# Clinical features of aviators with coronary artery disease diagnosed by multislice CT angiography

*Muhammed Erdal, Mustafa Aparcı, Zafer Işılak[1], Uğur Bozlar[2], Zekeriya Arslan, Murat Ünlü[3]*

Department of Cardiology and Aviation Medicine Center, Etimesgut Military Hospital; Ankara-*Turkey*
[1]Clinic of Cardiology, Haydarpaşa Training Hospital; İstanbul-*Turkey*
[2]Department of Radiology, Gülhane Military Medical Academy; Ankara-*Turkey*
[3]Department of Cardiology, Beytepe Military Hospital; Ankara-*Turkey*

## Abstract

**Objective:** Coronary artery disease (CAD) is one of the most incapacitating causes at military or civilian aviation. Aircrew population is crowding in number in our country. We aimed to identify the clinical features that could predict CAD in aircrew.
**Methods:** We retrospectively analyzed medical recordings of 26 aircrew (age 43.57±5.2) whose CAD was diagnosed via multislice computerized tomography angiography (MSCT). Clinical features, coronary risk factors and ST segment and T wave changes on resting ECG and treadmill test (TT), and laboratory findings of aircrew were recorded.
**Results:** ST depression <0.05 mV and minimally inversion (<0.03 mV) of T wave were found on 53.8% and 23.1% of resting ECG, respectively. 53.8% of patients had the family history of CAD. 73.1% of subjects were overweight. Family history was correlated with CAD and its type (p=0.023). 76.9% and 23.1% of the subjects had equivocal and positive result on TT, respectively. Presence of hypertension, hyperlipidemia, and smoking were lower and diabetes was absent. Additionally, subjects with two or more vessel disease were observed slightly older compared to those with one vessel disease (45.5±3.8 vs. 42.2±5.5, p=0.101).
**Conclusion:** Aircrew ≥40 years old, with family history, ST/T changes on resting ECG, and equivocal results on TT even in the absence of multiple coronary risk factors may need further cardiovascular tests. MSCT is an effective and noninvasive way of detection of CAD in aircrew when needed. *(Anadolu Kardiyol Derg 2014; 14: 150-4)*
**Key words:** aviation, coronary risk factors, atherosclerosis, multislice computerized tomography, coronary angiography

## Introduction

Coronary artery disease (CAD) is one of the most leading causes of incapacitation during either military or civilian flight operation (1). CAD may clinically be manifested as acute coronary syndrome with 50% potential of total incapacitation and may cause deleterious results (2). On postmortem studies, prevalence of CAD was reported with a rate of 69% and 37.64% in pilots who died at aircraft accidents during the period of 1980-82 and 1996-99 years, respectively (3, 4). Also its prevalence was increased with age e.g. 5.8 per 1000 for ages <40 years and 73.9 for ages >50 years (3).

Earlier prediction or detection of CAD is clinically significant in some professions that could challenge the public safety such as pilots, public transport drivers, and etc (5). Aircrew population is growing enormously in our country due to increasing number and globalization of airline companies. CAD is a clinical entity challenging not only military aviation but also civilian aviation. Also raised age criteria for retirement and prolonged employment durations caused the aircrew population getting older. Although the classical coronary risk factors have been defined exactly, they may not have been diagnostic in aircrew population who was periodically examined and relatively fitted compared to public society (6). Coronary angiography is still the gold standard for diagnosis of CAD; but it may physically and medically be unintended due to its invasive nature if the subject's probability of CAD was low. However either specific or equivocal changes on resting ECG or treadmill test (TT) may clinically be essential in guiding further cardiovascular tests to diagnose CAD in aviators. MSCT

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**Address for Correspondence:** Dr. Mustafa Aparcı, Etimesgut Askeri Hastanesi, Kardiyoloji ve Havacılık Tıbbi Merkezi, Etimesgut; Ankara-*Türkiye* Phone: +90 505 394 71 31 Fax: +90 312 244 49 77 E-mail: maparci@gmail.com
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angiography is an alternative method for estimating CAD in asymptomatic low risk patients. So far there is not known study estimating its value in aviators.

In this study we retrospectively collected the medical data of aircrew from the archives and statistically analyzed in order to determine any clinical, laboratory and ECG changes either at rest or TT which could potentially predict CAD.

## Methods

### Study design

We retrospectively reviewed the medical recordings of aircrew that were examined through January 2011 and December 2011 at the Aviation Medical Examination Center of Etimesgut Military Hospital, Ankara, Turkey. The study was approved by the local ethic committee. Subjects had been referred to TT and subsequently multislice computerized tomography coronary angiography (MSCT) due to coronary risk profile, changes of ST segment or T wave on ECG recordings at resting ECG or TT. TT was performed to the Bruce protocol with ending criteria of achieving 95% of age predicted target heart rate (220-age) or any symptom.

### Study population

All of aviators who were newly diagnosed as having CAD by MSCT were enrolled to the study. Subjects with diagnosis of CAD previously were excluded from the study.

### Data collection

Clinical features [age, height, weight, body mass index (BMI), systolic and diastolic blood pressure], laboratory parameters [serum levels of fasting blood glucose, total cholesterol, LDL and HDL cholesterol, triglyceride, alanine aminotransferase (ALT), aspartate amino transferase (AST), γ-glutamyltransferase (GGT), urea, creatinine)], coronary risk factors were obtained from the history taking and laboratory result chart of medical recordings recorded at the time of diagnosis. Coronary risk factors were defined as presence of family history of CAD (premature atherosclerosis at 45 years old male first degree relatives and 55 years old female ones), smoking, obesity (normal BMI<25 kg/m$^2$, overweight BMI=25-30 kg/m$^2$, obese BMI≥30 kg/m$^2$), hypertension (previous diagnosis of hypertension or blood pressure ≥140/90 mm Hg, diabetes (previous diagnosis of diabetes or fasting blood glucose >126 mg/dL), low HDL cholesterol (≤35 mg/dL). Abnormal changes of ST segment or T wave on resting ECG were defined and grouped as 1.absent or non-spesific, 2.ST segment depression <0.5 mm (0.05 mV) mm, 3. minimal T wave inversion (not symmetric and deep, <0.03 mV). Also ECG derivations where the changes were observed were grouped as 1. Derivations II, III, and aVF, 2.Derivations $V_4$, $V_5$, and $V_6$, 3.Derivations II, III, aVF+ $V_4$, $V_5$, and $V_6$. Abnormal changes of ST segment on TT and results were defined as 1.Equivocal [ST depression ≤1 mm (0.01 mV)] and 2.Positive [ST segment depression ≤2 mm (0.02 mV)] (7).

### Multislice computed tomography angiography

Coronary angiography had been performed by 64-sliced MSCT (Aquilion 64, Toshiba Medical Systems, Otawara, Japan). Coronary artery disease was defined as presence of any atherosclerotic plaque on coronary arteries. CAD was grouped as 1.One-, 2. Two- and 3. Three-vessel disease and 1. One and 2. Two or more vessel disease.

### Statistical analysis

Statistical analysis was performed by using SPSS 11.0 (SPSS Inc, Chicago, IL, USA) for Windows. Normality of distribution for continuous variables was tested by Kolmogorow-Smirnov test and histogram analysis. Thereafter numerical variables with normal distribution were analyzed by parametric test (Independent sample t-test). Categorized variables were analyzed by chi-square test. Correlation analyses of parametric and nonparametric data was performed by Pearson and Spearman's correlation test, respectively. $p<0.05$ was accepted as statistically significant.

## Results

The study group (43.57±5.2 years old) was composed of 15 (57.7%) pilots and 11 (42.3%) other aircrew. There was not statistically significant difference in comparison of clinical features and laboratory findings results between the pilots and other aircrew except age (46.2±5.1 vs. 40.0±2.5, p=0.001) (Table 1). Frequencies of coronary risk factors, abnormal ST and T wave changes on ECG and derivations, and results of TT and vessel distribution of coronary artery disease detected on MSCT were all depicted on Table 2. Twenty two (84.6%) of the patients were over age 40 years old. Family history was present in 53.8% (n=14) of patients (Fig. 1A), smoking was favorably of low rate with 26.9% (n=7). However 73.1% (n=19) of patients were overweighed. Hypertension and hyperlipidemia were low in rate (15.4% and 15.4%, respectively). Only the family history was found to be significantly correlated with types of coronary artery disease (r=0.440, p=0.024) in correlation analysis of variables. Although at least one of the ECG changes previously defined (76.9%, n=20) was present on resting ECG, no significant correlation was found (Fig. 1B). Similarly 76.9% of subjects had equivocal result on TT but it was not significant correlated with diagnosis of CAD (Fig. 1C).

## Discussion

In this study we aimed to describe the clinical features of aircrew with CAD and to draw a profile to flight surgeons or cardiologist to be highly suspicious of asymptomatic CAD.

**Table 1. Clinical and laboratory features of study population**

| Variables (n=26) | Mean±SD |
|---|---|
| Age, years | 43.5±5.2 |
| Gender | 26 male |
| Height, cm | 177.6±3.9 |
| Weight, kg | 81.5±7.4 |
| BMI, kg/m$^2$ | 27.3±1.9 |
| SBP, mm Hg | 124.4±10.2 |
| DBP, mm Hg | 80.3±5.4 |
| Total cholesterol, mg/dL | 226.8±23.5 |
| LDL-C, mg/dL | 148.5±27.2 |
| HDL-C, mg/dL | 46.8±9.6 |
| Triglyceride, mg/dL | 160.5±48.8 |
| FBG, mg/dL | 92.0±7.8 |
| ALT, U/L | 34.1±11.3 |
| AST, U/L | 29.7±8.1 |
| γ-GT, U/L | 42.8±21.0 |
| Urea, mg/dL | 26.3±6.4 |
| Creatinine, mg/dL | 0.99±0.11 |
| HR on ECG, bpm | 73.8±10.3 |

ALT - alanine amino transferase; AST - aspartate amino transferase; BMI - body mass index; DBP - diastolic blood pressure; ECG - electrocardiogram; FBG - fasting blood glucose; γ-GT - gamma-glutamyltransferase; HDL-C - high density lipoprotein cholesterol; HR - heart rate; LDL-C - low density lipoprotein cholesterol; SBP - systolic blood pressure; DBP - diastolic blood pressure; bpm -beat per minute; SD - standard deviation

Family history of CAD and/or minimally ST segment depression <1 mm and/or T wave inversion on resting ECG without even any symptom may be evaluated with TT. While a horizontal or downsloping ST segment depression ≥2 mm was accepted as positive test criteria for ischemia and indication for coronary angiography, ≤1 mm depression of ST segment may be an indication for coronary imaging by a less invasive method of coronary imaging; MSCT, in pilots or other aircrew.

Coronary artery disease was the most leading autopsy finding on postmortem studies of fatal aviation accidents (3, 4). While the first clinical manifestation of CAD in a subject may cause individual fatalities on ground, it will challenge the public safety and may lead large scaled casualties and fatalities in certain professions such as pilots, etc. So prediction and earlier detection of CAD gained importance in aviation medicine and guided studies to identify the pilots at high risk. Houston et al. (8) evaluated applicability of 10-year absolute cardiovascular disease (CVD) risk scores which were developed at Framingham Heart Study in a commercial pilot group. They reported that it may identify a group of pilots at high risk who were unidentified previously. Those high-risk pilots were about 60 years old (mean 59, median 60 year, ranging 40-81 years) in their study group. Our study group is composed of middle aged subjects who were relatively younger (43.57±5.2) compared to their study group.

**Table 2. Descriptive features of study group and clinical findings**

| Variable (n=26) | Group | Frequency (n, %) |
|---|---|---|
| **Clinical features, coronary risk factors of study group** | | |
| Profession | pilot | 15 (57.7) |
| | Other aircrew | 11 (42.3) |
| Age, years | <40 years old | 4 (15.4) |
| | ≥40 years old | 22 (84.6) |
| Family history | No | 12 (46.2) |
| | Yes | 14 (53.8) |
| Smoking | No | 19 (73.1) |
| | yes | 7 (26.9) |
| Body mass index, kg/m2 | Normal (BMI<25) | 3 (11.5) |
| | Overweight (25-30) | 19 (73.1) |
| | Obese (>30) | 4 (15.4) |
| Hypertension | No | 22 (84.6) |
| | Yes | 4 (15.4) |
| Diabetes mellitus | Absent | 26 (100) |
| Hyperlipidemia | No | 22 (84.6) |
| | Yes | 4 (15.4) |
| Low HDL cholesterol | No | 19 (73.1) |
| | Yes | 7 (26.9) |
| **Changes observed on resting electrocardiogram** | | |
| Types of changes | Absent or nonspecific | 6 (23.1) |
| | <1 mm depression ST segment | 14 (53.8) |
| | T wave inversion | 6 (23.1) |
| Presence of ECG changes | Absent or nonspecific | 6 (23.1) |
| | At least one of <1 mm ST depression or T wave inversion | 20 (76.9) |
| ECG derivation that changes observed | D-II, III, aVF | 7 (26.9) |
| | $V_4$, $V_5$, $V_6$ | 13 (50) |
| | D II, III, aVF+ $V_4$, $V_5$, $V_6$ | 6 (23.1) |
| **ST segment changes, METs and decision on treadmill test** | | |
| ECG changes on treadmill test | ≤1 mm ST depression | 20 (76.9) |
| | ≤2 mm ST depression | 6 (23.1) |
| METs derived on treadmill test | 10.1 METs | 13 (50) |
| | 13.4 METs | 13 (50) |
| Decision on treadmill test | Equivocal | 20 (76.9) |
| | Positive | 6 (23.1) |
| **Conclusion on MSCT angiography** | | |
| Number of coronary artery disease | One-vessel disease | 16 (61.5) |
| | Two-vessel disease | 7 (26.9) |
| | Three-vessel disease | 3 (11.5) |
| Number of coronary artery disease | One-vessel disease | 16 (61.5) |
| | Two or more vessel disease | 10 (38.5) |

BMI - body mass index; D - derivations on electrocardiogram; ECG - electrocardiogram; METs - metabolic equivalents; MSCT - Multi-slice computerized tomography coronary angiography

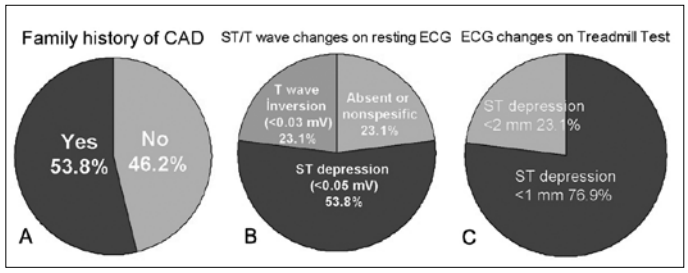


**Figure 1. A) Family history of coronary artery disease, B) ST and T wave changes on resting ECG, C) ECG changes on treadmill test**

Additionally we documented the diagnosis of CAD by MSCT. Our study group was far away from the effect of diabetes, hypertension, hyperlipidemia and smoking due to their lower rates. Also they had relatively a higher physical fitness. However military pilots and aircrew may expose extremely increased physical and mental stresses rather different from their civilian colleagues (9). Since coronary risk factors were lower in aircrew, family history may be a powerful indicator in a subject for further noninvasive cardiac evaluation in aircrew. Although minimally changes of ST segment and T wave on resting ECG without any symptom or coronary risk factor may appear insignificant in a young adult subject, they may indicate a next step; TT. In many health service systems, aviators may be examined by a cardiologist who is not a flight surgeon or by a flight surgeon that may not naturally be expertise in ECG and coronary artery disease. Those ECG changes may easily be overlooked if the aviator was asymptomatic or did not state any complaint. Prediction and detection of CAD at younger ages in commercial pilots may aid the flight surgeons and subjects for an effective cardiovascular risk management and prevention of further cardiac events.

Pilots had significantly a lower prevalence of obesity and smoking compared to general population (6). Our findings are consistent with the previous findings, since hypertension, smoking, hyperlipidemia, and diabetes was lower in our study group but not the overweight. Overweight and lower METs (metabolic equivalents) may represent the lack of physical condition which is common problem in aviation. Absence of diabetes was not surprising since it was a disqualifying cause in the aviation medicine. However CAD is not disqualifying medical condition unless it was medically treated and stabilized. Arva et al. (10) reported that for cardiovascular disease disqualification rates were lowered after 1997 probably due to improved treatment. We suggest that earlier detection or diagnosis of coronary artery disease will probably identify those subjects with CAD. Favorable attitudes such as lifestyle and dietary changes, regular sporting and physically fitness and also perception of those aviators on their disease and also profession may also contribute the long durability of stable CAD. Such a close follow up will be ensued with a more thousands of flight hours in a safety without any aviation fatalities due to cardiovascular events.

MSCT is a less invasive with a high sensitivity and specificity for detection of atherosclerotic coronary artery disease and its burden. Its radiation dose may be a handicap but more acceptable compared to invasive coronary angiography. In study of Arva et al. (10) it was demonstrated that myocardial infarction and coronary artery disease was cumulated around the fourth and fifth decades. Our findings are rationale and valuable since CAD was effectively documented in a group of aviators who were over 40 years old and did not suffered any cardiovascular events. Blair et al. (11) reported a case of young 38 years old military pilot with acute coronary syndrome developed after an 8 hour-flight and issued that TT followed by MSCT, in lieu of coronary angiography, was highly sensitive and specific in the diagnosis of CAD. In a review of cardiac events among USAF aviators during years 1988-92 it was reported that myocardial infarction occurred in 23 aviators, angina in 7 and sudden death in 8 aviators with an average of 7.6 events per year. Their ages were ranging 31-53 years with average of 44 years as well as in our study (43.57±5.2 years). They reported that 5-year average annual event rate by age group was increased in 45-49 year and 50-54 years group (12).

Recently Ohrui et al. (13) reported the decadal ECG changes such as left bundle branch block, left ventricular hypertrophy etc. which were relatively gross and detected at the annual examination in military pilots at age 50 compared to those 40 year of age. However in our study we documented that minimally ST segment changes or T wave inversion were not so innocent to be overlooked especially in aviators. A few decades ago those minor abnormalities of ST segment and T wave had been accepted nonspecific in an asymptomatic aircrew and a negative TT could easily be qualified for the flight (14). But new imaging modalities such as MSCT documented that minor nonspecific ST segment and T wave abnormalities in an asymptomatic patient might have been specific indicator for coronary artery disease and cardiovascular mortality (15). Additionally in a recent study at the end of 24 year follow up of Japanese men and women it was reported that ST segment depression and/or T wave changes on resting ECG were significantly correlated with cardiovascular mortality. Moreover that association was independent of age, BMI, systolic blood pressure, serum cholesterol, blood glucose, smoking and drinking (16). We observed that 76.9% of subjects presented at least one of the ECG changes; <1 mm depression of ST segment depression (53.8%) and T wave inversion (23.1%). Those changes were mainly observed at derivations of $V_4$, $V_5$, and $V_6$. We suggest that aircrew should carefully be examined and be sought for any family history of CAD and presence of any changes on resting ECG. They should be referred to further cardiac evaluation, e.g. TT, MSCT. TT may be mandatory at least within a 3-5 years period after 40 years old in the absence of any CAD. When it was detected TT should be performed annually even if the pilot had non-critical CAD and followed up medically. MSCT was effectively used by German Air Force and was advised to identify asymptomatic pilots with CAD (17). They also emphasized that MSCT was a valuable test owing to its high negative predictive value of almost 100%. MSCT is superior and the method of choice in the noninvasive diagnosis of CAD with a sensitivity and specificity of ranging 85-89% and 95-99%, respectively (18, 19).

**Study limitations**

Since the study was retrospective; lifestyle characteristics, daily physical activity, and dietary intake could not be collected. Additionally we could have been presented a clinical, laboratory, and ECG findings, TT and MSCT results of a highly selected small group of a specific group of aviators. So demonstration of a control group could not have been possible. A prospective study with a large populated study group from aviators may be designed to determine the specificity and sensitivity of those clinical features and family history in prediction of CAD documented by MSCT. Those were the limitations of our study.

## Conclusion

Earlier prediction of CAD in aircrew in military and civilian aviation is clinically essential in order to prevent aviation fatalities due to cardiovascular events. Aircrew ≥40 years old, with family history of CAD, ST segment and T wave changes on resting ECG, and equivocal results on TT even in the absence of multiple coronary risk factors may need further cardiovascular tests. MSCT angiography may be an effective and noninvasive way of documenting CAD especially in aviators. Identification of those aviators with CAD allows a better risk management and an effective pharmacotherapy in accordance with guidelines.

**Conflict of interest:** None declared.

**Peer-review:** Externally peer-reviewed.

**Authorship contributions:** Concept - M.A.; Design - M.E.; Supervision - Z.I.; Resource - U.B.; Materials - M.Ü.; Data collection&/or processing - M.E.; Analysis &/or interpretation - M.Ü., Z.I.; Literature search - Z.A.; Writing - M.A., M.E.; Critical review - Z.A., U.B.

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