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Review

STUDIES ON THE APPLICATION OF THE VIRTUAL BRONCHOSCOPY METHOD FOR TRACHEAL AND BRONCHIAL RUPTURES

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ABSTRACT
Traumatic injuries of major airways (trachea and main bronchus) are rare in medical practice but represent extremely life-threatening conditions. The study **aims** to present a summary of research findings on the diagnostic capabilities of Virtual bronchoscopy (VB) in ruptures of trachea and bronchi. There is very little research into the applicability of VB in Bulgaria. Still, the modern equipment for MDCT VB during the last years provides to use the VB in diagnostic practice and for scientific examinations. The method of VB is recognized as a reliable tool in diagnostic practice and the research of tracheal and bronchial ruptures.

Key words: ruptures, trachea, bronchi, Virtual bronchoscopy

INTRODUCTION

Tracheal and bronchial ruptures are relatively rare and difficult to diagnose (1-6), but with increasing frequency in the last ten years (7, 8). Many of them can be life-threatening (9). Tracheal and bronchial ruptures are defined as severe damage, which is often overlooked during the initial post-traumatic period. The best way out of trauma is with the earliest restoration of airway continuity associated with early diagnosis and the use of appropriate diagnostic methods (10). Fibreoptic bronchoscopy (FB) visualizes the mucosal layer, but the method is not applicable for the evaluation of the deep layers or adjacent tissues. Multidetector Computed Tomography (MDCT) with subsequent Virtual bronchoscopy (VB) has been identified as methods providing an excellent assessment of respiratory rate (11). At the same time, there is very little research into the applicability of VB in Bulgaria. Still, the modern equipment for MDCT VB during the last years provides to use the VB in diagnostic practice and for scientific examinations. The study aims to present a summary of research findings on the diagnostic capabilities of VB in tracheal and bronchial ruptures.

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RESULTS AND DISCUSSION

In scientific literature, the results of the application of the virtual bronchoscopy method in two categories of ruptures are mainly reported, according to their etiopathogenesis: postintubation and post-traumatic. Cases of left lower limb bronchus as a result of advanced oesophageal neoplasm have also been identified, as well as examples of mucosal erosion after instrumental manipulations perceived as ruptures after VB administration (1).

Postintubation airway ruptures are rare and probably underestimated in diagnostic practice. In these cases, the rupture has always been found to be a longitudinal linear rupture of the posterior membrane (12). Post intubation ruptures are more reported in women aged 51 to 67 (13-16, 1, 3, 4, etc). The main reasons for

this are the overweight and age-related abnormalities of the upper respiratory tract, increase with age of pressure from elongated and dilated ascending aorta, etc.

Post-traumatic ruptures have been reported mainly as a result of high-speed accidents. Patients have been found to have blunt throat or chest injuries. Penetration wounds (knife, bullet) are much less commonly reported. Studies on post-traumatic ruptures have known since the late 19th century (7, 8). For many years, distal bronchial ruptures and those of the major bronchi were considered 100% mortality. At the present stage, for their rapid diagnosis and treatment, he points to the VB method as an opportunity to significantly improve the clinical prognosis. Chest radiography remains the original screening test, but the role of CT are found increased because it provides a rapid, sensitive, accurate and comprehensive examination of patients with chest trauma. Chest ruptures have been found more closely to the carina, i.e., the distal part of the trachea and major bronchi (17, 8, 18, 19, etc). In post-traumatic ruptures, the presence or absence of pneumothorax, haemoptysis or emphysema are found of minor importance for early diagnosis. Rib fractures are always associated with bronchial rupture in patients over 30 years of age and rarely in patients below that age. In 86% of cases with bronchial ruptures, they are associated with the main bronchi (7). Injuries to the right have been reported with higher mortality than those to the left (18, 1, 3).

Traumatic injuries of major airways (trachea and main bronchus) are rare in medical practice - in about 1 to 3% of cases (9, 4, 6, etc.) but represent extremely life-threatening conditions (20, 4). FB is the primary diagnostic tool for proving them, but in an emergency, it could aggravate the injured condition of the victims. It makes clinicians look for other safer and faster-performing diagnostic techniques that have the same or better efficacy. Studies on the diagnostic capabilities of VB with MDCT in tracheal ruptures are extremely limited (9, 21, 22, 5, 1-3, etc.).

Burke (7) examined 167 cases of bronchial rupture. The trauma, according to the author, has 2 phases: the rupture of the bronchus itself, followed by the development of a structure at the tear site. The author points out that, the presence or absence of pneumothorax, haemoptysis or emphysema is of little importance for early diagnosis. Eijgelaar and Homan Van der Heide (10) discuss the problem of a reliable early symptom for rupture of the bronchi or trachea. The authors point out that patients' recovery depends on early diagnosis, and their diagnosis can be safely established by bronchoscopy. Bertelsen and Horwitz (8) discuss traumatic ruptures of the trachea and bronchi. The authors point out that, these ruptures can be the result of penetrating wounds, as a more common cause, however they highlight blunt trauma to the throat or chest. They emphasize that chest ruptures usually occur near the carina. Central tearing, the authors indicate that it appears with emphysema of the mediastinum and neck while tearing off the peripheral bronchi is presented with pneumothorax and atelectasis. According to the authors, central ruptures should be treated with a primary suture and lobectomy should be performed concerning the ruptures of the small bronchi. They note that in patients after a catastrophe, if there is no serious injury, even if there is only a rupture, no blood aspiration should be performed due to the ruptures, i.e. this would result in the death of patients. The authors conclude that ruptures are life-threatening. The diagnosis indicates that it can be confirmed by tracheobronchoscopy. Marty-Ané et al. (12) present tracheal membrane ruptures obtained after endotracheal intubation. According to the authors, the tracheal lesion, the lesion, is always a linear rupture of the posterior membrane wall. The diagnosis is supported by established common signs such as subcutaneous emphysema, respiratory distress, pneumomediastinum, and pneumothorax. The authors cite FB as the best means of confirming the diagnosis and determining the location and extent of the lesion. Kaloud et al. (14) recommend surgery for tracheal ruptures greater than 1 cm. Kiser et al. (18) present tracheobronchial trauma as a rare occurrence as a result of blunt chest trauma. According to the authors, diagnosis and treatment are often delayed, leading to attempts at surgical recovery that take months and even years. They track the anatomical position of the injury, the mechanism of injury, the time to diagnosis, treatment and outcome. They find that the injury is 2 cm from the carina in 76% of patients, and in 43% - in the first 2 cm of the right main bronchus. They point out that the closeness of the lesion to the carina does not have a significant impact on mortality. They found that injuries on the right side were

treated earlier but were associated with higher mortality than those on the left. There was no correlation between delayed treatment and successful recovery from trauma. 90% of patients treated more than one year after injury is reported to have recovered successfully. Nakamori et al. (9) report a tracheal rupture diagnosed with VB. They present the condition, research and treatment of a 25-year-old man after a motorcycle accident. Describe the condition found after CT has been performed. The scan revealed a lung injury, pneumomediastinum, pneumothorax, massive subcutaneous emphysema. Do not use conventional bronchoscopy due to patient hypoxemia. They process 133 axial images from a CT scan of the chest and subsequent VB images of the airways. Through three-dimensional images of the respiratory tract, a large rupture of the carina is established. They do not take a thoracotomy, which they believe would be lethal because of severe respiratory failure and a tendency to bleed after a massive transfusion. They emphasize that the use of an oxygenator for hypoxemia conceals the possibility of brain stem deterioration and lung injury. Therefore, they undergo non-surgical treatment. According to the authors, analysis of the published scientific literature on such incidents and tracheobronchial injuries shows that aggressive surgery reduces the incidence of primary tracheobronchial injuries, but also reports a high mortality rate from other traumas resulting from this treatment, while studies by other authors have shown a successful outcome by non-surgical treatment of tracheobronchial traumas in children and adults. Wintermart and Schnyder (19) describe cases of diagnosis in patients with chest trauma of a blunt object. They point out that chest injuries are a major problem in high-speed accidents because they are associated with a high mortality rate. However, their rapid diagnosis and treatment make it possible to improve the clinical prognosis of such patients significantly. According to the authors, chest radiography remains the initial screening test. Still, the role of CT is increasing as it provides a rapid, sensitive, accurate and comprehensive examination of patients with chest trauma. The authors analyze the various radiological and CT models in blunt lesions of the chest. Lacasse et al. (23) study the precision of VB in detecting endobronchial lesions. VB may, according to them, be applied without FB if in the patient's endobronchial lesions with suspected malignancies have not been detected. The authors aim to evaluate the accuracy (in terms of sensitivity and specificity) of VB in the detection of endobronchial lesions and to determine the anatomical limit for the detection of endobronchial lesions by VB. The study is related to a comparison of VB and FB in consecutive patients presented with symptoms or clear chest abnormalities that give rise to suspected lung tumours. The authors examined 190 patients. The primary analysis was obtained from 136 patients (including 63 with FB endobronchial lesions). Sensitivity and specificity of VB was obtained for detection of endobronchial lesions, respectively 68% (95% confidence interval [CI]: 55% to 79%) and 90% (95% CI: 81% to 96%). Overall, comparability between VB and FB with respect to the location of endobronchial lesions is significant. However, VB detected only 26 of 34 pulmonary lesions (sensitivity: 76%; CI: 59% to 89%) and 11 of 23 segmental lesions (sensitivity: 48%; CI: 27% to 69%). According to the authors, outside the bronchus, VB is not accurate enough to detect endobronchial lesions and to avoid FB in patients with suspected malignancy. Moorjani et al. (24) described studies in an 85-year-old woman presented with a spinal fracture of the shoulder bone. She had severe osteoporosis and was treated with alendronic acid and calcium carbonate. After physical examinations, they detected a pronounced kyphosis with a distortion of the spine of the thorax at 90 degrees forward. After treating her shoulder fracture with a collar and cuff, she developed stridor and then stopped breathing, requiring resuscitation and non-invasive positive pressure ventilation. They also established previous episodes of these striatal attacks with the patient. These attacks did not bind to specific markers and passed spontaneously after about 10 minutes. Following a pre-project study with FB, they revealed external compression of the middle part of the trachea, with a lumen narrowed to less than 5 mm. There was also a pulsation in the anterior wall of the trachea. In view of this, they performed a spiral CT of the patient in a lateral decubitus position due to the severe kyphosis that prevented the patient from lying on her back. Using three-dimensional reconstructions, they established airway compression as a priority against *arteria brachiocephalica*. They used VB to perform a retroverted view of this non-transverse lesion. Normally, the tracheobronchial tree was observed distally to

the compression. No other lesions in the mediastinum or lung were identified. On this basis, a tracheobronchial stent Ultraflex (Boston Scientific, USA) 6 cm (18 mm) in diameter was inserted by rigid bronchoscopy under fluoroscopic guidance. When performing postoperative CT, they established restoration of airway patency and positioning of the tracheal stent. Six weeks later, no additional seizures of stridor or respiratory distress were detected in the patient's examination. According to the authors, this is an unusual case of extrinsic tracheal secondary compression caused by severe kyphoscoliosis. The authors emphasize that the three-dimensional helical CT reconstructions and VB used to facilitate the insertion of an expanding metal stent, providing excellent symptomatic relief. Shabana et al. (2004) points out that the advantage of VB is that it gives a 3-dimensional evaluation of the tracheobronchial tree. The author described VB as more practical, shorter and more accurate in the evaluation of the trachea and major bronchi than FB. According to him, VB is better than FB for the diagnosis of ruptures in patients with pneumomediastinum. Gil et al. (25) classify tracheal and bronchial abnormalities as focal and diffuse. The focal group includes tracheal stenoses (post-intubation, post-infectious), iatrogenic injuries and neoplasms. For the diffuse group, they emphasize the importance of recognizing specific anomalies on the tracheal wall. Some of them, according to the authors, cause thickening of the peripheral wall (Wegener granulomatosis, amyloidosis, intestinal inflammatory disease), while others mainly affect tracheal cartilage (recurrent polychondritis, tracheobronchopathy, osteobronchoplasty). They point out that, although CT is, in most cases sufficient to assess most of the respiratory tract abnormalities, MDCT enables multiple volume reformation, CT bronchography, and VB. These techniques, in their view, can be instrumental in the pre-procedural evaluation and subsequent procedures. Jones and Athanasiou (26) state that VB is a method of the last decade of the 20th century, introduced as a potential complement to FB in the diagnosis, grading and monitoring of pulmonary diseases. The authors evaluate the diagnostic accuracy of VB compared to the gold standard study using the FB method. They summarize the results of seventeen studies involving 459 patients. Sensitivity and specificity indicators are analyzed. They found a total sensitivity of 84%, a specificity of 75%, etc., which, according to them, shows good diagnostic indicators of VB. Scientific analysis confirms that virtual bronchoscopy is highly discriminatory in the evaluation of patients with significant airway stenosis due to a wide range of pathological conditions. The authors demonstrate the good accuracy of virtual bronchoscopy in the overall diagnosis in patients with suspected airway lesions. VB, according to the analyzes analyzed, shows excellent accuracy in diagnosing severe stenotic lesions and high efficiency in lower grade stenoses. The accuracy of VB in the diagnosis of obstructive lesions or endoluminal malignancies has also been found to be excellent. However, they emphasize that the VB method is not reliable in diagnosing dynamic lesions of the airways or mucous membranes. The small collimation interval is found to not significantly improve the accuracy of VB, despite the increased image artefact at high collimation. VB is defined as a technically sound method, consistently showing adequate visualization of the airways and clinically insignificant artifact of images. It is non-invasive, operator-independent, fast, reproducible based on CT images that are often clinically shown. The authors indicate that further studies are needed to determine the location of VB relative to that of FB in respiratory diseases. Maniatis et al. (22) examined 65 patients evaluated after a FB with tracheobronchial anomalies. They then apply the VB and Thin-Section Computed Tomography methods. Compare the results obtained. One hundred two lesions were recorded, 44 of which had bronchial stenosis. There were no statistically significant differences in the degree of stenosis between FB and VB results, unlike those obtained with Thin-Section Computed Tomography. They conclude that VB gives a more accurate estimate of the degree of bronchial stenosis by Thin-Section Computed Tomography. Allah et al. (27) find that the data obtained for the evaluation of bronchial ruptures by FB and VB methods are comparable. However, they point out that FB has the advantage of giving direct symptoms of colour, vasculature and mobility. The advantages of VB indicate that it can bypass any obstruction and thus provide an excellent view, away from obstructive lesions or stenotic segments. VB, according to the authors, determines the optimal path for the instruments to pass in ruptures outside the field

of view. Lim et al. (28) present 3 cases of tracheal ruptures in women after endobronchial intubation. According to the authors, tracheal ruptures are rare, but serious complications occurred after endobronchial intubation. They are said to usually present as linear lesions in the tracheal membrane wall and are more common in women and patients over 50 years of age. It is indicated that the clinical manifestation of tracheal lesions includes subcutaneous emphysema and respiratory fatigue. CT and FB are applied. Kumar et al. (29) report a very rare case of a spontaneous rupture in a 32-year-old man with interstitial lung disease who had used steroids for two months, resulting in the development of spontaneously subcutaneous emphysema and pneumomediastinum. The tracheal rupture was diagnosed by MRI CT and reconstructed images by VB. Subsequently, the patient died of heart failure. According to the authors, early diagnosis with CT, FB and VB and with appropriate management of patients would prevent fatal outcome in patients with the symptoms described. Kucuk et al. (20) describe a tracheal injury from a wheel in a 6-year-old boy. According to them, tracheal ruptures are rare but are potentially life-threatening (occurrence rate of 0.4%). The authors point out that the tracheal ruptures diagnosis is often delayed or missed, but an increase in the number of cases associated with improving patient care has been proven. They find that the tracheal ruptures occur after blunt trauma, severe coughing, vomiting or maybe secondary iatrogenic from FB, tracheal intubation, and more. The radiographs in their studies indicate subcutaneous emphysema and pneumomediastinum. CT and VB of the thorax establish subcutaneous emphysema, pneumomediastinum and longitudinal tracheal rupture 15 mm long, 2 cm above the carina, in the posterior wall of the trachea. The injury can be transversal or longitudinal. Subcutaneous emphysema is identified as evidence of airway lesion at initial examination. In the case of suspected tracheal rupture and stable patient status, the authors recommend CT and VB with MDCT as a less aggressive technique. They point out that in patients with tracheal ruptures, follow-up is very important because of the existing risk of tracheal stenosis, in some cases requiring additional surgery. Barnes al. (11) provide an overview of possible central airway pathologies (focal lesions - benign neoplasms, malignant neoplasms, non-neoplastic lesions as tracheobronchial tuberculosis, postintubation stenosis, idiopathic tracheal stenosis, inflammatory pseudotumour, foreign body aspiration, tracheobronchial diffusion; tracheobronchial lesions as Mounier-Kuhn syndrome, acquired tracheobronchomegaly, rhinoscleromatosis, granulomatous bronchitis, amyloidosis, granulomatosis with polyangitis, sarcoidosis, relapsing polychondritis, tracheobronchopathia osteochondroplastica, tracheobronchomalacia). Pathologies illustrate CT images. They provide a comprehensive overview of the spectrum of central airway pathologies with their clinical and radiological characteristics. According to the authors, the division of diseases into diffuse and local lesions helps to narrow the differential diagnosis. They conclude that focal lesions with nodularity are more responsive to tumours, whereas focal lesions with stenosis are more responsive to inflammatory diseases. Indicate that involvement of the posterior airway wall is a significant feature in diffuse lesions with stenosis. According to the authors, although the majority of focal lesions are neoplastic, the distinction between the predominance of nodules and the predominance of stenoses may allow a difference to make between lesions of neoplastic origin and non-neoplastic origin. Also, according to them, the infiltrative nature of the lesion strongly suggests a malignant disease. The authors point out that diffuse lesions are unlikely to be associated with malignant disease. In these lesions, finding that involvement of the posterior wall and the presence of calcification may help reduce the likelihood of a different diagnosis. They define the method of FB as an important therapeutic and diagnostic weapon. FB, however, does not allow the assessment of the deep layers and the adjacent tissue. For FB, the authors emphasize that MDCT and after treatment techniques, such as VB, provide an excellent evaluation of the airway wall. Desale et al. (30) describe a case of spontaneous rupture of the trachea in an infant (one-year-old boy). The authors describe a patient with sudden respiratory distress and bilateral subcutaneous emphysema nailing the entire sternum and anterior abdominal wall. The chest X-ray shows the presence of pneumomediastinum and bilateral subcutaneous emphysema, including the atria and cervical sections without pneumothorax or rib fracture. High-resolution computed tomography and 3D reconstruction with VB reveal a tracheal rupture in the right posterior

wall just above the carina. The increase in respiratory distress and the development of cardiogenic shock prompts the authors to undertake intubation of the trachea to seal the tracheal opening by positioning the tip of the endotracheal tube just above the carina. The patient's condition improved (maintenance of oxygen saturation), and he was discharged on the seventh day with complete resolution of the problem of subcutaneous emphysema. They find spontaneous rupture of the trachea due to a sudden increase in intratracheal pressure with the closed glottis. They emphasize that, as in this case, the rupture is usually located in the weakest part of the trachea (on the posterior membrane wall in the lower third of the trachea). Cite HRCT with 3D reconstruction as the preferred diagnostic modality as it is sensitive to tracheal rupture and associated complications (subcutaneous emphysema). According to them, FB may miss a covered perforation, and therefore, the use of the FB method carries the risk of exacerbation of existing tracheal injury. They argue that the choice of therapeutic intervention must be individualized based on the clinical status, location and extent of the tracheal rupture, and response to conservative therapy. Conservative management by maintaining the airways and administering venous fluids, analgesia, and oxygen, is considered to be preferable to patients with minimal symptoms and minor tearing (<2 cm). The authors explain that in children with severe symptoms (shock and shortness of breath) it is essential to seal the rupture of the trachea by correctly positioning the endotracheal tube (thus preventing impaired ventilation of the lungs). Raman et al. (31) apply a bronchoscopic approach for the diagnosis of benign subglottic stenosis. The authors emphasize that subglottic stenosis are an abnormal narrowing of the lumen of the trachea at the level of the subglottis (the area between the vocal cords and the cricoid cartilage), which can cause significant symptoms due to severe damping of the airflow. The authors describe their attempt to alleviate the symptoms after examining the stenosis using FB methods. Investigate and treat ten patients. Stenosis types are defined as 'simple' if short (less than 1 cm in length), regular or concentric, and 'complex' if irregular, large, involving the subglottic space, two or more tracheal sites, or associated with tracheomalacia (according to the classification of Galluccio et al. (32)). Stenosis severity is determined by Myer et al. (33) classification based on percent lumen occlusion (class 1 from 0-50% blockage; class 2 from 51-70% blockage; class 3 from 71-99% blockage; class 4 - no detectable lumen). The authors conclude that tracheal stenosis, and in particular subglottic stenosis, are a recurrent process and their management requires extensive collaboration among treating specialists. Mitev et al. (2) present a rare case of tracheal and ruptures as a result of advanced oesophageal neoplasm in a 63-year-old man. Perform MDCT with subsequent VB. The patient has previously been diagnosed with Fiberoptic oesophagoscopy (FOE) and CT. According to the study, the authors indicate that MDCT with subsequent VB is a complex methodology for the described case of juvenile congestion with the finding of the tracheoesophageal fistula and the evaluation of mediastinum and pulmonary parenchyma. The authors conclude that it could be administered with equal efficacy compared to FB in the diagnosis of tracheal and bronchial ruptures caused by advanced neoplastic oesophageal processes. Akkas et al. (34) present tracheal rupture as a result of coughing. According to the authors, the rupture of the trachea is mostly traumatic or iatrogenic. According to the literature, the authors found a small number of cases with spontaneous tracheal rupture described for the posterior membrane wall, which is the weakest part of the trachea. They present for the first time a case of spontaneous anterolateral rupture of the trachea as a result of a cough that does not cause respiratory distress and which spontaneously recovers without any complications in a 24-year-old man with throat pain. After computed tomography scan of the neck and chest, he observed pneumomediastinum, free air in the cervical fascia and a 4 mm tracheal wall defect on the left anterolateral side of the level superior to the manubrium. The patient was short of breath and was, therefore, not undergoing emergency surgery. According to Grenier and Kanne (35), MDCT using thin collimation in the respiratory arrest is the preferred technique for imaging and estimation of respiratory diseases, including postintubation and posttraumatic ruptures. Nevertheless, the authors indicate that CT remains a reference technique for imaging and evaluation of pulmonary diseases.

Some authors consider CT as sufficient to evaluate most airway abnormalities, but MDCT allows for multidimensional volume reformation, CT bronchoscopy, and VB. VB,

as a non-invasive method, enables a three-dimensional evaluation of the tracheobronchial tree. It has been identified as more practical, shorter and more accurate for the assessment of the trachea and the main bronchus, as well as better for diagnosing ruptures in patients with pneumomediastinum compared to FB (36, 37, 1-4, etc.). Diagnosis of tracheal ruptures is often delayed or missed, but an increase in the success rate associated with improving patient care has demonstrated. The main reasons for their occurrence are blunt trauma, severe cough, vomiting or secondary iatrogenic injuries after tracheal intubation, etc. (25, 20, etc). Single studies concern the application of different methods of real bronchoscopy or the use of imaging methods for performing angiography, in maxillofacial surgery, etc. In this regard, more detailed studies have been carried out by Gagov (36) Gagov et al. (38), Gagov (39).

CONCLUSION

Research using VB with MDCT is being done in many countries around the world. It is a testament to the relevance and great importance attached to such research worldwide. At the same time, these studies are primarily concerned with clarifying the potential of VB as a non-invasive method of diagnosis, intervention and training. The advantages and disadvantages of VB compared to actual bronchoscopy are examined. A large number of publications refer to the application of different methods of real bronchoscopy, highlighting the benefits of better 3D VB images and the ability to determine the exact locations and sizes of lesions, especially in patients who cannot have real bronchoscopy. Some of the disadvantages of the VB method, as well as its inability to be used alone, for example, in patients with indispensable histology, are indicated. Most of the studies show an increase in the objectivity of the estimates when combining the real bronchoscopy with the VB. The insufficient study of VB capabilities with MDCT in Bulgaria, the increased interest of scientists worldwide to study and apply VB, increasing the technical capacity to apply VB after equipment with the new X-ray apparatuses, pose new challenges but also new opportunities for improvement of diagnostics based on modern high-quality 3D images and application of non-invasive methods in vulnerable patients (children, elderly persons, etc.). All these studies provoke interest and motivate the need to deepen research in this direction.

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