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ECHOCARDIOGRAPHIC AND COLOR FLOW DOPPLER FINDINGS IN MILITARY PILOT APPLICATIONS

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CLINICAL MEDICINE

Echocardiographic and Color Flow Doppler Findings in Military Pilot Applicants

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This report details the findings of 1476 Canadian Forces pilot candidates screened with echocardiography and Doppler. All candidates had previously been medically screened at a recruiting center. We found 115 (7.8%) to have disqualifying findings. Mitral valve prolapse (MVP) was the most common (4.8%). Other abnormalities included aortic regurgitation (2.3%), bicuspid aortic valve (0.9%), left ventricular hypertrophy, asymmetric septal hypertrophy, and atrial septal defect (<0.5%). Of the 71 candidates found to have mitral valve prolapse, 40 had positive clinical findings on careful auscultation. Echocardiography is a safe, cost-effective tool for screening candidates for military pilot training. Normative data on this population agree well with published norms.

CERTAIN ASYMPTOMATIC cardiac disorders are considered to represent an increased risk to flight safety. If discovered in trained pilots such disorders may require an operational flying restriction or disqualification from flying duties and so result in the loss of an expensive resource. Cardiovascular disorders are the most common cause for permanent grounding (10,13) and detection of cardiac disorders before training should be cost-effective.

The Canadian Forces screen all candidates for pilot training at the Defence and Civil Institute of Environmental Medicine (DCIEM). In 1985, echocardiography was introduced as a screening procedure in pilot candidates, and since 1989, this has included color flow Doppler.

This report summarizes the echocardiographic and color flow Doppler findings in candidates screened from 1989–91.

METHODS

Between March 1989 and December 1991, 1476 applicants for military pilot training were screened at the Canadian Forces Central Medical Board. These candidates had previously undergone an enrollment medical examination including a physical examination and an electrocardiogram at a Canadian Forces Recruiting Center, and were considered to be free from cardiovascular disease. Candidates were between the ages of 17 and 42.

At DCIEM, all applicants were examined by a flight surgeon, and an echocardiogram and color flow Doppler study was carried out. Candidates with any suspicion of an abnormal finding on the flight surgeon's assessment or on the echocardiogram were referred to the consultant internist for further evaluation. Careful cardiac auscultation was carried out with the candidate seated, supine, in the left lateral decubitus position, then standing and crouching. Auscultation was also carried out during amyl nitrate inhalation in most referred candidates.

Mitral valve prolapse (MVP) was diagnosed clinically, based on auscultation of an apical non-ejection click variable in timing with changes in left ventricular volume. The presence of a mitral regurgitant (MR) murmur was considered substantiating but not necessary evidence, and MVP was not diagnosed based solely on the basis of an MR murmur.

The echocardiograms were performed on a Hewlett Packard Sonos 500 (Andover, MA). Studies included M-mode and two-dimensional (2D) images, a color flow Doppler study and pulsed or continuous wave Doppler where indicated. Measurements were made using standard American Society of Echocardiography techniques (8) from the 2D parasternal long axis view, except for the right ventricular diastolic dimension which was taken as the widest transverse diameter on the apical four chamber view.

The echocardiographic diagnosis of MVP was based on current published criteria (6); i.e., clear movement of one or both leaflets across the plane of the mitral annulus on the parasternal long-axis view, or greater than 3

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mm late-systolic posterior motion on the M-mode. Holosystolic posterior motion was not diagnostic unless accompanied by findings on the 2D parasternal long axis view.

RESULTS

Of the 1476 candidates 115 (7.8%) were found on echocardiographic/color flow screening to have abnormalities that were disqualifying for pilot training. The distribution of these abnormalities is shown in Table I.

MVP was the most common finding resulting in disqualification from pilot selection. There were 67 (4.5%) candidates who had definite or equivocal echocardiographic evidence of MVP. Those with equivocal echo prolapse were disqualified only if there were definite clinical findings.

Aortic regurgitation was observed in 34 (2.3%). Of these, 19 had trileaflet valves. In some, there was visible thickening or sclerosis of a cusp or commissure. The amount of regurgitation was slight or mild in all those who had normal trileaflet valves. The two cases of moderate aortic regurgitation occurred in bicuspid valves.

There were 14 candidates (0.9%) who had bicuspid aortic valves. Slight to mild aortic regurgitation was seen in half of these, and in two the regurgitation was graded as moderate. One candidate with a bicuspid aortic valve also had a cleft mitral leaflet.

Table II summarizes the echocardiographic and clinical findings with respect to MVP.

The overall prevalence (clinical and echocardiographic) of MVP was 71/1476, or 4.8%. Of these 71, 4 had clinical findings with normal echos, 8 had positive clinical findings with equivocal echos, and 59 had definite echocardiographic MVP.

Of the 59 with definite echocardiographic MVP, 28 (47.4%) were found to have clinical findings of MVP; 31 "echo positive" had no clinical findings.

There were 40 candidates who had clinical findings considered diagnostic of MVP. Of these "clinically positive", 36 (90%) had either positive or equivocal echocardiographic findings of MVP.

TABLE I. DISQUALIFYING ECHO/DOPPLER ABNORMALITIES.

	No.	%
Mitral Valve Prolapse	67	4.5
Echo positive	59	
Echo equivocal/clinical +	8	
Bicuspid Aortic Valve	14	0.9
No regurgitation	5	
Slight/mild regurgitation	7	
Moderate regurgitation	2	
Aortic regurgitation	34	2.3
Normal valves	19	
Bicuspid valves	9	
Thickened leaflets	3	
Tubular hypoplasia of arch	1	
Left ventricular hypertrophy	5	0.3
Asymmetric septal hypertrophy	2	0.1
Atrial septal defect	1	<0.1
Endocardial cushion defect	1	<0.1
Total	115	7.8

TABLE II. CLINICAL AND ECHOCARDIOGRAPHIC MVP FINDINGS.

	Echo Pos	Echo +/−	Echo Neg	Totals
Clinical POS	28	8	4	40
Clinical NEG	31	50	1355	1436
Totals	59	58	1359	1476

Of the 59 definite echocardiographic MVP cases, 43 (73%) had slight or mild MR on color flow. Of these 43, 21 (49%) had positive clinical findings. Of the 16 without MR, 7 (44%) had positive clinical findings.

Of the 58 with equivocal echocardiographic findings, 26 (45%) had slight or mild MR, 5 (19%) of which were clinically positive. Of the 32 with equivocal echo MVP and no MR, 3 (9%) were clinically positive.

In addition to the 115 disqualifying findings on echocardiography, there were a number of incidental findings that were not considered disqualifying. These are listed in Table III.

The prevalence of tricuspid, pulmonic and MR greatly exceeded that of aortic regurgitation at 2.3% (Table II). The vast majority of these regurgitant jets were graded as slight, and occurred in valves that appeared structurally normal on echo.

Table IV gives the normative echocardiographic values in male and female candidates. These data were derived from those studies meeting the following criteria: 1) rated by the interpreting physician as excellent quality studies; 2) performed by an RDMS certified echocardiographer; 3) all echo parameters available for each study. Data from 448 male and 32 female candidates met these criteria. Measurements were taken from the 2D parasternal long axis view, except for the right ventricular dimension which was taken from the apical four-chamber view.

DISCUSSION

Cardiovascular disorders remain the most common medical reasons requiring an operational flying restriction or grounding in trained pilots (10,13). Most structural cardiac abnormalities of aeromedical concern can be detected prior to training with echocardiography in concert with a careful clinical examination.

The findings in this study underscore the importance of the latter. All 1476 candidates had been previously

TABLE III. INCIDENTAL ECHO/DOPPLER FINDINGS.

	No.	%
Tricuspid regurgitation	944	64
Slight	924	
Mild/moderate	20	
Pulmonic regurgitation	894	61
Slight	887	
Mild/moderate	7	
Mitral regurgitation	393	27
Slight	392	
Mild/moderate	1	
Tricuspid valve prolapse	6	0.41
Slight regurgitation	5	
Mild/moderate regurg	1	

TABLE IV. ECHOCARDIOGRAPHIC PARAMETERS (MM) IN AN AIRCREW CANDIDATE POPULATION.

	448 Male Candidates			32 Female Candidates		
	Mean	SD	±2 SD	Mean	SD	±2 SD
LVIDd	49.6	4.14	41–48	46.0	4.10	38–54
LVIDs	32.9	3.52	26–40	30.8	3.51	24–38
RVIDd	33.9	5.98	22–46	30.5	6.72	17–44
LVPWs	14.8	1.85	8–18	13.1	1.31	10–16
LVPWd	9.2	1.25	7–12	7.9	0.98	6–10
IVSs	14.4	1.78	11–18	12.9	1.35	10–16
IVSd	9.6	1.31	7–12	8.2	1.09	6–10
Ao	30.7	3.25	24–37	27.2	2.52	22–32
La	30.3	4.34	22–39	28.4	3.59	21–36

screened by a physician, yet 40 (2.7%) were found to have definite clinical findings of MVP on careful examination. The physical findings of MVP are notoriously variable (5,6), and may easily be missed unless careful auscultation is carried out in several positions. Physicians screening aircrew candidates should routinely auscultate the heart in at least the seated, supine and lateral decubitus, and standing positions.

The 4.8% prevalence of MVP in this population is in the lower range of other reported population studies (2). This may reflect a selection bias (pre-screening at recruiting centers), and stringent diagnostic criteria applied for echocardiographic diagnosis. This approach was taken to avoid conflict with later "second opinions," and because the prognostic significance of borderline echo-only prolapse is unclear. However, identification of borderline echo prolapse in this study was used to initiate an internist evaluation, and the rate of positive clinical diagnosis was 13.8% in this group, compared with 0.29% in those with normal echos. It should be pointed out that the internist reviewing candidates was generally aware of the echo findings as reported by the technician, raising the possibility of examiner bias in the clinical diagnostic outcome.

MVP is disqualifying for pilot training in the Canadian Forces because of the increased risk of complications over the course of a flying career, including progressive MR, infective endocarditis, arrhythmias, stroke, and possibly sudden death (4). The effect of exposure to repeated high sustained acceleration (G) on a prolapsing mitral valve is unknown, but is of concern in selecting candidates for universally-assignable military flying roles including tactical fighter operations. There is also some concern that MVP may be arrhythmogenic in the high-G environment (3,11) and may reduce G-tolerance to rapid onset $+G_z$ (12). This may be due at least in part to the associated autonomic dysfunction (1).

The high incidence of minor degrees of tricuspid and pulmonic regurgitation (64% and 61%, respectively) on color flow Doppler is consistent with the experience in most echo labs (7,14). Our observation is that aortic regurgitation is distinctly uncommon as an incidental finding in this young population, occurring in only 2.3%. Although slight degrees of MR were not uncommon (27%), mild to moderate MR as an isolated finding was also uncommon (1 case).

Bicuspid aortic valve and aortic regurgitation are of concern aeromedically because of the increased risk of progression and infective endocarditis (9). The effect of repeated exposure to high sustained G forces on anatomically or functionally abnormal aortic valves is unknown but is also of concern in selecting candidates for military flying training.

The echocardiographic parameters obtained in this population of young healthy adults is in close agreement with published normative data (8). This suggests that although aircrew candidates are generally fit and healthy, special normative data are not required and published data may be used.

Although the incidence of aeromedically significant, clinically silent structural cardiac abnormalities detected by echo Doppler is only about 5% in this study, because of the high cost of military pilot training, the procedure is easily demonstrated to be cost-effective. For example, the cost of carrying out 1476 echocardiograms with full Doppler including color flow, based on the current Ontario schedule is $539,109 (the actual cost was lower using a part-time technician and military internist). We discovered 115 disqualifying abnormalities on the screening echo. Assuming a cost of pilot training of $500,000, and assuming that 10% of the echo abnormalities would lead to grounding, the savings amount to $3530 per echocardiogram performed.

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