest: nothing to disclose.

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Функциональные особенности анатомических структур, влияющих на процесс эндотрахеальной интубации

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Аннотация

Изучение морфофункциональных особенностей различных структур головы и шеи, а также их врожденных и приобретенных изменений позволяет более глубоко понять условия, которые оказывают влияние на проведение эндотрахеальной интубации. Знание индивидуальных анатомических особенностей пациента позволяет спрогнозировать и минимизировать количество случаев неудачной интубации, приводящей к серьезным последствиям, включая травму зубов, повреждение дыхательных путей, гипоксическое повреждение головного мозга и даже смерть пациента. Анестезиолог уже на этапе сбора анамнеза должен предусмотреть возможные осложнения и распознать факторы, которые могут привести к трудной интубации и осложнить оказание анестезиологического пособия.

В настоящем обзоре проведен анализ функциональных особенностей анатомических структур, влияющих на процесс эндотрахеальной интубации, учтенных в шкалах для оценки трудных дыхательных путей и являющихся причиной затруднения видимости голосовой щели. Также в статье рассматриваются различные нозологии, которые могут быть причиной трудной интубации трахеи. Обобщенные результаты этих исследований могут помочь в разработке новых методов и подходов к процедуре интубации трахеи.

Ключевые слова: эндотрахеальная интубация, оценка проходимости дыхательных путей, запрокидывание шеи, открывание рта, обструкция дыхательных путей.

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INTRODUCTION

In the practical anesthesiology, the incidence of difficult airways is 2-5% from the total number of cases of tracheal intubation. Difficult airways might cause complications hazardous to the patient's life [1]. This situation occurs in the event the visibility of the glottis is obstructed. As early as on the stage of collecting the patient's history, the anesthesiologist has to anticipate possible complications and identify the factors that might lead to complicated intubation and provision of anesthetic support.

The study of the morphofunctional features of various structures of the head and the neck, as well as their congenital and acquired changes, enables a better understanding of conditions that influence performance of endotracheal intubation.

This study analyzes the functional peculiarities of the anatomical structures influencing the process of endotracheal intubation, that are considered in the scales for the assessment of difficult airways and that cause complications for the visibility of the glottis.

SCALES USED TO EVALUATE AIRWAY PATENCY

The following scales for the airway patency assessment are used in clinical practice: LEMON, El-Ganzouri, and Intubation Difficulty Score (IDS).

The LEMON score includes evaluation of the facial injuries, large incisors, mustache or beard, large tongue [1, 2]. In 2018, S. Ji confirmed the efficacy of the LEMON score having shown that it correlated with intubation difficulties in 114 adult patients with injuries who underwent urgent operation under general anesthesia. This means that the LEMON score may be instrumental in the prediction of difficulty of intubation of patients [3].

Mallampati described 4 classes of visualization of mouth cavity structures that can be used to predict difficult intubation. In Class I patients, the soft palate, the uvula, the palatoglossal and the palatopharyngeal are completely visible; in Class II, palatal arches and the soft palate are visible, but the uvula is obstructed by the tongue; in Class III, only the frontal section of the soft palate is visible; and in Class IV, the soft palate is not visible at all [4].

According to the El-Ganzouri index, the risk of difficult intubation increases if the oral opening expands by less than 4 cm between the lips, the thyromental distance is less than 6.5 cm, Mallampati Class II or III, amplitude of the neck mobility is below 90°, the jaw thrust is not possible, the body weight is over 90 kg, and there is a history of difficult intubation.

In contrast to the El-Ganzouri risk index, the LEMON scale primarily assesses the patient's appearance and the geniohyoid and thyrohyoid distances, and the presence of airway obstruction and protrusion of the lower jaw are taken into account, which is not considered in other scales.

The IDS distinguishes such criteria as sternomental distance and short neck [5]. Using the stereotopometric method, the location of the anatomical structures of the thyroid cartilage relative to three mutually perpendicular planes was determined, taking into account sexual dimorphism and the body type of the subjects. Using the data obtained, it is possible to predict the width of the glottis [6].

It is also worth considering the upper lip bite test developed by Z.H. Khan in 2003 to replace the Mallampati scale. To perform the test, the patient is asked to protrude the jaw and bit the upper lip with lower incisors. The test allows

evaluation of the movement range of the jaw and the work of the temporomandibular joint. The specificity of the upper lip bite test is considered to be considerably higher than the measurement of the tiromental, sternomental, and the interincisal distance separately [2, 7].

All three scales consider such factors as degree of mobility of the neck, mobility of the jaw: the degree of oral opening directly depends on these. In the process of tracheal intubation, the patient's head tilted back, and any problems of neck mobility might complicate the intubation. The sternomental distance, i.e. distance between the chin and the episternim, that is the indicator of the mobility of the head and the neck, is also to be taken into consideration: according to the IDS, it has to be at least 12.5 cm. If this value is below 12.5 cm, it is a case of difficult intubation [8].

CAUSES OF MOBILITY DISORDERS OF THE CERVICAL SPINE

We shall now look into the causes that impede normal back tilting of the head: the short neck, disruption of the biomechanics of the atlanto-occipital and atlanto-axial joints, hernias and injuries, and other diseases of the cervical section of the spine. The abnormally short neck is one of the causes of difficult intubation. The shorn neck may be seen in the Klippel-Feil deformity (congenital fusion of the cervical vertebrae) characterized by the distortion of the segmentation and differentiation of the cervical somite in the embryogenesis, where the second and third, fifth and sixth cervical segments are most frequently involved [9]. Usually people with dolichomorphic body type have a long and narrow neck, and people with brachymorphic body type, a short and broad neck [10]. The shape of the neck is identified individually by the specific features of the structure of cervical vertebrae, specific features of the upper aperture of the thorax and the external base of skull [11]. There are no national or international standards of the neck length. In their study, P.V. Mahajan, B.A. Bharucha (1994) attempted at compiling standards and percentile diagrams and calculate the correlations of the neck length with linear dimensions such as height in the standing and seating position that would be independent from the age. The neck length was, on average, 12.7±4.58% of the height and 20.1±6.73%, respectively. The linear regression equations independent from the age: neck length = 10 + (0.035 × height) and neck length = 9.65 + (0.07 × height in the seated position), were highly significant ($p < 0.001$) [12].

The range of flexion of the atlanto-occipital joint is approx. 13°. If the range is below this value, there may occur difficulties in the back tilting of the head, which, in its turn, may obstruct the visibility of the glottis [13].

Stability disorders in the cervical region of the spine may be caused by degenerative disk diseases, which result in the replacement of the fibrous ring tissue with scar tissue with much lower strength; therefore, the intervertebral disk becomes weak, and, with increased pressure, the fibrous ring might rupture. The mobility of the neck may be affected by the invagination (indrawal) of the odontoid [14]. In the operations in the region of the medial atlanto-axial articulation there may occur difficulties in choosing the intubation method due to close passage of the upper respiratory tract [15, 16].

Bekhterev's disease (ankylosing spondylitis of the neck) that involves both the vertebral body and the anular epiphysis and is characterized with progressive pathological kyphosis and scoliosis, presence of tendonitis, tendovaginitis and enthesitis, leads to a complete ankylosing of the joints, also affects the biomechanics of the cervical region of the spine [17]. The difficulty in the back tilting of the head may be accounted for by the rigidity of the occipitalis muscle in meningitis [18].

The mobility of the neck depends directly on the fractures of the cervical spine. Tracheal intubation for this category of patients is reasonably difficult due to a high probability of iatrogenic damage during the manipulation [19].

The hernias in the cervical spine are characterized with clinical polymorphism and lead to disorders in the static condition of this region, to displacement of the vertebral pulp, and pinching of the spinal nerves. The rate of incidence of herniation of the cervical disk increases with age and comprises up to 60% of cases, among patients of either sex it was diagnosed most frequently in the age group of 51-60 years [20]. The damage of the cervical region of the spine is seen in patients with rheumatoid arthritis in 86% of cases [21].

Limited mobility of the neck is seen in cases of obesity that created additional burden on the cervical spine [22].

This emphasizes the necessity of taking into account of the individual features of the patient, their somatotype and length of the neck in order to choose the best approach and ensure safety of the procedure.

DEGREE OF ORAL OPENING

The degree of oral opening directly depends on the mobility of the jaw and the proper biomechanics of the temporomandibular joint. The average value and the range of maximum oral opening was identified at 50.3±6.26 mm for men and 49.9±6.74 mm for women, which correlated to the width of three fingers. The maximum average oral opening was registered in the younger age group, and the minimum in the senior age group of either sex [23].

Micrognathia and abnormal bite directly affect the mobility of the mandible. Micrognathia may be the cause of the short tiromental distance, which is considered an indicator of the mandibular space. It was found that successful intubation needs more than 6.5 cm of tiromental distance. If this distance is less than 6.5 cm, it is a case of difficult intubation [1]. Micrognathia may be congenital and acquired. Congenital micrognathia is rooted in disorders of the embryogenesis (first arch syndrome), damage of the growth plate of the mandible, lack of or damage of primordia of the primary and secondary teeth, Down's syndrome and Pierre Robin syndrome [24]. Micrognathia may be the cause of abnormal bite. The formation of the abnormal bite may also be based on the infants' habit of suckling (long-term breast-feeding, bottle feeding, habit of sucking a pacifier or a finger), as well as on night-time open-mouth breathing [25].

Another reason of poor oral opening may be the pathology of the temporomandibular articulation. According to results of epidemiological studies, muscle and joint dysfunction of this articulation is found in 5-12% of the population, much more frequently in women (70-82%), than in men [26]. The pathologies of the organ may include several conditions: arthritis, arthrosis, ankyloses, and others. The causes of

development of the arthritis of the joint may be as follows: local infection (paradontosis, gingivitis, stomatitis, otitis, tonsillitis, osteomyelitis of the jaw), general infectious diseases (acute respiratory infections, influenza, pneumonia, dysentery, tuberculosis, syphilis), allergic diseases, outcomes of trauma [27]. Osteoarthritis of the temporomandibular joint is characterized with synovitis, cartilage destruction and remodeling of the subchondral bone [28]. Ankyloses develops due to fibrous or osseous fusion of the articular surface of the temporomandibular joint [29]. In the case of hyperplasia of the coronoid process, there are clinical observations of progressive reduction of the amplitude of oral opening, usually bilateral and painless [30]. The fracture of the condylar process causes loss of integrity of the mandible, which results in disorders of the joint biomechanics, ankyloses, loss of balance in the growth of the lower jaw (in children), which is detrimental to its function [31].

Tumors of the head and neck region may also restrict oral opening. Radiotherapy assigned to patients with malignant tumors of the head and the neck causes microvascular and lymphatic changes, tissue fibrosis, edema, and reduced salivations. It is related to an increased risk of development of trismus, or a masticatory spasm, limiting the mobility in the temporomandibular joint (5-38%), which directly influences the capability of normal opening of the mouth [32].

MACROGLOSSIA

Large tongue may also cause difficult intubation. The length and the width of the organ are placed within the range of 70-120 mm and 45-75 mm, respectively. Macroglossia may be congenital and acquired. Congenital macroglossia either had genetic background or is due to harm to the fetus in the course of pregnancy: Beckwith-Wiedemann syndrome, Down's syndrome, Pompe's disease, mucopolysaccharidosis [33-35]. Among the causes of acquired macroglossia, there are various injuries (mechanical, physical, or combined), endocrine dysfunction, and tumor masses [36]. In the cases of misplacement of the thyroid gland, tongue size was also observed, and this may complicate the endotracheal intubation [37]. Cancer of the tongue accounts for 65% in the incidence rate of malignant neoplasms of the mouth cavity; it develops from the elements of squamous epithelium. The disease is found 5-7 times more frequently in men than in women, usually in advanced age, after 50 [38].

CAUSES OF OBSTRUCTION OF RESPIRATORY TRACT

Laryngomalacia may cause obstruction of the airways due to changes in the position of the epiglottic cartilage, arytenoepiglottic and interarytenoid folds. The assessment of entry into the larynx in such patients sometimes reveals the collapse of the epiglottic cartilage, dense arytenoepiglottic folds, omega epiglottis, retroflexed epiglottis, prolapse of the interarytenoid fold. The distance from the laryngeal ventricle to the vocal process of the arytenoid cartilage varied from 7.8±0.2 to 12.4±0.33 mm [39].

In tracheomalacia, weakness is observed in tracheal rings that perform the carcass function of the airways, which causes its anterior inclination. Thus, the patency of airways is impeded and the positioning of the endotracheal tube is complicated. Clinical practice has seen lots of cases, in which patients with tracheomalacia developed tracheal diverticulae caused by congenital or acquired weakness of the tracheal wall. In emergency situations, the presence of large tracheal diverticula can complicate the process of inserting a tube into the airway, since diverticula are benign cystic formations that obstruct the lumen of the airway [40].

Gastroesophageal reflux disease may cause abnormal laryngostenosis due to the effect of chemical components [41]. Chronic inflammation of the laryngeal mucosa leads to its swelling and disruption of the normal structure of the organ tissues, replacing them with scar tissue and causing a narrowing of its lumen, which makes it difficult to visualize the glottis [42].

Angioedema can make intubation more difficult because the airway becomes narrower, making the glottis invisible [43].

Descending purulent mediastinitis, which causes swelling of the soft tissues surrounding the upper and lower airways, can make it difficult to open the oral slit and complicate tracheal intubation due to narrowing of the airways and a decrease in the angle of view of the glottis [44].

Securing the airway in patients requiring surgery due to deep infectious involvement of the neck poses a significant challenge for anesthesiologists because of alterations in airway anatomy, limited mouth opening, tissue edema, and restricted range of motion of the cervical spine. It is crucial to assess the risk of potential airway passage issues and select the most appropriate intubation method. Studies among patients with neck infections have shown that in cases of mucosal infections of the oral cavity or pharynx, intubation requires more extensive equipment preparation. The choice of intubation method depends on the extent to which the infection affects the airway anatomy, particularly at the level of the epiglottis and aryepiglottic folds [45].

Epidemic parotitis can also lead to airway obstruction due to the enlargement of the salivary glands, venous stasis, and excessive salivation [46].

CONCLUSION

The study of the morphofunctional characteristics of various structures of the head and neck, as well as their congenital and acquired changes, allows for a deeper understanding of the conditions that affect the performance of endotracheal intubation.

Causes of difficult intubation may include a short neck, diseases of the cervical spine, conditions associated with biomechanical joint disorders (atlanto-occipital, atlantoaxial, temporomandibular), macroglossia, micrognathia, malocclusion, as well as the presence of diseases in the patient that lead to airway obstruction.

Understanding anatomical peculiarities and their association with pathologies during the history-taking stage will help anesthesiologists and resuscitation specialists prepare more effectively for tracheal intubation and minimize potential complications.

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Conflict of Interest. The authors declare that there are no obvious or potential conflicts of interest associated with the content of this article.	***Конфликт интересов.*** Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с содержанием настоящей статьи.
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