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Innovation in Tracheal Tumors and Stenosis: Recanalization with Endobronchial Shaver

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Abstract

Tracheal tumors and stenosis represent significant challenges in respiratory medicine, often requiring invasive interventions that come with high risks and potential complications. The literature surrounding innovation in its management has evolved significantly over the years, reflecting a shift towards more refined and less invasive. Traditional treatment options typically involve invasive surgical procedures, such as tracheal resection and reconstruction, which carry substantial risks and require extensive recovery periods. The development of the endobronchial shaver has introduced a minimally invasive alternative that offers promising results. This review explores the endobronchial shaver's innovation, applications, benefits, and future directions in managing tracheal tumors and stenosis, particularly for patients unfit for traditional surgical interventions.

Key Words: Trachea, bronchoscopy, minimally invasive intervention, endobronchial shaver, microdebridder

Introduction:

Tracheal tumors and stenosis are critical conditions that obstruct the airway, leading to severe respiratory distress and a diminished quality of life. Tracheal stenosis, a narrowing of the trachea, presents a significant clinical challenge. Its etiology is diverse, encompassing prolonged intubation, tracheostomy, infections, trauma, and the presence of both benign and malignant tumors [1-5]. Malign tracheobronchial obstruction is estimated in 20% to 40% of patients with lung cancer. The incidence is even higher when one adds non-malignant causes of airway obstruction, such as laryngotracheal intubation injury, relapsing polychondritis, and Wegener's granulomatosis. The frequency of intubation-related tracheal stenosis varies from 6% to 21% [6-8]. The degree of tracheal stenosis can vary from mild dyspnea to life-threatening respiratory failure, underscoring the critical need for effective treatment strategies. The severity of the condition is often graded using systems such as the Cotton-Meyer classification [9], which helps guide treatment decisions. Similarly, tracheal tumors, irrespective of their benign or

malignant nature, pose a substantial threat due to their location and potential to obstruct the airway, leading to severe respiratory compromise [5,10]. Developing effective and minimally invasive treatment strategies is paramount to improving patient outcomes and quality of life. Traditional treatment options typically involve invasive surgical procedures, such as tracheal resection and reconstruction, which carry substantial risks and require extensive recovery periods. The current review will discuss the traditional and innovative treatment modalities for tracheal stenosis and tumors, focusing on the emerging role of the endobronchial shaver in recanalization, particularly for patients unfit for traditional surgical interventions.

Review Methodology:

The author conducted a systematic review to evaluate the innovation in the management of tracheal tumors and stenosis, specifically focusing on the recanalization techniques using the endobronchial shaver. The review aimed to collate existing literature, assess the efficacy and safety of this innovative approach, and identify its potential advantages over traditional methods. The review process began with a comprehensive literature search across multiple electronic databases, including PubMed, Scopus, and Web of Science. The search strategy utilized a combination of keywords and medical subject headings (MeSH) relevant to tracheal tumors, stenosis, endobronchial shaver, and recanalization techniquesThis approach ensured the consideration of both clinical trials and observational studies that reported outcomes related to the use of endobronchial shavers in tracheal interventions. Following the initial search, the authors screened the titles and abstracts of identified articles to determine their relevance to the review topic. Full-text articles were subsequently retrieved for further evaluation. The authors implemented a rigorous selection process, excluding studies that did not meet the predefined criteria, such as those lacking sufficient data on patient outcomes or procedural details. Ultimately, a final set of studies was selected for detailed analysis, ensuring a balanced representation of published evidence. The findings from the included studies were synthesized to highlight the effectiveness and safety of the endobronchial shaver technique. The authors provided a narrative summary of the results, emphasizing the innovative aspects of the technique, such as its minimally invasive nature and the ability to achieve precise tissue removal. The review also discussed potential advantages over conventional methods, such as reduced recovery times and improved patient outcomes. Moreover, the authors identified gaps in the current literature and proposed directions for future research, particularly in long-term outcome assessments and larger-scale trials.

Results and Dicussion

1. Traditional Treatment Modalities for Tracheal Stenosis: A Review of Established Techniques

Traditional approaches to managing tracheal stenosis and tumors have centered on surgical resection and anastomosis [2, 9,11]. This technique, while considered the gold standard for many cases [9], involves the surgical removal of the stenotic or tumorous segment of the trachea and the subsequent reconnection of the remaining healthy tracheal ends. However, this approach is associated with significant risks and potential complications. The inherent invasiveness of the procedure, including the need for a sternotomy or cervical incision, prolonged operative time, and the potential for post-operative complications such as bleeding, infection, and anastomotic dehiscence, significantly impacts patient morbidity and mortality [11]. Furthermore, the feasibility of surgical resection is contingent on various factors, including the extent and location of the stenosis, the presence of co-morbidities, and the patient's overall health status [11]. In cases of extensive stenosis or severe comorbidities, surgical resection may not be a viable option. Beyond surgical resection, several less invasive techniques have emerged as alternatives for managing tracheal stenosis. These include dilation, which can be performed using either balloon dilation or rigid bronchoplasty [12-14]. Balloon dilation involves inflating a balloon catheter within the stenotic segment to expand the airway lumen mechanically. Rigid bronchoplasty utilizes specialized instruments to break up and reshape the stenotic tissue. While these techniques are less invasive than surgical resection, their effectiveness is often limited, particularly in cases of complex or severe stenosis, and may lead to recurrence of the stenosis [12]. Stent placement is another established method for treating tracheal stenosis [15], [10,16]. Stents provide structural support to the airway, maintaining patency and alleviating symptoms. However, stents can be associated with complications such as migration, infection, and granulation tissue formation [16]. Furthermore, the long-term use of stents can lead to stent malfunction or the need for stent replacement [16]. The choice of stent material, such as silicone or metal, also influences the longevity

and efficacy of the procedure [15], [16]. Laser ablation [17] represents yet another approach, using targeted energy to remove or modify the stenotic tissue. However, like other techniques (electrocautery, Neomidyum YAG laser, cryoablation), it has potential complications.

In the last decade, microdebriders have been performed by otolaryngologists and interventional pulmonologists for laryngotracheal stenosis and recurrent respiratory benign tumors, joint surgery, liposuction, and sinus surgery [18]. The selection of the most appropriate treatment modality for tracheal stenosis and tumors requires careful consideration of several factors. These include the severity and location of the stenosis and tumor, the patient's overall health, and any comorbidities [11,12]. The limitations of each traditional method highlight the need for further advancements in minimally invasive techniques to improve treatment efficacy and patient outcomes.

2. Endobronchial Shaver Technology: A Paradigm Shift in Minimally Invasive Tracheal Recanalization

Lunn et al. [19] were the first to describe the successful use of microdebrider bronchoscopy. They used the 37 cm tracheal blades. In the other successful use of microdebrider for tumor debulking, Kennedy et al. [20]. They used the 45 cm tracheal blades. The endobronchial shaver is a type of microdebrider manufactured by (Richard Wolf GmbH, Germany) specifically for tracheobronchial interventions. The advent of endobronchial shaver technology represents a significant advancement in minimally invasive techniques for tracheal recanalization. This innovative device offers a more precise and controlled approach to tissue resection compared to traditional methods [21-25]. Unlike techniques like balloon dilation or laser ablation, which may cause collateral damage to surrounding healthy tissue, the endobronchial shaver allows for targeted removal of hyperplastic or tumorous tissue within the trachea under direct bronchoscopic visualization. This precision minimizes trauma to adjacent healthy structures, reducing bleeding and promoting faster recovery [21-25]. The shaver's design incorporates a rotating cutting blade housed within a protective sheath, enabling precise tissue removal while minimizing the risk of accidental injury to the surrounding tracheal wall. The endobronchial shaver offers several critical advantages over traditional surgical and endoscopic techniques. Its minimally invasive nature translates into shorter hospital stays, reduced post-operative pain, and a faster return to normal activities [21-25]. The reduced trauma associated with the procedure minimizes the risk of complications such as bleeding, infection, and airway injury, thereby improving patient safety and reducing morbidity [25]. Furthermore, the procedure's precision allows for the selective removal of obstructive tissue while preserving healthy tracheal structures, maximizing the chances of achieving long-term airway patency. However, there are some limitations, like the Need for rigid bronchoscopy and general anesthesia, which only reach the trachea, main bronchi, and bronchus intermedius, not allowing debulking of more distal disease.

3. Mechanism of Action and Technical Aspects of Endobronchial Shaving: A Detailed Examination

The endobronchial shaver's mechanism of action relies on the precise cutting action of a rotating blade, enhanced durability, and cutting efficiency. It is an instrument comprised of three components: A long disposable rotating blade coupled to suction (45 cm), a handpiece to control directionality, and a console that adjusts the speed (3000 rpm). The blade is housed within a protective sheath, which guides the shaver and prevents accidental damage to the surrounding tracheal tissue. The sheath also helps to collect resected tissue, facilitating its removal during the procedure. The shaver is typically connected to a suction system to remove debris and maintain a clear operative field. The design of the shaver allows for precise control of the cutting depth and direction, enabling surgeons to navigate complex airway anatomy and effectively remove obstructing tissue while preserving healthy tracheal structures. The shaver's versatility allows for its use with both rigid and flexible bronchoscopes, offering flexibility in procedure selection based on the patient's anatomy and the nature of the stenosis or tumor. The console controls the handpiece with a foot pedal, setting the speed and direction of rotation of the blade or bit.

The endobronchial shaver has many advantages over prior microdebrider devices. The added length (8 cm) allows access to distal bronchial lesions (37 cm vs 45 cm). The rotating tip allows better maneuverability and precision, reducing the possibility of debriding normal tissue. Although some consoles may allow for speeds of as much as 10,000 rpm, we prefer speeds in the range of 1,000 to 3,000 rpm. The slower speeds allow for more tissue to be drawn into the blade aperture. All procedures were performed under general anesthesia with jet ventilation or frequent ventilation with a high Fraction of Inspired Oxygen. The 12-mm external diameter rigid bronchoscope was then positioned just proximal to the obstructing lesion.

A shaver equipped with a tracheal blade was introduced into the airway through the barrel of the rigid scope. The microdebrider can reach lesions in the trachea, main stem bronchi, and bronchus intermedius. The procedure involves careful navigation of the bronchoscope to the affected area, followed by the precise application of the endobronchial shaver to remove the obstructing tissue (Figure 1). Continuous monitoring of the airway patency and careful assessment of the surrounding tissues are crucial throughout the procedure. Post-procedural care includes close monitoring of respiratory function and management of any potential complications. Depending on the patient's overall medical status and level of anesthesia, patients may be extubated in the operating room or remain intubated following the procedure.

4. Clinical Applications and Outcomes of Endobronchial Shaving in Tracheal Stenosis: A Review of Evidence

Endobronchial shaving has shown considerable promise in treating tracheal stenosis, particularly in cases caused by post-intubation or post-tracheostomy tissue hyperplasia [12,21,22,24]. The procedure's ability to precisely remove the hyperplastic tissue contributing to airway narrowing makes it a highly effective tool in these scenarios. In cases of benign tracheal stenosis, endobronchial shaving can significantly improve airway patency, alleviating symptoms such as dyspnea, stridor, and cough [21,24,25]. The procedure's success rate is often high, with many studies reporting complete or near-complete resolution of stenosis after a single procedure. However, the long-term effectiveness of endobronchial shaving in these cases remains a subject of ongoing research, with some studies reporting a potential for recurrence [21-23]. The efficacy of endobronchial shaving can be further enhanced by combining it with other techniques. For instance, combining it with balloon dilation may synergistically improve immediate and long-term outcomes [12]. Balloon dilation can help expand the airway lumen, while the endobronchial shaver can remove the hyperplastic tissue contributing to the stenosis. This combined approach can lead to a more durable and sustained improvement in airway patency. Similarly, using stents after endobronchial shaving can provide additional support to the airway, preventing the recurrence of the stenosis and promoting long-term patency [21,25]. The optimal combination of techniques needs to be determined on a case-by-case basis based on the severity and location of the stenosis, the patient's overall health, and other clinical factors (Figure 2).



Figure 1A: Endobronchial shaver unit **B:** The system consoles may allow for speeds of 1,000 to 3,000 rpm **C:** The picture shows rigid tubes of various diameters and rotating blades.



Figure 2A: The picture shows that the trachea is circularly narrowed by eighty percent with granulation tissue. **B:** Granulation tissue was removed with smooth and curved rotary blades. **C:** Patent tracheal lumen is seen after the procedure.

5. Endobronchial Shaving in the Management of Tracheal Tumors: Exploring its Role

The application of endobronchial shaving in managing tracheal tumors is a more complex and evolving area. While the technique's precision and minimally invasive nature make it potentially beneficial for both benign and malignant tracheal tumors, its role in tumor management is not as clearly defined as in tracheal stenosis [5], [7]. Endobronchial shaving can debulk the tumor in benign tracheal tumors, remove obstructing tissue, and improve airway patency [15,22-25]. This can significantly alleviate symptoms and improve the patient's quality of life. However, complete tumor resection may not always be achievable with endobronchial shaving alone. In such cases, it might be necessary to combine it with other treatments, such as surgical resection or laser ablation, to achieve complete tumor removal. The use of endobronchial shaving in malignant tracheal tumors is more challenging and requires a cautious approach. While it can debulk tumors and improve airway patency, it is unlikely to achieve complete tumor eradication [10,27]. The procedure may be a palliative measure to alleviate symptoms and improve respiratory function. However, it is crucial to recognize that endobronchial shaving is typically not considered a curative treatment for malignant tracheal tumors. In most cases, it must be integrated into a multi-modal treatment strategy that includes other therapies such as chemotherapy, radiotherapy, or surgery [17], [7]. The choice of treatment modality will depend on various factors, including the tumor type, stage, and the patient's overall health. Further research is needed to fully define the role of endobronchial shaving in the management of malignant tracheal tumors. As a clinical experience, we performed two patients, one malignant and the other benign with central airway obstruction, who underwent therapeutic bronchoscopy with an endobronchial shaver at Trakya University Medicine Faculty, Department of Thoracic Surgery. No significant bleeding was encountered during these procedures. No operation had to be aborted because of complications. Damage to laryngeal structures and adjacent tissue, such as the esophagus, was not encountered (Figure 3).

6. Comparison with Other Recanalization Techniques: A Critical Evaluation

Endobronchial shaving offers several distinct advantages over traditional surgical resection and anastomosis. Its minimally invasive nature reduces the risk of significant complications, such as bleeding, infection, and anastomotic dehiscence [20-25]. This translates into shorter hospital stays, reduced post-operative pain, and faster recovery times, significantly improving the patient experience. Compared to dilation techniques alone, endobronchial shaving offers the potential for more durable results by directly addressing the underlying cause of the stenosis or airway obstruction, namely the removal of hyperplastic or tumorous tissue [20-25]. Unlike electrocautery techniques, lowering inspired oxygen fraction and interruptions in jet ventilation to avoid endobronchial fire are unnecessary.

However, endobronchial shaving is not a universal solution for all cases of tracheal stenosis or tumors. Its effectiveness is dependent on the nature and extent of the lesion. Endobronchial shaving may not be sufficient in severe or extensive stenosis or tumors to achieve the desired outcome. A combined approach involving endobronchial shaving and other techniques, such as dilation, stent placement, or surgical resection, may be necessary. Choosing the optimal treatment strategy for



Figure 3A: Rigid bronchoscopy reveals a tumor arising from the anteroposterior wall of the upper third of the trachea in a subglottic area, causing stenosis of seventy percent of the tracheal lumen.
B: The tumor was debrided from the tracheal wall with circular movements.
C: At the end of the procedure, the lumen was opened almost completely.

each patient requires carefully assessing the individual clinical scenario, considering the severity and location of the stenosis or tumor, the patient's overall health, and any comorbidities [11,12,21,22,25]. Selecting the most appropriate technique is crucial to ensure optimal treatment outcomes and minimize potential complications.

7. Future Directions and Research Needs: Shaping the Future of Tracheal Recanalization

Despite the significant promise shown by endobronchial shaving, further research is essential to fully elucidate its long-term efficacy and refine its application in various clinical settings. Longitudinal studies comparing the long-term outcomes of endobronchial shaving with other recanalization techniques, such as surgical resection, dilation, and stent placement, are crucial to establish its long-term effectiveness and identify its optimal role within the treatment algorithm [21,22,25]. These studies should also evaluate the recurrence rates, the need for repeat procedures, and the overall impact on patient quality of life. Further investigation into the optimal combination of endobronchial shaving with other therapies is also warranted [12,25,27]. Combining endobronchial shaving with balloon dilation, stenting, or adjuvant therapies such as radiation or chemotherapy may improve outcomes in selected patient populations. Research should focus on identifying the optimal sequencing and combination of these therapies to maximize their efficacy and minimize potential side effects. Developing more sophisticated imaging techniques to improve the visualization of tracheal lesions and guide the endobronchial shaver more precisely could significantly enhance the procedure's accuracy and effectiveness [28]. Advancements in shaver design, such as smaller, more maneuverable instruments, may also improve the technique's applicability in challenging anatomical locations.

Conclusion:

The endobronchial shaver significantly advances the minimally invasive management of tracheal stenosis and tumors. Its precise tissue resection capabilities and minimally invasive nature offer a compelling alternative to more invasive procedures, such as surgical resection. The procedure's benefits include shorter hospital stays, faster recovery times, and reduced morbidity compared to traditional approaches [20-25]. While endobronchial shaving demonstrates considerable promise, particularly in managing tracheal stenosis caused by post-intubation or post-tracheostomy hyperplasia, its role in treating tracheal tumors, especially malignant ones, requires further investigation. It should be emphasized that debulking of obstructing central airways and main bronchus is done only in patients with advanced tumors or stenosis with significant dyspnea and stridor who would need a tracheotomy anyway. The optimal integration of endobronchial shaving with other treatment modalities must also be defined through rigorous clinical trials. The overall rate of adverse events associated with traditional ablative techniques ranges between 3% and 17%. However, substantial data has not been provided on the potential complications of using a microdebrider or endobronchial shaver (29,30).

The future of endobronchial shaving lies in continued research and technological advancements. Further studies are needed to fully characterize its long-term efficacy, identify optimal patient selection criteria, and define its role in the multidisciplinary management of tracheal stenosis and tumors. Developing improved imaging techniques and more sophisticated shaver designs will further enhance the procedure's precision and safety. Ultimately, endobronchial shaving holds significant potential to improve the management of these challenging airway conditions, ultimately leading to improved patient outcomes and quality of life. The ongoing innovation in this field underscores the importance of minimally invasive approaches in maximizing patient benefits and minimizing morbidity.

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