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Measurement of Tracheobronchial Angles of COVID-19 Patients on Computed Tomography and Correlation with Pneumonia Severity in Turkish Population

Türk Popülasyonunda Bilgisayarlı Tomografide COVID-19 Hastalarının Trakeobronşiyal Açılarının Ölçümü ve Pnömoni Şiddeti ile Korelasyonu

Burcu AKMAN[1]
0000-0002-1067-9008
Hatice Ayça ATA KORKMAZ[2]
0000-0001-9987-3351

[1]Department of Radiology, Amasya University Faculty of Medicine, Amasya, Turkey

[2]Department of Radiology, University of Health Sciences, Kanuni Training and Research Hospital, Trabzon, Turkey

Corresponding Author
Sorumlu Yazar
Burcu AKMAN
burcuakman80@gmail.com

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ABSTRACT

Aim: This study aimed to evaluate the values of tracheobronchial angles on computed tomography (CT) and to investigate the relationship between angles and CT severity scores (CT-SS) of coronavirus disease 2019 (COVID-19) patients. There is no available literature measuring tracheobronchial angles of adult COVID-19 patients and investigating the relationship of angles with pneumonia severity.

Material and Methods: This study was a single-center retrospective analysis of 92 RT-PCR positive patients, aged between 18-40 years, who underwent CT between May and October 2020. The right bronchial angles (RBA), left bronchial angles (LBA), subcarinal angles (SCA), and interbronchial angles (IBA) were measured by a radiologist on coronal CT images with the measurement model used in past. CT-SS was calculated by using a visual scoring system with a global score of 0-25.

Results: Thirty-seven (40.2%) patients had normal CT imaging and 55 (59.8%) patients had pulmonary involvement. The CT-SS were ranged from 0 to 24, with a median value of 2.5. The mean IBA was calculated as 81.67±15.20°, mean SCA 77.65±15.78°, mean RBA 39.26±7.51°, and mean LBA 43.35±8.43°. No statistically significant difference was found in SCA, IBA, RBA, and LBA between the groups with and without COVID-19 pneumonia (p=0.277, p=0.389, p=0.218, and p=0.227, respectively). Also, no significant correlation was found between tracheobronchial angles and pneumonia CT-SS of the patients.

Conclusion: We calculated the distribution range of tracheobronchial angle values in the adult Turkish COVID-19 patients. According to our study, tracheobronchial angles don't affect the disease severity and clinical outcome of COVID-19 patients.

Keywords: COVID-19; computed tomography; chest CT severity score; bronchial angle; subcarinal angle; interbronchial angle.

ÖZ

Amaç: Bu çalışma, koronavirüs hastalığı 2019 (coronavirus disease 2019, COVID-19) hastalarının bilgisayarlı tomografide (BT) trakeobronşiyal açı değerlerini hesaplamayı ve bu açılar ile BT şiddet skorları (BT-ŞS) arasındaki ilişkiyi araştırmayı amaçlamaktadır. Yetişkin COVID-19 hastalarının trakeobronşiyal açılarını ölçen ve açıların pnömoni şiddeti ile ilişkisini araştıran mevcut bir literatür bulunmamaktadır.

Gereç ve Yöntemler: Bu çalışma, Mayıs ve Ekim 2020 arasında BT çekilen 18-40 yaş arasında 92 RT-PCR testi pozitif hastanın tek merkezli retrospektif analizidir. Sağ bronş açıları (sağ BA), sol bronş açıları (sol BA), subkarinal açılar (SKA) ve interbronşiyal açılar (İBA), geçmişte kullanılan ölçüm modeli ile koronal BT görüntülemelerinde bir radyolog tarafından ölçüldü. BT-ŞS, global skoru 0-25 olan bir görsel skorlama sistemi kullanılarak hesaplandı.

Bulgular: Otuz yedi (%40,2) hastanın BT görüntülemeleri normal iken, 55 (%59,8) hastada akciğer tutulumu vardı. BT-ŞS 0 ile 24 arasında olup ortanca değeri 2,5 idi. Ortalama İBA 81,67±15,20°, ortalama SKA 77,65±15,78°, ortalama sağ BA 39,26±7,51° ve ortalama sol BA 43,35±8,43° olarak hesaplandı. SKA, İBA, sağ BA, sol BA değerleri bakımından COVID-19 pnömonisi olan ve olmayan gruplar arasında istatiksel olarak anlamlı bir farklılık saptanmadı (sırsıyla, p=0,277; p=0,389; p=0,218 ve p=0,227). Ayrıca trakeobronşiyal açılar ile pnömoni BT-ŞS arasında istatiksel olarak anlamlı bir korelasyon bulunmadı.

Sonuç: Çalışmamızda, erişkin Türk COVID-19 hastalarında trakeobronşiyal açı değerlerinin dağılım aralığını hesapladık. Çalışmamıza göre trakeobronşiyal açılar, COVID-19 hastalarında, hastalığın şiddetini ve klinik sonucunu etkilememektedir.

Anahtar kelimeler: COVID-19; bilgisayarlı tomografi; toraks BT şiddet skoru; bronş açısı; subkarinal açı; interbronşiyal açı.

INTRODUCTION

The trachea extends from the inferior aspect of the cricoid cartilage to the carina and its craniocaudal length is measured usually 10-12 cm (1,2). Trachea branches to the left and right main bronchus (LMB and RMB) at the 4-5th thoracic vertebra level generally (3).

Conventional chest radiographs (posterior-anterior, PA) and lateral chest radiographs are the imaging modalities used for the initial evaluation of the trachea and central airways. Computed tomography (CT) scan shows the anatomy of the airways better and allows evaluation in three planes as axial, coronal, and sagittal. Coronal images of CT are very useful for imaging the trachea in a single plane (2).

Tracheal bifurcation angle means both subcarinal angles (SCA) and interbronchial angles (IBA). The angle measured between the central axes of the right and left main bronchi is called the IBA. The angle formed at the intersection of the lines drawn along the lowest surfaces of the right and left main bronchi is defined as SCA (4-7). Tracheobronchial angles may differ depending on race, age, and individual and angle measurement techniques (1,8-15). Therefore, it is difficult to decide the range of "normal" tracheobronchial angles.

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which was firstly reported in Wuhan, China (16). The patients with COVID-19 mostly have a good prognosis and mild symptoms. But, severe pulmonary involvement, pulmonary edema, acute respiratory distress syndrome (ARDS), multiple organ failure, and death were observed in some patients (17). While some patients with COVID-19 have no pulmonary involvement, some patients have extensive pulmonary involvement and a poor prognosis.

In our study, we investigated whether tracheobronchial anatomy features may be a risk factor for the occurrence of severe pneumonia in patients with COVID-19. To our knowledge, no study in the literature measured tracheobronchial angles on thorax CTs of adult COVID-19 patients and investigate the relationship of angles with pneumonia severity. The aim of this study was to evaluate the values of tracheobronchial angles on CT and to investigate the correlation between angles and CT severity score (CT-SS) of COVID-19 patients.

MATERIAL AND METHODS

This study was approved by the Ethics Committee of Kanuni Training and Research Hospital (dated 26.11.2020 and no: 2020/71), and was conducted according to the Declaration of Helsinki and Good Clinical Practice.

Study Group and Data Collection

Our study was a single-center retrospective analysis of 92 patients with a positive COVID-19 polymerase chain reaction (PCR) test. Chest CT examinations of all study patients were performed in Kanuni Training and Research Hospital at the time of admission. Patients who underwent chest CT scans between May and October 2020 were included in the current study. We included only laboratory confirmed patients with RT-PCR positivity in samples from the oropharyngeal and nasopharyngeal regions. The RT-PCR tests were performed in the Microbiology Laboratory at the same hospital. RT-PCR tests were repeated in patients with a high radiologic and clinic suspicion of COVID-19 when the initial PCR test was negative. We collected the data for retrospective analysis including demographic characteristics, PCR test results, and initial CT imaging. Exclusion criteria include being younger than 18 years or older than 40 years, having any comorbidities, having a history of heart disease, mediastinal abnormalities, musculoskeletal deformity, vascular anomalies, or any previous thoracic injury, or a history of tracheobronchial surgery that may affect the normal anatomy of trachea and bronchus.

Computed Tomography Protocol

All patients underwent chest CT examinations on two multidetector CT scanners (16- slice Somatom Sensation; Siemens Healthineers or 128- slice GE Healthcare Computed Tomography Revolution EVO System). Chest CT imaging was applied in the supine position during a breath-hold.

The non-contrast scans were performed with the following parameters: tube current=70-114 automatic milliamperes; tube voltage=130 kV: helical pitch=1; slice thickness=5 mm and interval=5 mm (16- slice Somatom Sensation; Siemens Healthineers) or tube current=70-280: automatic milliamperes: tube voltage=120 kV; helical pitch=1.375; slice thickness=5 mm and interval=5 mm (128- slice GE Healthcare Computed Tomography Revolution EVO System). Images were reconstructed with a 1.25 mm slice thickness. All chest CT scans were performed at a lung window of 1200 WW and -600 WL and a mediastinal window of 400 WW and 40 WL.

Image Analysis

A radiologist with more than 14 years of experience in chest CT imaging, applied the CT image analysis in a picture archiving and diagnostic system (PACS) workstation, blinded to the clinical data and laboratory findings. Measurements of right bronchial angles (RBA), left bronchial angles (LBA), SCA, and IBA were made in coronal reformat CT images with a slice thickness of 1.5 mm or 1.25 mm. All measurements were performed by the same chest radiologist. We used a measurement model defined in previous studies (1). We calculated the range of distribution of tracheobronchial angle values in adult patients with COVID-19.

The RMB angle is defined as the angle between the vertical line passing through the lower point of the tracheal bifurcation and the line drawn on the mid-axis of the RMB. The LMB angle is defined as the angle between the vertical line passing through the lower point of the tracheal bifurcation and the line drawn on the mid-axis of the LMB. The angle formed between the intersection points of the lines drawn along the central axis of the right and left main bronchi is called the interbronchial (tracheal bifurcation) angle. Sum of RBA and LBA gives IBA. The angle measured at the intersection of the lines drawn along the right and left upper bronchi's lower borders is called the SCA (1, Figure 1).

In addition, the 25 Point CT-SS was calculated in all cases by using a visual semi-quantitative CT severity scoring system that was suggested by Pan et al. (18). In this method, scoring between 0 and 5 was made for 5 lung lobes. Zero if there is no lung involvement; if there is <5% involvement 1; if there is 5-25% involvement 2; 26-50% if

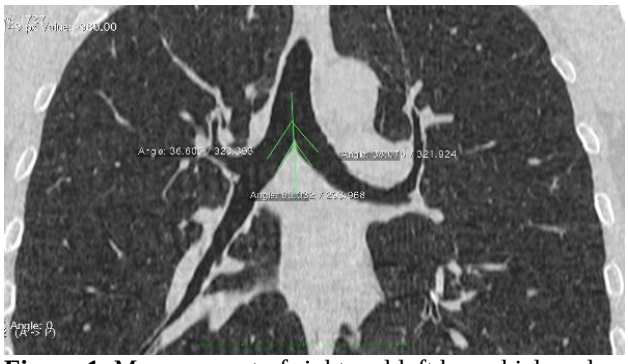

Figure 1. Measurement of right and left bronchial angles, and subcarinal angle on a coronal reformatted computed tomography image. The sum of the right and left bronchial angles gives interbronchial angle.

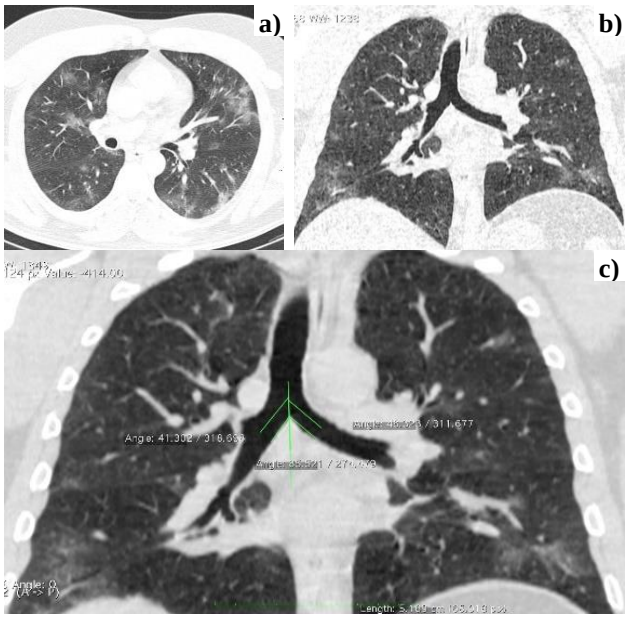

Figure 2. A 40-year-old male with COVID-19. He was discharged after medical treatment at the hospital. **a)** axial and **b)** coronal chest computed tomography scans show bilateral multifocal rounded ground-glass opacities and the computed tomography severity score was calculated 15. **c)** Measurement of right and left main bronchial angles and subcarinal angles on the coronal reformatted computed tomography image; right bronchial angle: 41.3°, left bronchial angle: 48.3°, subcarinal angle: 85.5°, and interbronchial angle: 89.6°.

any 3; if there is 51-75% involvement 4; and it is calculated as 5 if there is >75% involvement. Chest CT-SS is obtained by the sum of 5 lung lobe scores (0-25).

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp. Released 2017. Armonk, NY). The conformity of the variables to the normal distribution was examined using the Kolmogorov-Smirnov test. In descriptive statistics, mean and standard deviation were used for normally distributed variables, and median and interquartile range (IQR) were used for non-normally distributed variables. In the comparison of continuous variables according to tracheobronchial angles, Student's t-test was used for those with normal distribution, and the Mann-Whitney U test for those who were not normally distributed. Spearman's rho correlation coefficient was used to evaluate the correlation between SCA, IBA, RBA, and LBA measurements in CT imaging with CT-SS. Statistical significance was established at the $p<0.05$ level.

RESULTS

A total of 92 patients, 53 (57.6%) females and 39 (42.4%) males were included in the study. The mean age of the patients was 31.48±6.55 years ranging from 18 to 40. The diagnosis of COVID-19 was confirmed by RT-PCR in 100% of these patients. Of the 92 cases, 89 (96.7%) were discharged (Figure 2), and 3 (3.3%) were died in the intensive care unit of the hospital.

Fifty-five (59.8%) COVID-19 confirmed cases had pneumonia and 37 (40.2%) COVID-19 confirmed cases had no pneumonia in their chest CT imaging at the time of admission. CT-SS were ranged from 0 to 24, with a mean value of 4.63±5.57 and a median value of 2.5 (IQR, 8). Of the 55 patients, 7 (12.7%) with only right lung involvement (mean CT-SS: 6.14±8.83), 2 (3.6%) with only left lung involvement (mean CT-SS: 1), and 46 (83.6%) with bilateral lungs involvement (mean CT-SS: 8.28±4.48).

On the coronal CT scans, the mean SCA was 77.65±15.78° (range, 43-126), the mean IBA was 81.67±15.2° (range, 31-119), the mean RBA was 39.26±7.51° (range 21-61), the mean LBA was 43.35±8.43° (range 28-77) of all patients (Table 1). In our study RBA was smaller than LBA in 72 (78.3%) patients, RBA was greater than LBA in 17 (18.5%) patients and RBA-LBA was equal in 3 (3.3%) patients.

To investigate the statistical relationship between the angles and age, we divided our patients into two age groups. The mean age of our total study patients was 31.48±6.55 years ranging from 18 to 40. To provide a numerically balanced distribution between the groups, we divided the age groups as the patients aged ≤30 years (n=45) and those aged >30 years (n=47). We could not find a statistically significant difference in SCA, IBA, RBA, and LBA between the two groups (p=0.882, p=0.459, p=0.705, and p=0.501, respectively). Also, there was no statistically significant difference between gender in terms of SCA, IBA, RBA, and LBA (p=0.826, p=0.662, p=0.994, and p=0.404, respectively).

When the patients with and without COVID-19 pneumonia were compared, results showed no statistically significant difference in SCA, IBA, RBA, and LBA in terms of occurrence of COVID-19 pneumonia (p=0.277, p=0.389, p=0.218, and p=0.227, respectively, Table 2).

There was no statistically significant correlation between the CT-SS of all patients (with and without COVID-19 pneumonia) with SCA (r_s=0.085, p=0.420), IBA (r_s=0.089, p=0.397), RBA (r_s=0.115, p=0.273), and LBA (r_s=0.105, p=0.321) measurements in CT imaging (Table 3). Also, there was no significant correlation between the CT-SS of patients with pulmonary involvement (the patients with CT-SS: 0 were excluded) with SCA (r_s=0.011, p=0.936), IBA (r_s=-0.030, p=0.828), RBA (r_s=0.005, p=0.972), LBA (r_s=-0.021, p=0.881) measurements in CT imaging.

Table 1. Descriptive statistics for tracheobronchial angles and computed tomography severity scores

	Mean±SD	Median (IQR)	Min-Max
SCA	77.65±15.78	77 (22)	43-126
IBA	81.67±15.20	82 (22)	31-119
RBA	39.26±7.51	40 (10)	21-61
LBA	43.35±8.43	43 (13)	28-77
CT-SS	4.63±5.57	2.5 (8)	0-24

SCA: subcarinal angle, IBA: interbronchial angle, RBA: right bronchial angle, LBA: left bronchial angle, CT-SS: computed tomography severity score, SD: standard deviation, IQR: interquartile range

Table 2. Comparison of tracheobronchial angles by the presence of COVID-19 pneumonia on CT images

	Absent (n=37)	Present (n=55)	p
SCA	75.46±14.56	79.13±16.52	0.277
IBA	80.00±13.43	82.8±16.30	0.389
RBA	38.08±6.58	40.05±8.04	0.218
LBA	42.03±7.14	44.24±9.15	0.227

COVID-19: coronavirus disease 2019, CT: computed tomography, SCA: subcarinal angle, IBA: interbronchial angle, RBA: right bronchial angle, LBA: left bronchial angle

Table 3. Correlations between tracheobronchial angles and computed tomography severity score

	SCA	IBA	RBA	LBA
CT-SS				
r_s	0.085	0.089	0.115	0.105
p	0.420	0.397	0.273	0.321

CT-SS: computed tomography severity score, SCA: subcarinal angle, IBA: interbronchial angle, RBA: right bronchial angle, LBA: left bronchial angle

DISCUSSION

In the current study, the SCA, IBA RBA, and LBA were measured on the reformat coronal CT images of COVID-19 patients. We investigated the correlation between SCA, IBA, RBA, and LBA measurements with the CT-SS of patients. We investigated the effects of tracheobronchial anatomy on the occurrence and severity of COVID-19 pneumonia. Our study is the first to evaluate the relationship between tracheobronchial angles and the severity of pneumonia in patients with COVID-19. Our results showed no statistically significant difference in terms of age and gender in SCA, IBA, RBA, and LBA measurements in CT imaging. We think that we gained these results because we only included adult patients older than 18 years of age in our study. Also, we did not find any statistically significant difference in SCA, IBA, RBA, and LBA in terms of the occurrence of COVID-19 pneumonia.

In the literature, tracheobronchial angle measurements were made using different techniques. Chest radiography, chest CT and cadavers were used for measurement in the studies (8). Tracheobronchial angles may differ depending on race, age, and individual and angle measurement techniques (1,8-15). In many studies on tracheobronchial angle measurements, generally, children were included in the study. Herek et al. (8) measured SCA, IBA, RBA, and LBA on coronal the reformat CT imaging of the children. They reported that SCA, IBA, and RBA values were statistically significant between children of ages younger than 10 years and older than 10 years.

In the previous studies, the IBA was found to be slightly wider than the SCA in the measurements performed on helical CT images (12). The tracheal bifurcation angle has been found an average of 65° (range, 40° to 99°) (19-22). Most authors agree in their studies that the RBA is smaller than the LBA, regardless of gender and age (4,6,7,11,20-25). In addition, according to the major clinical and anatomical texts, the RMB is wider and steeper than the left, and therefore foreign body aspiration is mostly through the right bronchus (1,4,7,19-22,24,26).

Kubota et al. (14) measured the tracheal bifurcation angle on the chest radiographs of infants and children and they found the mean tracheal bifurcation angle about 80°. We found the mean SCA was 77.65±15.78° and the mean IBA was 81.67±15.20°. In their study, they found that the RBA was always smaller than the LBA (14). RBA was smaller than LBA in 78.3% of the patients, RBA was greater than LBA in 18.5%, and RBA-LBA was equal in 3.3% of the patients, in our study, RBA was smaller than LBA in most patients. Many studies in the literature indicate that the tracheal bifurcation angle in both children and adults has a wide range with many different values (8). Mi et al. (9) included in their study 2107 subjects, ranging in age from 18 to 89 years in the Chinese population and they measured the tracheobronchial angles using multi-slice spiral CT and MPR. They found that in one-fifth of the Chinese population, RBA was larger than LBA and the left mainstem bronchus is more vertical (9). We also found that in 18.5% of the patients in our study RBA was larger than LBA.

Kamel et al. (4) found the mean SCA values were 81° in females and 76° in males without any correlation with age. These results are different from our results. We found that mean SCA values were 77.3° in females and 78° in males. We found no relationship between gender and the tracheobronchial angles in adults.

SCA and IBA may increase due to various cardiac diseases (cardiomegaly and pericardial effusion) and mediastinal lesions (11,12). Cardiac enlargement, such as cardiomegaly due to heart failure, has been reported to widen the angle between RMB and LMB (11-13). Some studies have found positive correlations between the SCA, IBA, and the size of the left atrium (1,12,27). Thus, we excluded patients with heart disease and mediastinal abnormalities.

Although the standard diagnosis of COVID-19 is the RT-PCR test, it may give false-negative results in some cases. False-negative RT-PCR results may be possibly due to insufficient viral specimens or early stages of the disease or technical problems (28,29). According to past clinical information, chest CT imaging can show abnormalities before RT-PCR testing. Therefore, recently, high-resolution CT has become one of the main screening methods, for diagnosing and assessing disease severity (30). COVID-19 pneumonia's typical imaging findings are bilateral, peripheral, and basal dominant ground-glass opacities (GGOs) with or without consolidation and bronchovascular thickening in chest CT (31). In our study, the severity of lung involvement was scored by using the visual method suggested by Pan et al. (18).

Some studies have reported that COVID-19 patients have a worse prognosis and severe clinical outcomes, especially when multiple risk factors such as diabetes, hypertension, coronary artery, and lung disease are present (32,33). To date, a wide variety of studies have been conducted on the risk factors of COVID-19 patients with pneumonia. In different studies in the literature, it has been reported that older age and comorbidities (cardiovascular and cerebrovascular diseases) are important high-risk factors that may lead to increased mortality in severe COVID-19 patients (34-36). So, we included only patients aged 18-40 years in our study. Several studies have reported a history of diabetes, hypertension, and lung and coronary artery disease as risk factors for worse prognosis and serious clinical outcomes in COVID-19 patients (32,33). Therefore, we did not include patients with comorbidities in our study.

Our study has several limitations. The first limitation is that our study is a retrospective study conducted at a single center and included a relatively limited group of patients. Therefore, a multicenter study with a large sample size is needed for further validation. Second, we used a visual semi-quantitative CT severity scoring system, so assessment of disease severity scores on CT imaging can be subjective.

CONCLUSION

In conclusion, we calculated the distribution range of tracheobronchial angle values in adult Turkish COVID-19 patients. We couldn't find a statistical relationship between the tracheobronchial angles with the severity of pneumonia in COVID-19 patients. Therefore, according to our study, the tracheobronchial angle values do not affect the severity of pneumonia and patients' clinical outcomes in COVID-19. But a large sample size study is needed for further validation.

Ethics Committee Approval: The study was approved by the Clinical Researches Ethics Committee of Kanuni Training and Research Hospital (26.11.2020, 2020/71).

Conflict of Interest: None declared by the authors.

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Acknowledgments: Since our study was retrospective, previous laboratory findings and previous CT scans of the patients were examined. Additional laboratory tests or CT scans were not performed for our study.

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Author Contributions: Idea/Concept: BA, HAAK; Design: BA; Data Collection/Processing: BA, HAAK; Analysis/Interpretation: BA, HAAK; Literature Review: BA; Drafting/Writing: BA; Critical Review: BA, HAAK.

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