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Three-dimensional printed trachea helps to design tailored treatment for tracheobronchomalacia

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Title: Three-dimensional printed trachea helps to design tailored treatment for tracheobronchomalacia

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Short title: 3D-printed trachea in the treatment for tracheobronchomalacia.

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Tracheobronchomalacia is a rare disease of the central airways that is manifesting by impaired ventilation with expiratory collapse of the tracheal wall [1]. Patients with severe symptoms and confirmed obstruction of the central airways, can be offered an operation – tracheobronchoplasty.

Thirty-nine-year-old male patient suffered from diabetes and asthma required multiple hospitalizations due to exacerbations of respiratory failure. Problems with recurring episodes of wheezing, coughing, shortness of breath were a real distress for the patient. As a result of further diagnostic investigation, the patient was diagnosed with tracheobronchomalacia with dynamic narrowing of thoracic trachea and main bronchi.

A computed tomography (CT) of the chest with gating the respiratory phases (4D-CT), bronchofiberoscopy have shown narrowing of the airways during expiratory phase. To plan the operation we have performed 3-dimensional (3D) visualization and created the airway pattern transformed to a 3D-printed plastic model. A model was made by GE-AW Suite, *Autodesk Inventor* and *Monkeyfab Prime3D* software followed by printing using polylactide filament [2].

Through right posterolateral thoracotomy the trachea and main bronchi were exposed after ligation of the azygous vein. The membranous wall of the trachea and main bronchi was plicated and narrowed with a polipropylen mesh by the series of 4 mattress sutures. A narrowing of the membranous wall was obtained, which resulted in the satisfactory widening of the trachea and the main bronchi. Patient was extubated in the first day and required bronchofiberoaspiration and antibiotic therapy due to respiratory infection.

Control bronchoscopies in 3rd , 6th and 12th month after the operation have shown satisfactory widening of the airways. Although no improvement in spirometry results (FEV1% 33 vs 27) was observed, the patient felt a significant improvement after surgery. St. George Respiratory Questionnaire (SGRQ) indicates that the symptoms have subsided and persist for more than a year after the operation. Both components of the SGRQ test, i.e.

Symptoms Score, Activity Score and Impact Score as well as Total Score before and more than a year after surgery were: 95, 93, 94, 94 and 49, 30, 8, 22 respectively.

Tracheobronchoplasty, the method of sewing a mesh into a membranous wall is considered to be an effective method of treatment of tracheobronchomalacia [3,4]. This intervention requires meticulous preparation and design of implanted materials preoperatively. The 4D-CT reconstruction enables to visualise the tracheal shape and helps to design meshes and rings that should be prepared in detail due to anticipated anatomical circumstances. Low resolution and inability to directly create a 3D-model are the main limitation of CT, so in this case it does not fully meet requirements. Therefore, the solution is rapid prototyping. Addition of 3D-printing of the trachea gives furthermore comfortable situation for the surgeon in the planning of operation strategy. The rarity of this condition, and especially the particularly wide extension of the membranous wall, prompted the authors to look for any available means to effectively plan the operation.

In conclusion, the three-dimensional model of the airways printed in preparation for non-standard surgical treatment can help in planning details of the surgery.

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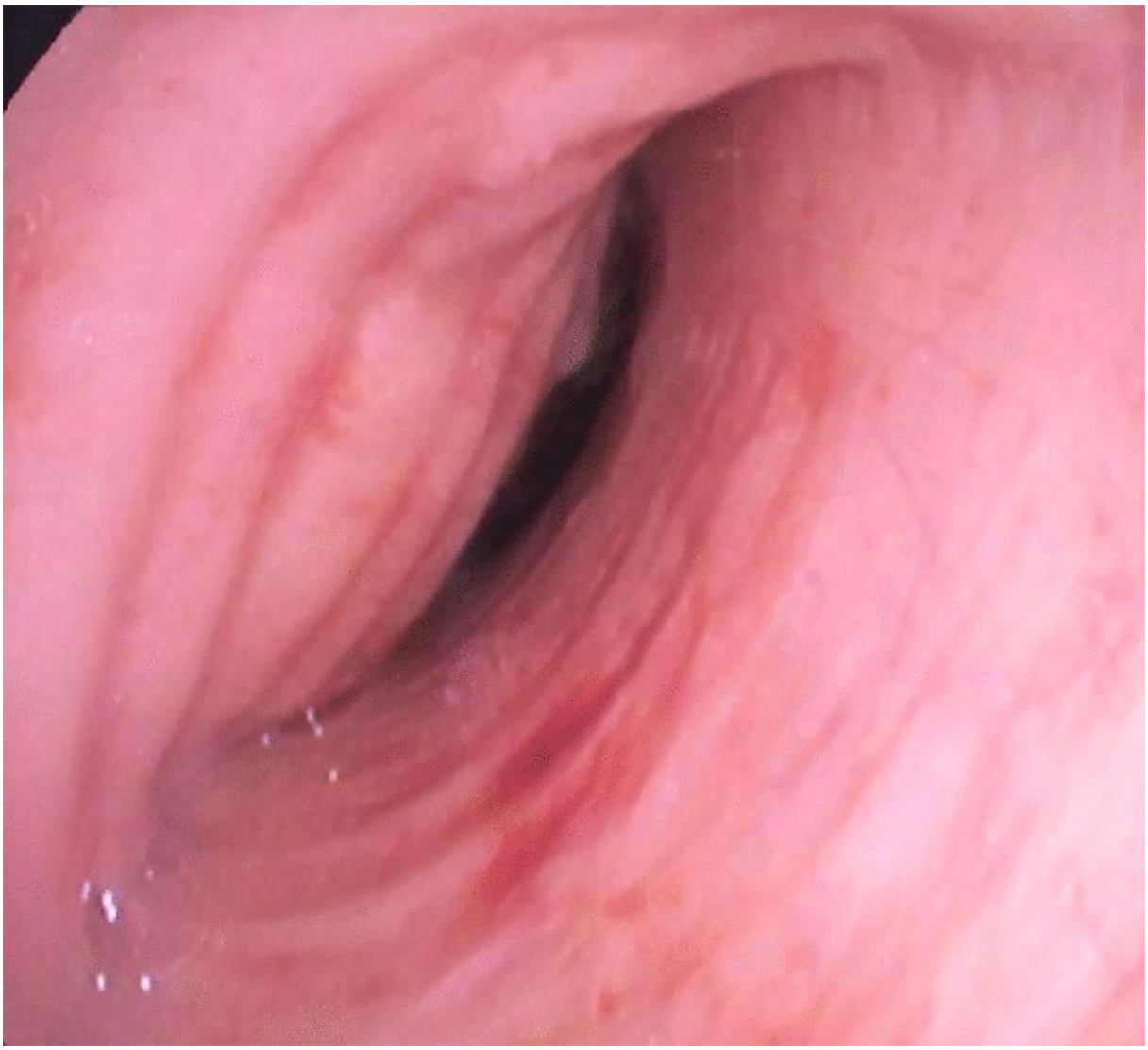
A



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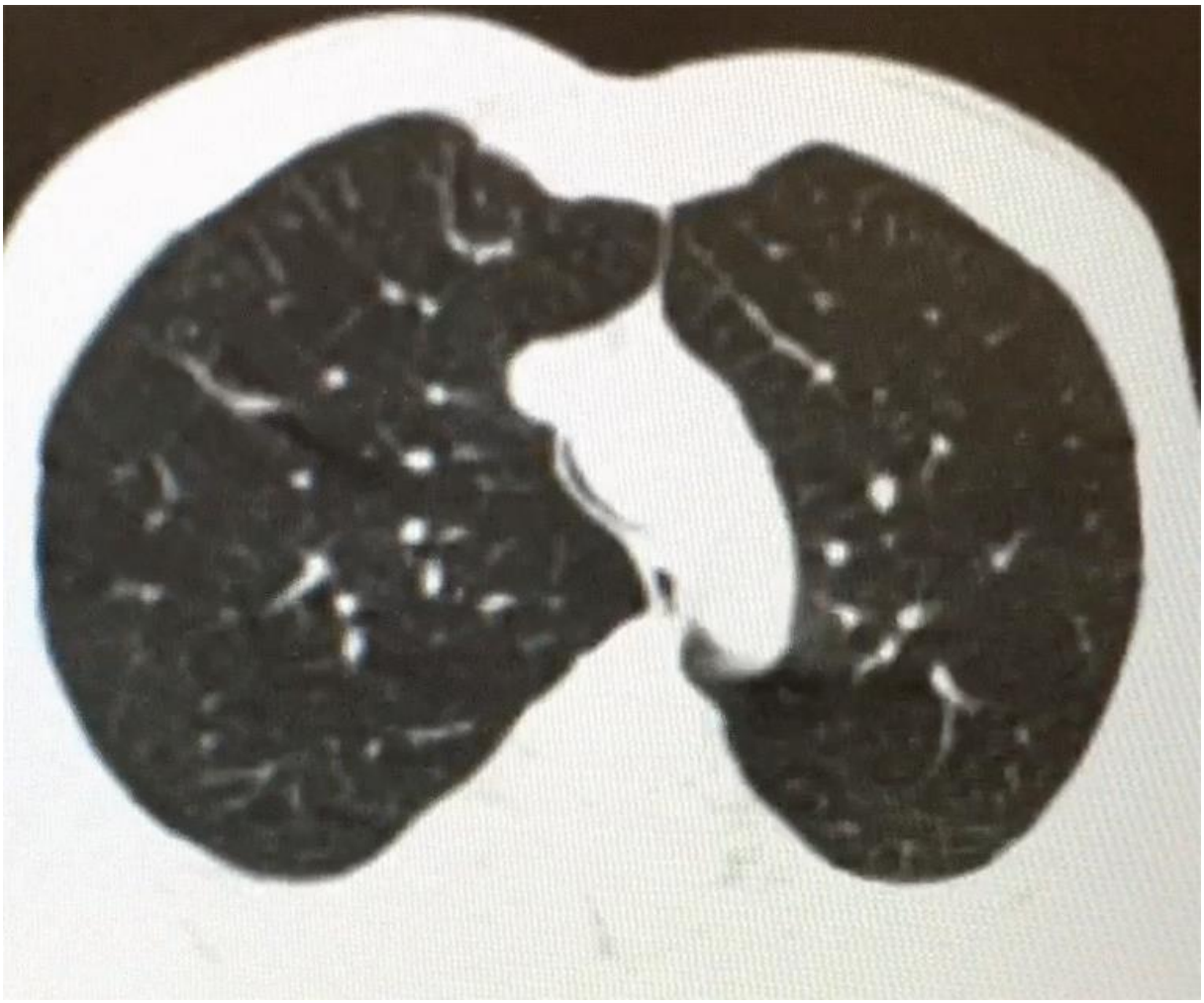

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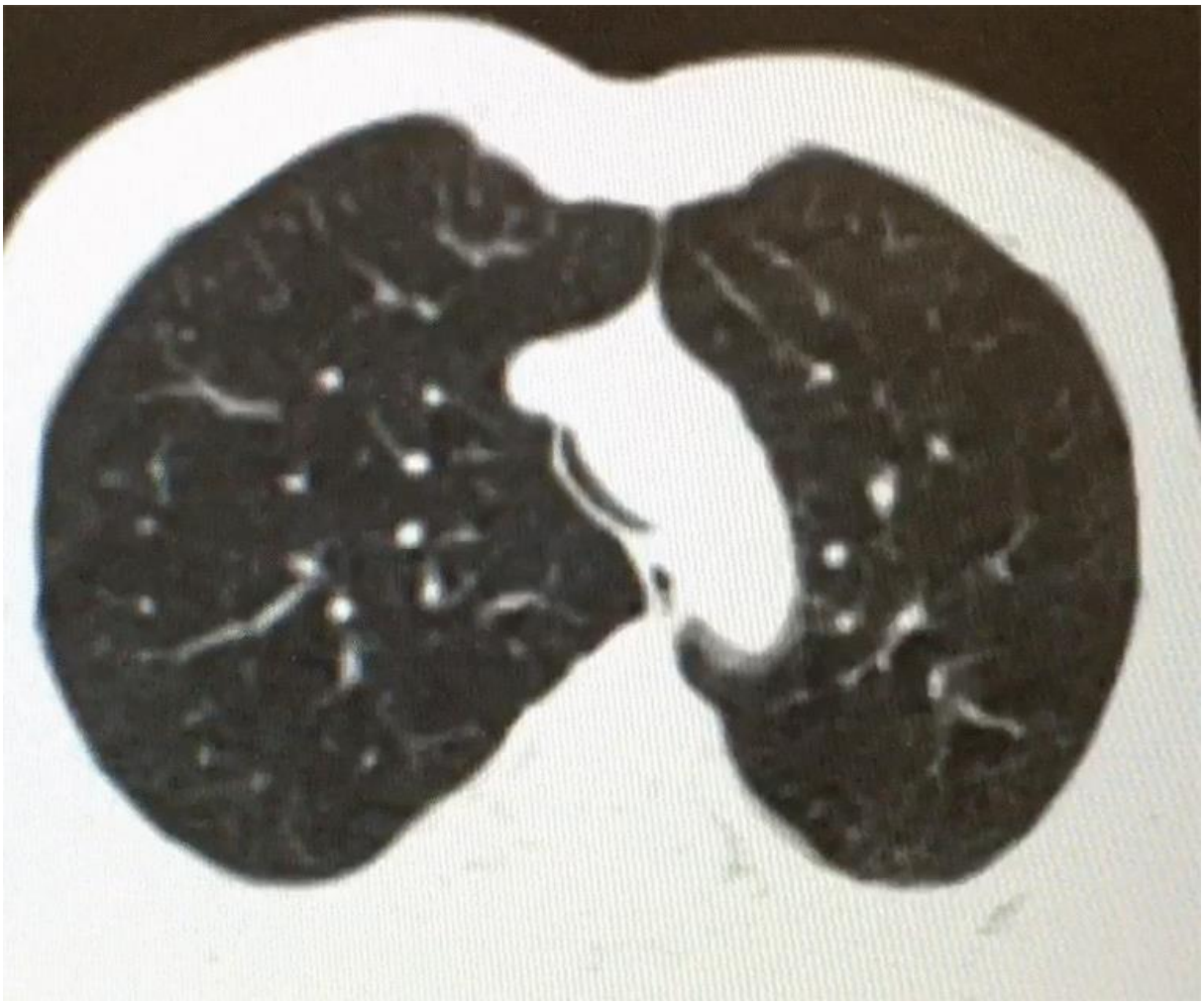

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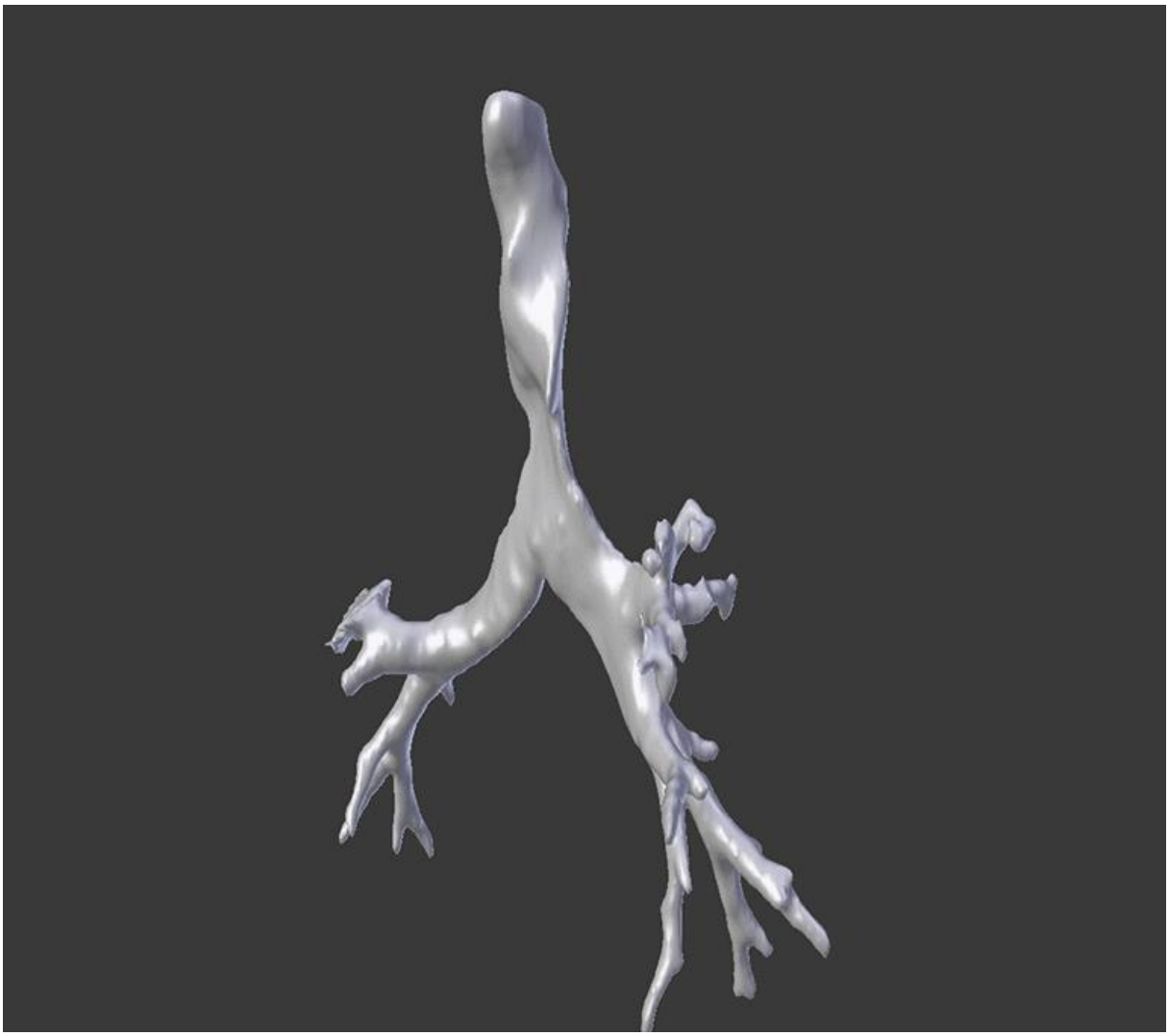

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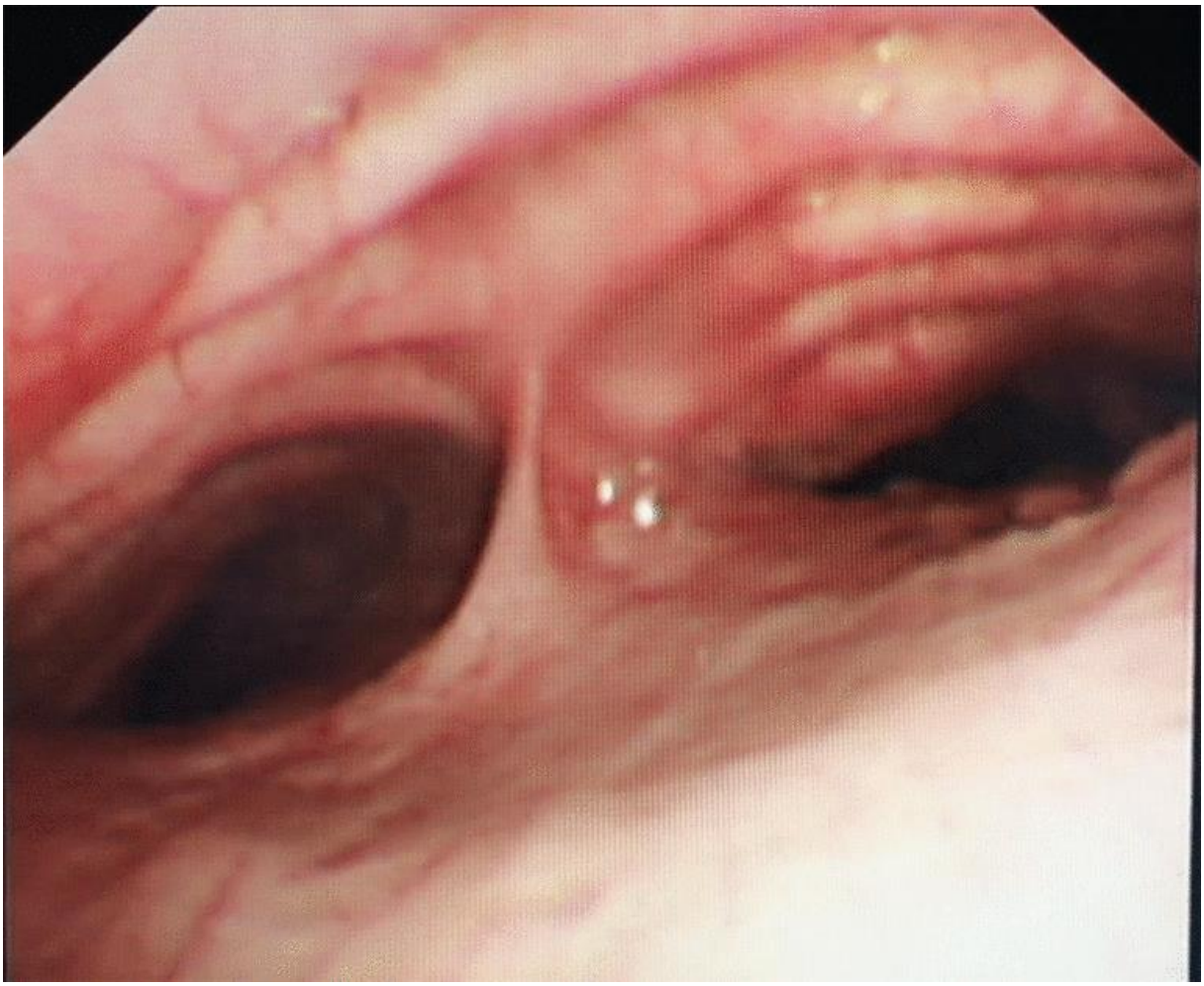

Figure 1. A bronchoscopy is showing critical tracheal stenosis (A), an arrow is indicating membranous wall of the trachea, (B) expiration and (C) inspiration faze of breathing on dynamic tomography. (D) Virtual model of airways, (E) 3-dimentional printed model. (F) bronchoscopy performed in follow-up is showing wide lumen of the trachea and main bronchi.