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**Aviation Epidemiology Data Register:  
Coronary Angiography Outcomes  
of Civilian Aviators  
Flying U.S. Army Aircraft**

**By**

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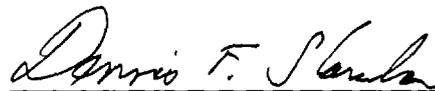
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<p>All Army aviators participate in a cardiovascular disease screening program. Five percent of Army aviators are civilian. The U.S. Army Aviation Center requested a review of cardiovascular disease screening outcomes among this subgroup of aviators. The AEDR was queried to determine the coronary angiography outcomes of civilian aviators who failed levels 1 and 2 of cardiovascular disease screening program during the period 1988 to 1992.</p> <p>Among 847 civilian aviators, 364 failed level 1 cardiovascular disease screening due to elevated risk factors for coronary artery disease. Among the 364, 289 passed level 2 screening with a normal exercise treadmill test and a normal cardiac fluoroscopy. The remaining 75 failed level 2 by having an abnormal exercise treadmill test and/or an abnormal cardiac fluoroscopy. These 75 were referred for further diagnostic testing in levels 3 and 4.</p> <p style="text-align: right;">(Continued on next page)</p>			
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Of the 55 aviators undergoing coronary angiography, 17 had normal coronary arteries, 14 had uncomplicated minimal coronary artery disease, 3 had complicated minimal coronary artery disease, and 21 had significant coronary artery occlusions. Eight other aviators had advanced heart conditions other than coronary artery disease, such as cardiomyopathy. Of 36 aviators with documented significant cardiovascular disease, 32 (88.9 percent) denied symptoms when their disease was detected by the screening program. They were referred for clinical, and in some cases, emergent care.

The positive predictive value of an abnormal graded exercise treadmill test for significant coronary artery occlusion by coronary angiography was 33.3 percent. The positive predictive value of an abnormal cardiac fluoroscopy for significant coronary artery occlusion by coronary angiography was 53.3 percent. There was a significant association between the finding of cardiac calcifications by cardiac fluoroscopy and significant coronary artery occlusions by angiography (OR=5.1, CI<sub>0.95</sub>=1.40,18.9). Six of the 21 aviators with significant coronary artery disease had an abnormal cardiac fluoroscopy with normal treadmill tests and normal thallium scans. Thallium scan fails to predict disease  $\geq$ 50 percent of the time. Selection of aeromedical catheterization candidates should not be based on thallium scan results when either the graded exercise treadmill test or cardiac fluoroscopy are abnormal.

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## Background

### Military relevance

In mid-1993, the Commander, Aviation Training Brigade, Chief of Staff, U.S. Army Aviation Center, and Commander, U.S. Army Aeromedical Center, Fort Rucker, Alabama, requested a review of the cardiovascular disease screening program outcomes of civilian aviators in the Fort Rucker area from when the program was modified in 1988 until 1992. This technical report summarizes the cardiovascular disease screening outcomes extracted from the Aviation Epidemiology Data Register (AEDR) for this subgroup of Army aviators. Five percent of Army aviators are civilian. Civilian aviators are a unique subgroup with an older average age than military aviators, placing them at greater risk for developing diseases associated with aging, to include coronary artery disease (Mason and Shannon, 1994a; Mason and Shannon, 1994b).

### Cardiovascular disease and flying

The U.S. Army owns and operates "public use" aircraft. Agencies that own public use aircraft are responsible for the medical certification of aircrew flying the aircraft, both military and civilian aircrew members. The Army is responsible for the safe operation of Army aircraft over public and private property. It carries the burden of liability for the aircrew, equipment, and property in the event of a mishap. The Army wants to conserve the aircrew member training investment, anticipating an aircrew member will remain medically qualified during a flying career. Therefore, the Army has developed medical fitness standards for flying duties, conducts an examination program, and makes final disposition on medically disqualified cases.

One facet of the examination program is screening for cardiovascular disease, especially asymptomatic coronary artery disease. Coronary artery disease is the leading cause of unexpected, premature death in our society, especially in men over the age of 40. Advanced disease is present often without symptoms. The first symptoms of coronary artery disease can be dramatic and incapacitating, to include sudden death (55 percent), severe chest pain, nausea, vomiting, and loss of consciousness. The risk for coronary artery disease increases significantly after the age of 40 (Kannel et al., 1975; Kannel and McGee, 1985). Table 1 shows the biennial incidence rate of sudden death due to coronary artery disease per 1,000 U.S. population stratified by age.

Table 1.  
Incidence\* of sudden death stratified by age and gender.

Gender	Age				
	<45	45-54	55-64	65-74	≥75
Male	0.8	2.0	4.0	6.0	8.2
Female	0.0	0.5	1.1	2.5	6.1

\* Incidence is biennial rate of sudden death per 1000 in the U.S. population (adapted from Kannel and McGee, 1985).

Internationally, the leading cause of permanent removal from flying duties is cardiovascular disease, primarily coronary artery disease. Despite medical preselection, health monitoring, and availability of preventive care, aircrew members with adverse cholesterol profiles are at higher risk for developing coronary artery disease (Hickman, 1987; Loecker et al., 1992; Mason, 1992).

Three of every 1,000 general aviation mishaps are associated with inflight medical incapacitation. Forty percent of these medical incapacitations are due to cardiovascular disease. The risk for cardiovascular medical incapacitation inflight increases with age, significantly after 50 years old, as shown in Table 2. Inflight medical incapacitation is associated with a fatal aircraft mishap 84 percent of the time (Booze, 1989; Dark, 1983).

Table 2.  
Annual incidence rate of general aviation mishaps due to cardiovascular incapacitation per 100,000 pilots by age group.\*

Age group	<29	30-39	40-49	50-59	>60
Incidence per 100,000 pilots	0.0	0.6	2.3	3.0	22.0
Expected cases per year	0.0	1.6	3.9	3.1	5.4

\* Adapted from Booze, 1989.

## Aviation Epidemiology Data Register

The AEDR is a family of related databases that stores the history and physical parameters of U.S. Army aviators. The database elements include a sequential file of all history and physical elements derived from the annual flying duty medical examination (FDME file) and an index of significant diagnoses (waiver and suspense file) that references a medicolegal document archive of the aeromedical board summary findings. The outcomes of coronary angiography are referenced in the diagnoses index. The detailed histories of cases are found in the image library.

### U.S. Army aeromedical cardiovascular disease screening program

The U.S. Army aeromedical cardiovascular disease screening program uses a stratified four-level approach to screening and diagnosis. After age 39, a progressive series of screening tests are applied to those with an increased risk at each level. Those at greatest risk for asymptomatic coronary artery disease are referred for cardiac catheterization. Appendix A outlines the program in greater detail (Department of the Army, 1991a).

### Method

The AEDR FDME file was searched for physicals conducted on Fort Rucker, Alabama, area civilian aviators during calendar years 1986 to 1992. The identified aviators were cross-referenced with the waiver and suspense file searching for failure of level 1 of the cardiovascular disease screening program. The medical document archive for each identified case was reviewed. The findings of cardiovascular disease tests among those aviators failing the various levels of screening were tabulated.

Statistical Analysis Systems software was used for analysis (SAS Institute, Incorporated, 1992). Cross tabulations and univariate analysis were derived using SAS® PROC FREQ.

### Results

#### Age distribution

The age distribution by decade of civilian aviators examined at Fort Rucker from 1988 to 1992 is shown in Table 3 (derived from Table B-1, Appendix B). Aviators enter the cardiovascular disease screening program at age 40. Table 4 shows the relationship between two age cohorts divided at 40 years old from 1988 through 1992. The percentage of civilian aviators examined at Fort Rucker who are 40 or older was 76.5 percent in 1988, and increased to 80.9 percent in 1992. The increase in the number of civilian aviators who are age 40 or older was significant, whether you compare single years ( $p=0.0064$ ), or average year-pairs, 1988-1989 and 1991-1992 ( $p=0.004$ ).

Table 3.  
Age distribution of civilian aviators examined at Fort Rucker  
from 1988 through 1992 by decade age cohorts.

Age cohort	1988 N	1989 N	1990* N	1991 N	1992** N
20-29	34 (5.7%)	34 (5.7%)	31 (4.8%)	18 (3.0%)	9 (1.9%)
30-39	107 (17.8%)	111 (18.5%)	117 (18.0%)	100 (16.6%)	83 (17.2%)
40-49	290 (48.3%)	297 (49.5%)	348 (53.6%)	318 (52.9%)	240 (49.7%)
50-59	137 (22.8%)	129 (21.5%)	129 (19.9%)	144 (24.0%)	129 (26.7%)
60 or >	32 (5.4%)	29 (4.8%)	24 (3.7%)	21 (3.5%)	22 (4.5%)
Total N	600	600	649	601	483

\* Population increase likely due to Desert Shield efforts.

\*\* Reductions begin in the Fort Rucker civilian pilot work force.

Table 4.  
Comparison of civilian aviator age cohorts by single years  
or averaged year-pairs from 1988 to 1992.

Comparison	Single years		Averaged year-pairs	
	1988	1992	1988-1989	1991-1992
Age < 40 (N)	141 (23.50%)	92 (19.05%)	143 (23.84%)	105 (19.34%)
Age ≥ 40 (N)	459 (76.50%)	391 (80.95%)	457 (76.16%)	437 (80.66%)

## Cardiac findings

An average of 586 civilian aviators were examined annually at Fort Rucker from 1988 through 1992. Accounting for new hires, retirements, and layoffs, there were 847 different individuals examined in this period (Mason and Shannon, 1994b). Among 847 civilian aviators, 364 (43.0 percent) failed level 1 cardiovascular disease screening due to elevated risk factors for coronary artery disease. Among the 364, 289 (79.4 percent) passed level 2 screening with a normal exercise treadmill test and a normal cardiac fluoroscopy. Among the 364, 75 (20.6 percent) failed level 2 by having an abnormal exercise treadmill test and/or an abnormal cardiac fluoroscopy. These 75 were referred for further diagnostic testing in levels 3 and 4. Of the 75, 68 (90.6 percent) were eligible for military health care to complete levels 3 and 4. The remaining seven (9.4 percent) had to rely on private insurance or personal funding to complete the evaluation. The case histories of the 75 aviators failing both levels 1 and 2 of the screening program are summarized in Table 5.

Table 5.  
Summary findings of 75 civilian aviators failing levels 1 and 2 of the cardiovascular disease screening program from 1988 to 1992.

Category of outcome	N=75
Declined further evaluation, condition unknown.	8
Had significant heart diseases other than coronary artery disease, such as cardiomyopathy, recurrent ventricular tachycardia, etc.	8
Underwent coronary angiography and were found to have-	
Normal coronary arteries or intimal roughening only.	17
Minimal coronary artery disease, uncomplicated.	4
Minimal coronary artery disease, complicated by other heart conditions.	3
Significant coronary artery disease.	21
Had symptomatic events while on full flying duties.	4

The administrative dispositions of the 75 civilian aviators failing levels 1 and 2 are summarized in Table 6. Thirty-one were returned to flying duties with an aeromedical waiver for their medical condition and 44 were medically terminated from aviation service. Of the 36 aviators with documented significant cardiovascular disease, 32 (88.9 percent) denied symptoms when their disease was detected by the screening program. The incidence of new cases increased as the new screening program was placed into effect in 1988. The incidence dramatically decreased after 1990. This likely is due to case finding phenomenon caused by a major change in screening program methods in 1988, followed by identified cases not being subject to repeat screening.

The analysis of cardiac test findings and coronary angiography outcomes are summarized in Tables 7 through 9.

Table 6.  
Administrative disposition of 75 cases failing levels 1 and 2 of the cardiovascular disease screening program from 1988 to 1992.

Year	Number of new cases failing Level 2		
	Waiver	Suspension	Total
1988 (N)	3	6	9
Incidence*	5.0	10.0	15.0
1989 (N)	7	12	19
Incidence	11.6	20.0	31.6
1990 (N)	10	16	26
Incidence	15.4	24.6	40.0
1991 (N)	7	9	16
Incidence	11.6	15.0	26.6
1992 (N)	4	1	5
Incidence	8.3	2.1	10.4

\* New cases per 1000 aviator-years per year.

Table 7.  
Analysis of image-intensified cardiac fluoroscopy and coronary angiography outcomes\*.

Fluoroscopy	Angiography	Significant CAD only		Any degree of occlusion	
		Yes	No	Yes	No
Abnormal		16	14	26	4
Normal**		4	18	10	12
Positive predictive value		53.3%		86.7%	
Odds ratio		5.1		7.8	
95% C.I.		(1.40,18.9)		(2.03,30.0)	

\* All patients failed Level 1 CAD screening.

\*\* All patients with normal fluoroscopy had an abnormal exercise treadmill test.

**Table 8.**  
Analysis of graded exercise treadmill test and coronary angiography outcomes\*.

	Angiography		Any degree of occlusion	
	Significant CAD only			
Graded exercise treadmill	Yes	No	Yes	No
Abnormal	13	26	25	14
Normal or borderline**	8	8	13	3
Positive predictive value	33.3%		64.1%	
Odds ratio	0.50		0.41	
95% C.I.	(0.153,1.64)		(0.100,1.70)	

\* All patients failed Level 1 CAD screening.

\*\* All patients with normal graded exercise treadmill test had an abnormal cardiac fluoroscopy.

**Table 9.**  
Analysis of planar thallium scan and coronary angiography outcomes\*.

	Angiography		Any degree of occlusion	
	Significant CAD only			
Thallium scan	Yes	No	Yes	No
Abnormal	8	3	10	1
Normal or borderline	9	22	21	10
Positive predictive value	72.7%		90.9%	
False negative rate	52.9%		67.7%	
Odds ratio	n/a**		n/a**	

\* All patients had an abnormal fluoroscopy or abnormal graded exercise treadmill test before thallium scanning.

\*\* Inadequate sample size for multivariate analysis.

## Discussion

Army civilian aviators are mostly retired military aviators or are associated with the Army Reserve or Army National Guard (Mason and Shannon, 1994b). Their average age is in the zone of exponentially increasing risk for coronary artery disease events. From 1988 to 1992, 42 in 100 (362/847) were found to be at high risk for coronary artery disease in the primary level of stratified risk assessment. Nine in 100 (75/847) were found to be at higher risk for coronary artery disease in the secondary level of stratified screening due to abnormal graded exercise treadmill test or abnormal image intensified cardiac fluoroscopy. Four in 100 aviators (36/847) had significant cardiovascular disease placing them at substantial risk for unpredictable, sudden incapacitation.

Of 36 aviators with documented significant cardiovascular disease, 32 (88.9 percent) had no symptoms when their disease was detected by the screening program. They were referred for clinical, and in some cases, emergent care.

Four aviators on full flying duties had symptomatic events with one death. One who willfully dodged secondary screening evaluations died suddenly at home after work. One had a myocardial infarction after scheduling for level 2 screening. One had a myocardial infarction despite passing level 2. One developed atrial fibrillation due to undiagnosed cardiomyopathy before entering the screening program. None were in the cockpit during their events.

A fifth aviator had a myocardial infarction about 2 weeks after medical suspension from flying duties for significant coronary artery disease. A sixth aviator who had abnormal level 2 testing, but who declined diagnostic catheterization, was reported to have chest pain followed by sudden death after medical suspension from flying duties (telephonic report only). Many of the 44 suspended aircrew members are lost to followup, so the true postdetection event rate is not known.

The predictive value of positive level 2 screening tests for any degree of coronary artery occlusions ranged from 64 percent to 87 percent. Six of the 21 aviators with significant coronary artery disease had an abnormal cardiac fluoroscopy with normal treadmill tests and normal thallium scans. Thallium scan fails to predict disease  $\geq 50$  percent of the time. It should not be relied upon to select aeromedical cardiac catheterization candidates when either the graded exercise treadmill test or cardiac fluoroscopy are abnormal.

This study shows the effect of "case finding phenomenon," with a large number of cases found in the initial screening (finding the prevalent cases) followed by a decreasing number of new cases (finding the incident, new cases) after initial screening (Table 6). Patients with significant disease are removed from the screening cohort. Those with normal coronary arteries are entered into a modified followup with level 2 screening being repeated 5 years later.

## Summary and conclusions

All Army aircrew members who control Army aircraft participate in a cardiovascular disease screening program. About 1 in 20 aviators flying Army aircraft is a civilian aviator. The command staff of the U.S. Army Aviation Center requested a review of cardiovascular disease screening outcomes among this subgroup of aviators. The AEDR was queried to determine the coronary angiography outcomes of civilian aviators who failed levels 1 and 2 of cardiovascular disease screening program.

Among 847 civilian aviators, 364 failed level 1 cardiovascular disease screening due to elevated risk factors for coronary artery disease. Among the 364, 289 passed level 2 screening with a normal exercise treadmill test and a normal cardiac fluoroscopy. Among the 364, 75 failed level 2 by having an abnormal exercise treadmill test and/or an abnormal cardiac fluoroscopy. These 75 were referred for further diagnostic testing in levels 3 and 4.

Fifty-five aviators underwent coronary angiography. Of these, 17 had normal coronary arteries, 14 had uncomplicated minimal coronary artery disease, 3 had complicated minimal coronary artery disease, and 21 had significant coronary artery occlusions. Eight other aviators had advanced non-coronary artery heart conditions, such as cardiomyopathy. Of the 36 aviators with documented significant cardiovascular disease, 32 (88.9 percent) had no symptoms when their disease was detected by the screening program. They were referred for clinical, and in some cases, emergent care.

The positive predictive value of an abnormal graded exercise treadmill test for significant coronary artery occlusion by coronary angiography was 33.3 percent. The positive predictive value of an abnormal cardiac fluoroscopy for significant coronary artery occlusion by coronary angiography was 53.3 percent. There was a significant association between the finding of cardiac calcifications by cardiac fluoroscopy and significant coronary artery occlusions by angiography (OR=5.1, CI<sub>0.95</sub>=1.4,18.9). Six of the 21 aviators with significant coronary artery disease had an abnormal cardiac fluoroscopy with normal treadmill tests and normal thallium scans. Thallium scan fails to predict disease  $\geq 50$  percent of the time. Selection of aeromedical catheterization candidates should not be based on thallium scan results when either the graded exercise treadmill test or cardiac fluoroscopy are abnormal.

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## Appendix A.

### U.S. Army Aeromedical Cardiovascular Disease Screening Program: principles and guidelines

#### General principle

The principle of the U.S. Army aeromedical cardiovascular disease screening program (ACVDSP) is multiple level stratification of aircrew members based on risk assessment and test findings. First, Army aircrew members are stratified into low and high risk groups for the likelihood of developing cardiovascular disease by assessment of risk factors using history and physical findings. Only aircrew members found to be at high risk in the primary screening are referred to level 2 of noninvasive screening tests (Department of the Army, 1991a). This method applies Bayes theory to enhance the predictive value of the second level screening tests by applying the tests only to a population with a theoretical higher prevalence of underlying disease (Hickman, 1987).

#### Level 1

Level 1 is the primary level of stratification for screening. Aircrew members are asked questions relating to their cardiovascular system history, to include smoking history. They undergo a resting electrocardiogram (EKG), which is compared to previous tracings. Serum lipids are evaluated, with total cholesterol (T-CHOL) and high density lipoprotein cholesterol (HDL-CHOL) required as a minimum. The Framingham Risk Index is calculated.

Aircrew members with signs and symptoms of cardiovascular disease, such as exertional chest pressure or serial EKG changes, are considered as screening program failures. They are referred for clinical care and evaluation as symptomatic patients.

Asymptomatic aircrew members are divided into low and high risk groups for the likelihood of developing cardiovascular disease by assessment of risk factors. High risk aircrew members are those who are 40 years old and older; and who have a Framingham Risk Index of 5.0 percent or greater, or a serum T-CHOL 270 mg/dl or greater, or a ratio of the serum T-CHOL over the serum HDL-CHOL of 6.0 or greater. High risk aircrew members are referred for secondary level of screening in level 2.

## Level 2

Asymptomatic aircrew members at high risk by level 1 screening are referred for secondary screening. Secondary screening tests are graded exercise treadmill test and cardiac fluoroscopy. The graded exercise treadmill test is abnormal if there is greater than or equal to 1.0 mm ST segment depression in any of 12 leads in any 3 consecutive heart beats at any time during the test. Certain exercise induced electrocardiographic arrhythmias, such as ventricular or supraventricular tachycardia, or left bundle branch block, also are abnormal findings (Department of the Army, 1989). The cardiac fluoroscopy is abnormal if any degree of calcification is seen moving synchronously with the heart shadow in a location consistent with coronary artery anatomy by multiple views (Department of the Army, 1991b; Mason and Shannon, 1993; Mason, 1993). Aircrew members with one or more level 2 screening abnormalities are referred for occupational, diagnostic evaluation in level 3 and 4.

## Level 3

Aircrew members entering level 3 are referred for noninvasive testing. The tests include 24 hour Holter monitor testing, echocardiogram, and thallium scan. Abnormalities found by these tests may result in medical termination of aviation service, and thus, may be a contraindication for referring the aircrew member to level 4, invasive diagnostic testing. The most common contraindications found by level 3 testing are recurrent, aeromedically significant electrocardiographic arrhythmias and left ventricular hypertrophy (Mason, 1992).

## Level 4

Aircrew members entering level 4 are referred for occupational, invasive diagnostic testing. The tests include left heart catheterization with coronary angiography and left ventriculography (Mason, 1992). Electrophysiologic studies are performed as indicated.

Appendix B.

Age distribution table for Fort Rucker civilian aviators.

Table B-1.

Age distribution of civilian aviators examined at Fort Rucker.

Age group	1988	1989	1990	1991	1992
22-23	1	0	0	0	0
24-25	3	4	1	1	0
26-27	15	12	9	7	1
28-29	15	18	21	10	8
30-31	16	19	18	17	10
32-33	22	23	25	18	12
34-35	19	22	23	29	19
36-37	19	18	17	15	23
38-39	31	29	34	21	19
Subtotal age <40	141 23.50%	145 24.17%	148 22.98%	118 19.63%	92 19.05%
40-41	65	59	60	42	18
42-43	50	69	96	70	43
44-45	71	64	69	92	75
46-47	56	53	75	64	43
48-49	48	52	48	50	61
50-51	27	37	43	47	42
52-53	45	31	21	26	28
54-55	29	35	35	28	13
56-57	20	15	18	31	32
58-59	16	11	12	12	14
60 or >	32	29	24	21	22
Subtotal age 40 to 60 or >	459 76.50%	455 75.83%	501 77.20%	483 80.37%	391 80.95%
<b>Total</b>	<b>600</b>	<b>600</b>	<b>649</b>	<b>601</b>	<b>483</b>