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TRACHEOBRONCHIAL MORPHOMETRY CORRELATES WITH DEMOGRAPHIC CHARACTERISTICS AND INFECTIONS IN CRITICALLY ILL PATIENTS

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SUMMARY – Tracheal measurements in the intensive care unit (ICU) are important for the choice of endotracheal tube and may correlate with patient demographic characteristics and infections. The study included 42 surgical patients, age 60 [48-71] years, who underwent diagnostic chest computed tomography (CT) scans during treatment in the ICU, Osijek University Hospital, in 2019 and 2020. CT scans were analyzed using AW Server 3.2. Measurement analysis showed that the diameters of the tracheobronchial tree, the length of the trachea and left main bronchus were significantly larger in men compared to women ($p<0.05$ all). The smallest tracheal upper diameter was 15.25 [IQR 11.8-18.8] mm vs. 17.95 [13.55-20.05] mm in septic and nonseptic patients, respectively ($p=0.028$). A total of 26 patients who underwent CT scans developed nosocomial pneumonia. It was right-sided in 15, left-sided in 6 and bilateral in 5 patients, and correlated significantly with the left main bronchus length ($\rho=0.515$, $p=0.007$). No correlation was observed between tracheobronchial measurements and length of ICU treatment, number of hours spent on mechanical ventilation, or survival. A larger study could provide better data on the importance of tracheobronchial tree measurements in ICU patients.

Key words: *Trachea; Bronchi; Pneumonia, bacterial; Intensive care unit; Tomography, x-ray computed; Comorbidity*

Introduction

Diagnostic imaging methods in intensive care units (ICU) provide the possibility of assessing the patient's current condition and the dynamics of the disease that is the reason for admission to the ICU. Advances in imaging methods provide a quick insight into the patient's health condition, and a series of analyses that often remain unused.

Computed tomography (CT) analysis of the neck and chest is used in ICUs for the diagnosis of intrathoracic pathology, most often for analysis of lung morphology, solid formations of the mediastinum, or for analysis of bone morphology in the neck and chest trauma. It is possible to analyze air spaces, bone, and soft tissue structures of different densities. By applying this method with appropriate computer programs, it is possible to reconstruct the tracheobronchial tree, analyze its morphology, and observe changes that would not have been observed by routine analysis, i.e., tracheal deviations or irregularity of the lumen or tracheal wall edema, as shown in Figure 1.

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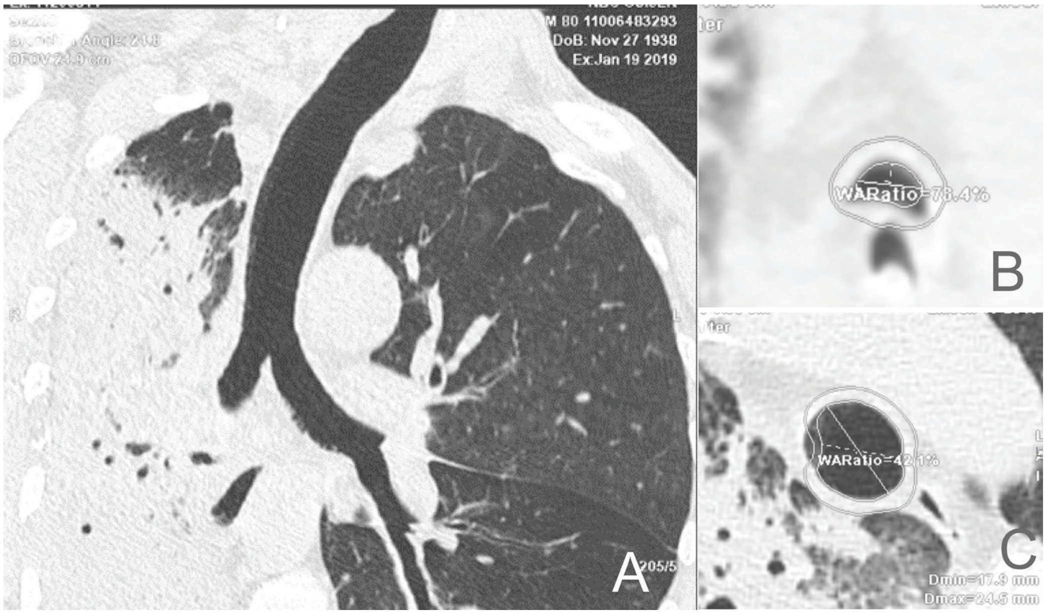

Fig. 1. Coronal section of the multislice computed tomography scan in the patient with massive right-sided pneumonia, right-sided tracheal deviation (A); immediately below the bifurcation, both main bronchi are edematous and deformed with the membranous part pushed into the lumen of the bronchus (B); representation of the smallest and largest diameter of the trachea with an indication of the place where the membranous part of the trachea protrudes into the lumen (C).

The development of programs that enable segmentation of the tracheobronchial tree from CT images greatly contributes to faster and more accurate morphometry of the tracheobronchial tree. Basic measurements of the tracheobronchial tree, the length of the trachea, assessment of the location of the narrowest and widest part of the trachea, the length of individual bronchi, the curvature and slope of the tracheobronchial tree, the length of the main bronchi, the angles of their separation, analysis of the airway diameter at given sections and several other variables are assessed. Normal reference values and ranges for anthropometric measurements of the tracheobronchial tree vary among different races, as well as among different ethnic groups within the same race. These measurements may deviate from the physiological ones and influence the ability to breathe and cough in critically ill ICU patients.

Multislice computed tomography (MSCT) enables precise localization of the lesion and empowers quality of 3D reconstruction. In addition to visual representation, it is also possible to determine the degree of stenosis, the length of the stenotic segment, and distance of the stenotic segment from the vocal cords, which is of great importance in surgery. In post-intubation stenosis, CT can show a localized area of narrowed tracheal lumen. By using CT, it is possible to show adjacent mediastinal structures, as well as numerous pathological conditions such as compression of the airways by mediastinal masses and infiltration of the mediastinum by tumors. In addition to direct effects in pulmonary physiology and thoracic surgery, information on the morphometry of the tracheobronchial tree is also useful in anesthesiology practice, for example, during intubation.

It is possible that these changes are related to some demographic characteristics of the patient. It is thus expected that taller patients will have a longer trachea, while shorter people will have a narrower and shorter trachea. In inflammatory conditions due to swelling of the mucous membrane, the airways can be narrowed. In a study by Shinohara *et al.*, it was confirmed that choosing a tube that was too wide in women was associated with post-extubation stridor and airway edema[1]. This can be reflected in the size of the tube that can be used in an individual patient[1]. Since the trachea follows the course of the spine, pathological curvature of the spine may be present in diseases such as scoliosis or other deformities, also affecting the position of the trachea and main bronchi with consequent potential complications of mechanical ventilation[2]. It is also possible that the inclination and curvature of the trachea and main bronchi are different in the elderly who have more frequent deformations and arthrosis of the spine[2].

A recent study on a computational airway model extracted from a CT reconstruction by Mortazavy Beni *et al*. showed that the curvature of the airway and the speed of the air flow affect the distribution of viral droplets. Appreciating these data, a prediction may be done for the place of entry of the virus into the body and difference in the appearance of symptoms in the case of a COVID-19 infection[3]. The same assumption can also apply to lung segments, where droplets with bacteria will enter more quickly and easily.

Ventilator-associated pneumonia (VAP) is characterized by the presence of new lung infiltrates and signs of systemic infection. It is one of the most common infections in ICUs[4]. It accounts for almost half of all hospital-acquired pneumonia cases. Approximately one-third (9%-27%) of all mechanically ventilated patients develop VAP, which makes it the most common nosocomial infection in mechanically ventilated patients[3]. Earlier studies found a mortality risk of 33%-50% for VAP, but the risk is variable and largely depends on the underlying disease. Over years, this risk has decreased and today it is estimated to 9%-13%, mainly due to the implementation of preventive measures[4,5].

The length of the trachea and main bronchi and their inclination angles may be in correlation with the frequency and localization of pneumonia. It seems logical that mechanically ventilated patients who have longer airways have difficult secretion removal from the airways and more frequent pneumonia.

The aim of this study was to obtain basic measurements of the tracheobronchial tree in mechanically ventilated patients in the ICU. We will show separately men and women and compare the width of the narrowest part of the upper part of the trachea with the standard width of the tube for those two populations. We will examine whether the measurements of the tracheobronchial tree are related to demographic characteristics and localization of pneumonia in patients who had pneumonia during their ICU treatment.

Patients and Methods

This retrospective cross-sectional study was approved by the Ethics Committee of the Faculty of Medicine, Josip Juraj Strossmayer University of Osijek No. 2158-61-07-21-76. All patients treated at the Department of Intensive Care Medicine at the Osijek University Hospital who underwent a diagnostic chest CT during 2019 and 2020 were included. There

Fig. 2. Schematic representation of the tracheobronchial tree derived from multislice computed tomography scans, with lines on which the points for the main measurements (A) and cross section of the trachea (B) are visible. On the cross-section view (B), the surface of the cross-section at that level can be seen by moving the cursor.

were 51 such patients, however, 9 patients were excluded from the study for technical reasons, i.e, it was not possible to perform segmentation of the tracheobronchial tree necessary for the analysis. Finally, a total of 42 patients were eligible for the study. If more than one CT session was performed, then the first one was analyzed. The interventional radiologist performed all the measurements and analyses of the tracheobronchial tree from CT image using Sectra and AW Server 3.2 programs (Fig. 2A and B). After segmentation of the tracheobronchial tree, measurements were performed.

The following measurements were recorded: the length and diameter of the trachea, the length and diameter of the two main bronchi, the curvature of the trachea, and the angles at which the main bronchi diverge (Fig. 2). The length of the trachea was measured from the lower edge of the cricoid cartilage, at the level of jugular fossa, to the bifurcation. Four tracheal diameters were measured, i.e., the smallest and largest diameter of the proximal trachea, measured at the level of jugular fossa, and the smallest and largest diameter of the distal trachea, measured 1 cm above the bifurcation (Fig. 2B). The lengths of the main bronchi were measured from the bifurcation to the separation of the first branch, while the diameters were measured immediately after the bifurcation. The angles at which the main bronchi separate from the sagittal plane were also measured. Tracheal curvature is shown as an index of tracheal curvature in the coronary and sagittal planes. Their values were obtained by dividing the length of the trachea in the coronary or sagittal plane by the initial length of the trachea.

By reviewing the available medical documentation (hospital information system, medical charts, therapy lists), demographic data (age, gender), department from which the patient was admitted to the ICU, date when chest CT was performed, information on previous operations and reoperations, laboratory parameters at admission to the ICU (hemoglobin value, white blood cell count in the blood, values of C-reactive protein and procalcitonin) were recorded. The frequency of other diseases and conditions such as polytrauma, conditions after cardiopulmonary resuscitation, and/or continuous inotropic support on admission, respiratory failure requiring mechanical ventilation, cardiac, vascular, respiratory, coagulation, neurological, renal, gastrointestinal, hepatobiliary, neoplastic, metabolic, endocrinologic and psychiatric diseases was also recorded. The first occurrence of pneumonia after admission to the ICU and its localization were recorded. The outcome of treatment was the length of stay in the ICU, the length of mechanical ventilation, and the outcome of treatment.

Statistical methods

Categorical data were expressed as absolute and relative frequencies. Numerical data were described by the median and limits of the interquartile range (IQR). Distribution of data was tested with the Kolmogorov-Smirnov test. Differences in numerical variables between two independent groups were tested with the Mann Whitney *U* test, whereas comparisons among three groups, for comparisons of data in the patients who developed pneumonia were done using Kruskal Wallis ANOVA. The association of continuous numerical variables was tested with Pearson's correlation coefficient *r*, and non-parametric data were tested using Spearman's correlation ρ (rho). Patients with missing data were excluded from analysis. All p values are two-sided. The significance level was set at $\alpha=0.05$. The IBM® SPSS® 20.0 software was used on statistical analysis.

Results

Demographics

The study included 42 surgical or trauma patients who underwent chest CT during the ICU stay. The most common reasons for ICU admission were respiratory insufficiency and the need for mechanical ventilation in polytraumatized patients (n=11), Glasgow Coma Score <8 after trauma or spontaneous bleeding (n=10), systemic infections (n=8), respiratory insufficiency due to intrathoracic diseases (hemothorax, heart disease, pulmonary embolism, abscesses) (n=9), and mediastinitis and anaphylactic shock in one patient each. Most of them had multiple comorbidities and required mechanical ventilation (Table 1).

Information on height and weight was recorded on 24 subjects, from which body mass index (BMI) was calculated, median 33.9 kg/m^2 [IQR 25.7-60.5], minimum value of 18.1 kg/m^2 and maximum value of 62.3 kg/m^2.

A total of 12 (35%) subjects underwent laparotomy, while 23 (68%) subjects underwent other types of operations, among which neurosurgical and trauma

Table 1. Demographic data and comorbidities in 42 patients who underwent diagnostic chest computed tomography scanning during their treatment in the Intensive Care Unit

Patient characteristic	N =42
Age	60 [IQR 48-71]
Sex (male/female)	29 (69%)/13 (31%)
Mechanically ventilated (n, %)	38 (90%)
Mechanical ventilation (hours)	208.5 [IQR 42-504]
Duration of ICU stay (days)	10.5 [3.5-24]
Comorbidity, n (%):	
Respiratory failure	41 (98)
Neurological	25 (60)
Vascular	22 (52)
Post-resuscitation/hypotensive	17 (40)
Cardiologic	16 (38)
Gastrointestinal	15 (36)
Renal	13 (31)
Neoplastic	13 (31)
Metabolic	11 (26)
Endocrinologic	7 (17)
Psychiatric	9 (21)
Polytrauma	7 (17)
Hepatobiliary	6 (14)
Coagulation	6 (14)
Elective/emergency	25 (60)/17 (40)
Surgical/medical	34 (81)/8 (19)
Hemoglobin (g/L)	109.5 g/L [95.2-129.2]
White blood cells x 10^9/L	12.9 [9.8-16.4]
CRP (mg/L)	42.3 mg/L [9.2-130]

ICU = intensive care unit; CRP = C-reactive protein; data are expressed as numbers (%) for categorical variables and median (interquartile range, IQR] for continuous data

operations were most common. Out of 42 subjects, 29 (69%) had an infection at admission or during treatment, and the most common infection was pneumonia and/or lung atelectasis, which was recorded in 26 (61%) subjects.

Tracheobronchial tree morphometry

The median value of tracheal length was 99.2 mm [IQR 86.6-114.6]. The length of the left main bronchus was longer than the right main bronchus 54.8 [48.5-58.8] *vs.* 22.6 [17.6-25.9] mm. Most values differed between male and female patients (Table 2).

In male patients, the largest proximal diameter of the trachea, the largest distal diameter of the trachea, the length of the trachea, and the length of the left main bronchus were statistically significantly greater than those measured in women. Furthermore, there was a significant correlation between the length of the trachea and the main left bronchus (r=0.385, p=0.012), between tracheal diameters and diameters of the main bronchi (p=0.006), and between the length of the trachea and tracheal sagittal inclination (r=0.888, p<0.001).

Some measurements correlated with demographic parameters and comorbidities. The largest diameter of the left bronchus was associated with BMI (r=0.414, p=0.045). In patients who underwent chest MSCT

Table 2. Comparison of tracheobronchial tree measurements in male and female Intensive Care Unit patients who underwent diagnostic computed tomography scanning

Measurement (mm)	Male (n=29)	Female (n=13)	Difference†	95% CI	p*
Largest proximal tracheal diameter	21.7 [19.4-24.9]	18.6 [17.8-19.9]	-2.7	-5.6 to -0.1	**0.04**
Smallest proximal tracheal diameter	18.3 [11.8-20.1]	16.3 [15.5-17.8]	-1.7	-3.7 to 2.2	0.29
Largest distal tracheal diameter	18.7 [16.9-21.5]	15.4 [13.8-16.6]	-4.1	-6.2 to -2.0	**<0.001**
Smallest distal tracheal diameter	12.4 [11.9-17.2]	12.1 [10.3-13.7]	-1.3	-4.0 to 0.4	0.23
Length of the trachea	104.2 [88.4-119.9]	89.6 [80.9-100.2]	-14.6	-28.3 to -2.0	**0.02**
Length of the trachea in coronal plane	81.4 [74.0-95.9]	75.7 [68.6-87.5]	-7.5	-17.2 to 2.6	0.15
Length of the trachea in sagittal plane	96.4 [83.5-112.1]	85.1 [73.9-94.6]	-12.8	-22.9 to -0.9	**0.03**
Curvature index in coronal plane	0.81 [0.75-0.87]	0.88 [0.82-0.9]	0.04	-0.02 to 0.1	0.16
Curvature index in sagittal plane	0.93 [0.87-0.98]	0.92 [0.89-0.98]	0.01	-0.04 to 0.04	0.88
Smallest diameter of the right bronchus	11.6 [10.3-13.0]	10.8 [8.2-11.9]	-1.3	-3.3 to 0.2	0.09
Largest diameter of the right bronchus	16.5 [14.2-17.0]	13.2 [12.1-14.1]	-3.0	-4.1 to -1.4	**0.002**
Smallest diameter of the left bronchus	10.5 [8.5-12.1]	8.5 [7.7-9.1]	-1.8	-3.2 to -0.3	**0.02**
Largest diameter of the left bronchus	14.7 [13.3-15.9]	11.2 [10.3-12.4]	-3.2	-4.6 to -1.6	**<0.001**
Length of the right bronchus	22.0 [17.5-27.1]	23.0 [20.3-24.9]	0.0	-4.1 to 3.9	>0.99
Length of the left bronchus	57.4 [50.2-61.4]	47.4 [43.4-53.1]	-8.6	-13.9 to -3.5	**0.001**
Angle of separation of the right bronchus from sagittal plane	39.4 [34.8-47.3]	37.2 [33.3-46.2]	-1.4	-7.5 to 5.6	0.71
Angle of separation of the left bronchus from sagittal plane	47.0 [41.9-52.6]	51.4 [34.9-52.2]	0.5	-7.7 to 6.3	0.98

The values obtained are expressed as median [interquartile range]; CI = confidence interval; *Mann Whitney *U* test; †Hodges-Lehmann difference of medians

during ICU treatment, the inclination of the right bronchus increased with age (N=42, r=0.316; p=0.041), whereas the minimal proximal diameter of the trachea decreased with age (Fig. 3).

Tracheobronchial characteristics and comorbidities

Patients admitted from thoracic surgery had narower upper tracheal diameters (r=0.338, p=0.028), whereas no correlation with tracheal measurements

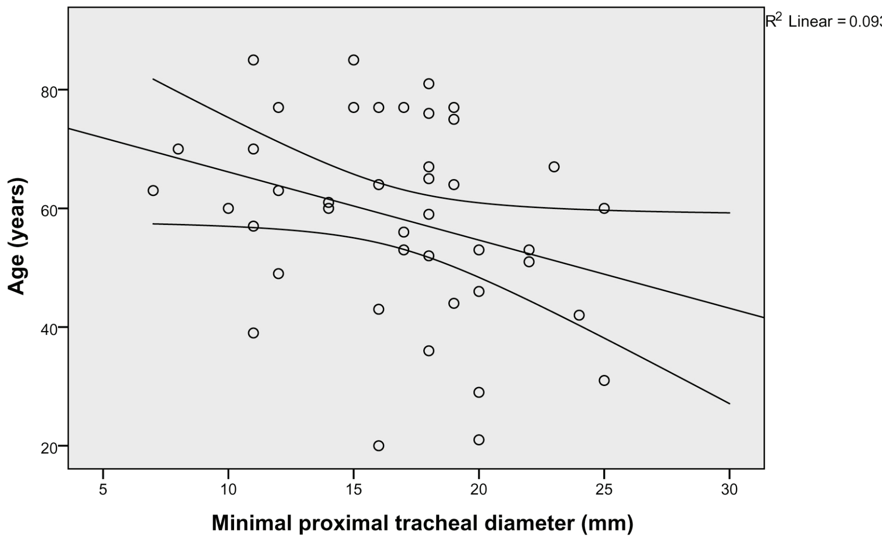

Fig. 3. Minimal diameter in the upper part of the trachea and age in patients treated in the Intensive Care Unit (ICU) who underwent multislice computed tomography scan during ICU treatment; a statistically significant negative correlation between the variables was confirmed by Pearson's correlation (r=-0.324; p=0.036).

was observed for abdominal, neurosurgical or patients with cardiologic diseases.

Among the diagnoses on admission, only infections were associated with measurements of the tracheobronchial tree. In patients who were admitted to the ICU with infections, mainly with sepsis, pneumonia and mediastinitis, the trachea was shorter compared to patients without infections. Tracheal length was 90 [84.3-105.8] mm *versus* 114.4 [IQR 96-127] mm in patients with and without infections, respectively (MW *U* test, p=0.038). The narrowest part of the upper trachea was significantly smaller in septic patients as compared with patients who were not septic (Fig. 4).

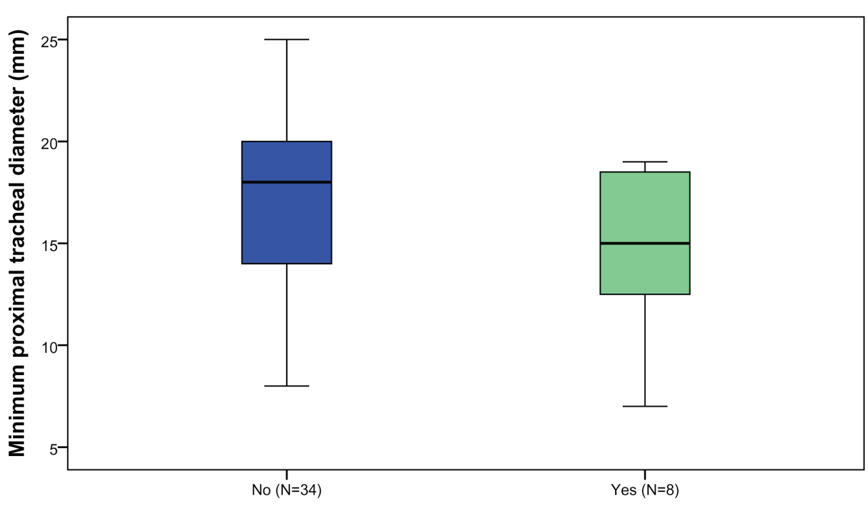

Fig. 4. Minimal proximal tracheal diameter in patients during ICU treatment; difference in diameters between the two groups of patients was calculated using Mann-Whitney U test; the narrowest part of the trachea was 15.25 [IQR 11.8-18.8] mm vs. 17.95 [13.55-20.05] mm in septic and nonseptic patients, respectively (MW U test, p=0.028).

In elderly patients, the inclination of the right bronchus in relation to the sagittal axis was significantly higher than in younger ones (r=0.309, p=0.046). This angle was different in septic patients too. It was 48.55 [40.75-54.4]° in septic patients *versus* 38.10 [IQR 33.05-44.38]° in patients who did not have sepsis (MW *U* test, p=0.013).

Pneumonia was confirmed in 26 patients during ICU treatment, in some of patients with accompanying atelectasis. Pneumonia was right-sided in 15, left-sided in 6, and bilateral in 5 patients. Patients who developed bilateral pneumonia had a significantly lower BwMI compared to patients who had left- and right-sided pneumonia (KW ANOVA, p=0.022) (Fig. 5).

The length of the main left bronchus was significantly associated with localization of pneumonia. In patients who had right-sided pneumonia, the

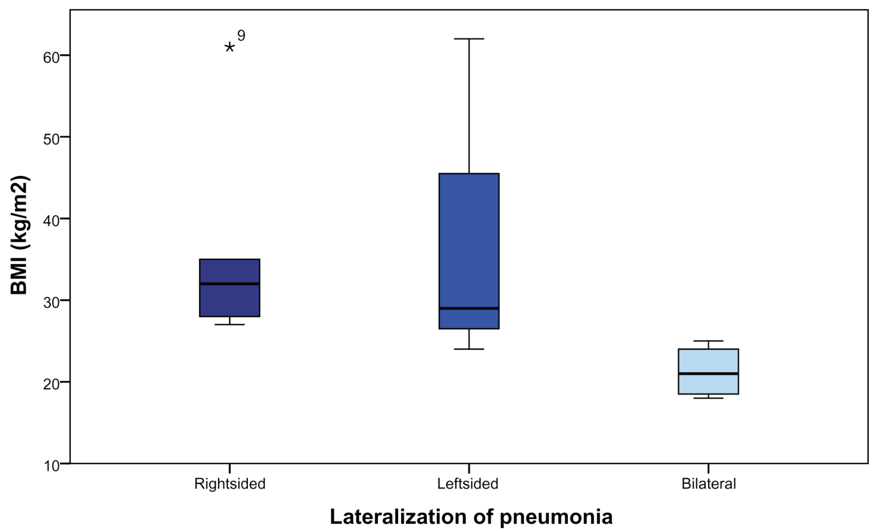

Fig. 5. Lateralization of first ever pneumonia and body mass index (BMI) in Intensive Care Unit patients undergoing diagnostic computed tomography scans at the Osijek University Hospital Center.

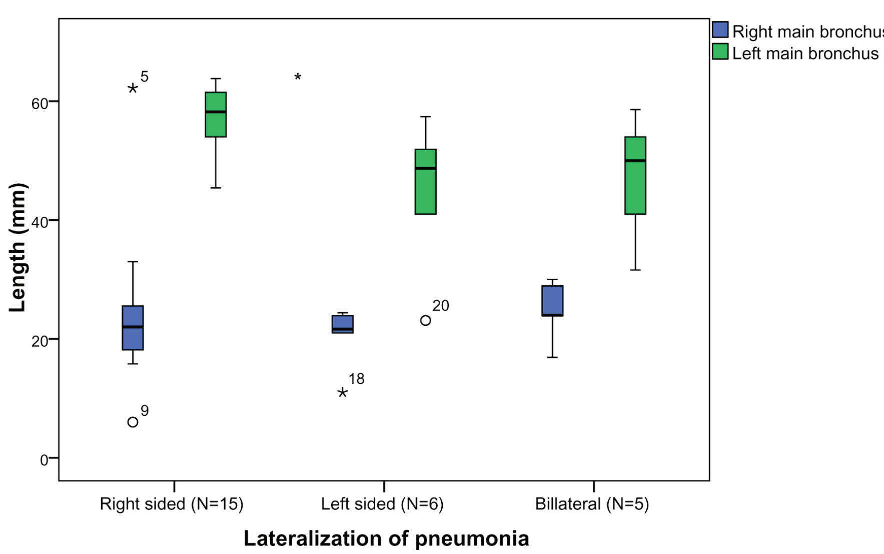

Fig. 6. The length of the left and right bronchus in patients who developed pneumonia during treatment in the Intensive Care Unit.

left bronchus was significantly longer compared to the length of the left bronchus in patients who had right-sided or bilateral pneumonia (KW ANOVA p=0.022). The length of the right bronchus did not differ in patients who had pneumonia of any localization (Fig. 6).

For this analysis, only the first occurrence of pneumonia was considered because some patients, especially those who were mechanically ventilated for longer time or underwent reoperation, had repeated episodes of pneumonia at various sites.

Discussion

This study confirmed the measurements of the tracheobronchial tree to correlate with the patient demographic characteristics and inflammatory complications, especially pneumonia. The measurements of the trachea are characteristics of a certain population, and they differ between men and women[6]. Kamel *et al.* confirmed significant population differences in tracheal dimensions using the standardized breath holding technique in ambulatory patients. According to their study, the average length of the trachea was 105 mm in men and 98 mm in women, while the average antero-posterior diameter of the trachea was 22.6 and 19.2 in men and women, respectively[7]. The dimensions of the trachea obtained in their study are slightly larger than in our patients, which may be due to the fact that they excluded from the study all patients who had significant intrathoracic pathology[7].

Tracheal diameters are important for anesthesiologists and ICU physicians. The choice of the endotracheal tube size will depend on its outer diameter and its relation to the tracheal wall. Given that the outer diameter of the tube must lie non-compressible within the upper part of the trachea, and allow for changes in the dimensions of the trachea that occur during changes in position, pressure, straining and coughing, the tube should be narrower than the narrowest part of the upper trachea[8]. Too large endotracheal tube can lead to barotrauma of the trachea and post-extubation edema, especially if the pressure in cuff is not measured[1]. According to the results of our study, the standard tube size, i.e., 7.5 for women and 8.5 for men with only 1 mm of empty space that would allow minimal balloon inflation in this population, would have been too large for 10 (24%) of our patients, 8 male and 2 female. As this study found that septic patients and patients with pneumonia had a narrower trachea than non-infected patients, these patients would need a smaller tube to avoid tracheal injury, post-extubation stridor, or emergency tracheotomy[8]. On the other hand, patients who have edema of tracheal mucosa and are breathing spontaneously could have a problem with sputum elimination due to the significant narrowing of the tracheal lumen when coughing[9].

Results on the correlation of tracheobronchial tree measurements with aging were obtained in a study with cadaveric specimens by Otoch *et al.*[10] In their study of 100 autopsies, it was found that the length of the trachea increased with age, which was also recorded in our study, but this correlation was not statistically significant[10]. Even though there are no studies on histologic changes of the trachea in the elderly, the reasons for its lengthening may be the loss of elasticity of the connective tissue, as well as the influence of gravity.

The role of bronchial mucosa in the removal of secretions, occurrence of pneumonia and phagocytosis of bacteria has so far been investigated mostly in patients with chronic lung diseases and in smokers. Morphological characteristics are less often associated with infections. The study by Nambu *et al.*[11] examined morphological characteristics of pneumonia that can be measured by CT. The authors found that infections by different causative agents resulted in typical morphology in the lung parenchyma, as well as peribronchial infiltration. They describe consolidation typical of alveolar or lobar pneumonia, peribronchial nodules typical of bronchopneumonia, ground-glass opacity, and random nodules seen in hematogenous or granulomatous infection. The authors also report on the existence of typical changes, thickening of the bronchial walls in bronchopneumonia, but do not state whether these changes were related to the tracheobronchial tree morphology[11]. Significant data on the intensity of bronchopneumonia can be obtained from bronchoalveolar lavage. The presence of neutrophils and lymphocytes in the bronchial lavage are part of the inflammatory response to pulmonary infection. Kono *et al.* found the lymphocyte *versus* neutrophil count ≥25% or <20% to be predictive of survival after acute exacerbations of interstitial lung disease[12].

Morphometry of the bronchi itself has not been correlated to the occurrence of pneumonia. In several studies with the use of radiolabeled microparticles, it has been confirmed that the largest number of inhaled microparticles are retained in the central part of the lungs. If infectious droplets carrying bacteria and viruses behave in the same way as found in the respiratory tract models, it is expected that their greatest number will remain on the mucous membrane of the respiratory tract in the central compartment, i.e., the trachea and large bronchi[13]. Bronchial mucosa participates in strong defense against infection by mucus production, neutrophil activation, antimicrobial peptide production, mediating mucosal-associated invariant T cells, muco-ciliary clearance, and phagocytosis[14-16]. According to the above, it is expected that a longer airway can have a protective role regarding the occurrence of pneumonia owing to adhesion and neutralization of a larger portion of droplets or aerosols containing bacteria.

Dispersion of aerosol particles was examined in a study by Verbanck *et al.* on a model of the human airway. In this study, it was confirmed by scintigraphy that air flow in the right lung was 1:0.88 compared to the left. The authors also confirmed that there was a greater deposition of aerosol particles in the wall of the left main bronchus compared to deposition of particles in the right one[13]. In another study that investigated the movement of microparticles of a drug for the treatment of asthma, radiolabeled using technetium-99 m, Usmani *et al.* confirmed that half of the particles sized 0.1 and 1.0 μm were retained in the central compartment, i.e. on the wall of the trachea and main bronchi[17]. Similar results on the movement of particles in a study on a respiratory tract model, which excluded the mouth-throat region were confirmed by Zhang *et al.* They confirmed that large particles of around 10.0 μm were retained in the central airways, trachea and main bronchi by sedimentation[18].

Our study confirmed that the length of the respiratory tract, especially the trachea and the main left bronchus, was associated with the incidence of pneumonia. In clinical setting, it is difficult to prove the mode of spread of infection in humans and its dependence on the number of infectious particles, or on the respiratory tract morphology. However, our results are consistent with the results obtained on the lung model on the spread of particles through the trachea and bronchi[13,17]. The gas flow is faster on the right side because the right main stem bronchus is wider and shorter, and it is directed in a more vertical orientation relative to the trachea[19]. Therefore, we can assume that a minor proportion of infectious droplets will be removed from bronchial mucosa and more bacteria will reach the right side of the lung, where pneumonia will develop more often. This is consistent with our observation that first ever pneumonias are more frequent on the right side. In the further course of ICU treatment, especially in immunocompromised patients, it is expected that the inflammation will spread to wider areas of the lungs.

This study had some limitations. These include data on a small number of patients and refer to the most severe cases, which may not be a representative sample for all patients in the Department of Intensive Care Medicine. Therefore, it may not represent the overall population for comparisons with other populations and studies. The study population was very heterogeneous, including different profiles of patients, from previously healthy and traumatized, obese to severe chronic patients. An adequate and uniform sample of respondents would provide data on deviations in measurements that can be better compared with other studies. Furthermore, data on some variables such as BMI were not recorded for all patients. Given that medical records usually contain data that deviate from normal, it is very likely that most of other respondents had normal BMI.

In conclusion, this article presents data derived from noninvasive measurements of the tracheobronchial tree in ICU patients. This was the first study that analyzed the tracheobronchial tree dimensions in critically ill and predominantly mechanically ventilated patients. Through analysis of heterogeneous patients, we were able to record correlations that may otherwise have gone unnoticed, such as a higher frequency of right-sided pneumonias in the ICU patients with longer main left bronchus. One of the important results was narrower tracheal diameter in septic and pneumonia patients compared to patients with no infection. For clinicians, this is a warning that special attention must be paid to the selection of tube sizes, bronchoscopes, and suction catheters in critically ill patients, especially in septic patients. Given that the airway is particularly vulnerable in the state of inflammation, this is also a warning of the need to reduce additional trauma to the airway during airway manipulations.

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Sažetak

TRAHEOBRONHALNA MORFOMETRIJA KORELIRA S DEMOGRAFSKIM OBILJEŽJIMA I INFEKCIJAMA U KRITIČNO OBOLJELIH PACIJENATA

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Izmjere traheje u jedinici intenzivnog liječenja (JIL) važne su zbog odabira veličine tubusa te mogu korelirati s demografskim obilježjima bolesnika i infekcijama. U ovoj studiji su analizirana 42 kirurška bolesnika u dobi od 60 [48-71] godina kojima je učinjena dijagnostička kompjutorizirana tomografija (CT) prsnog koša za vrijeme liječenja u JIL-u Kliničkog bolničkog centra Osijek tijekom 2019. i 2020. godine. Snimci CT-a su analizirani programom AW Server 3.2. Analiza izmjera pokazala je da su promjeri traheobronhalnog stabla, duljina dušnika i lijevog glavnog bronha značajno veći kod muškaraca nego kod žena ($p<0,05$ za sve). Najuži gornji promjer dušnika bio je 15,25 [IQR 11,8-18,8] naspram 17,95 [13,55-20,05] mm u septičkih i neseptičkih bolesnika ($p=0,028$). Kod ukupno 26 bolesnika koji su podvrgnuti CT-u tijekom liječenja u JIL-u dijagnosticirana je pneumonija. Bila je desnostrana u 15, lijevostrana u 6, a obostrana u 5 bolesnika i značajno je korelirala s duljinom lijevog glavnog bronha ($\rho=0,515$, $p=0,007$). Nije uočena korelacija između traheobronhalnih mjerenja i duljine liječenja u JIL-u, duljine mehaničke ventilacije ili preživljenja. Veća studija bi mogla pružiti bolje podatke o značenju dimenzija traheobronhalnog stabla kod kritično oboljelih pacijenata.

Ključne riječi: *Traheja; Bronhi; Pneumonija, bakterijska; Jedinica intenzivnog liječenja; Tomografija, rendgenska kompjutorizirana; Komorbiditet*