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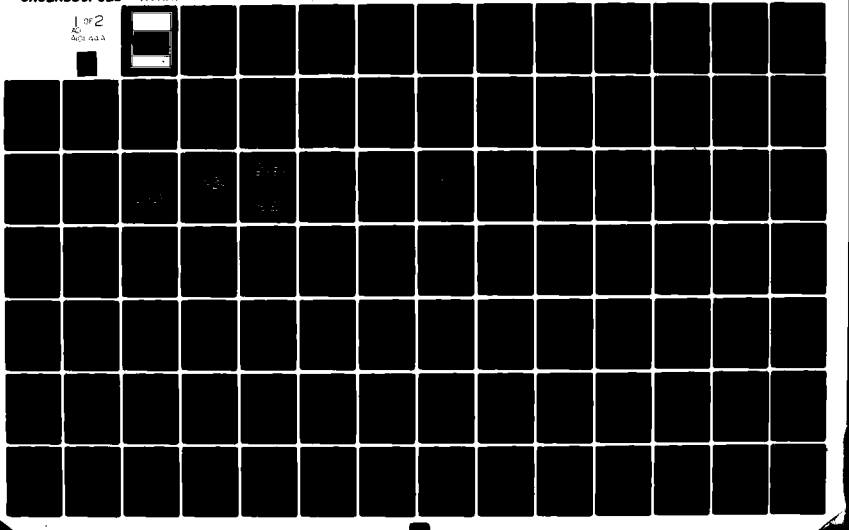

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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

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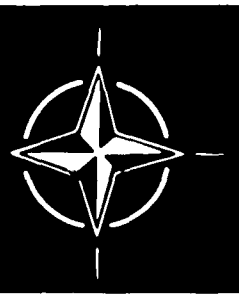
AGARD REPORT No.681

Sixth Advanced Operational Aviation Medicine Course

Centre de Médecine Aéronautique,
Quartier Roi Albert I,
Brussels, Belgium

24-28 March 1980

NORTH ATLANTIC TREATY ORGANIZATION



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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Report No.681

SIXTH ADVANCED OPERATIONAL AVIATION MEDICINE COURSE

at CENTRE DE MEDECINE AERONAUTIQUE
QUARTIER ROI ALBERT I
RUE DE LA FUSEE, 70
B-1130 BRUSSELS, BELGIUM

24–28 MARCH 1980

Edited by

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This Course was conducted under the auspices of the Aerospace Medical Panel of AGARD.

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PREFACE

From 24 to 28 March 1980 the sixth advanced operational Aviation Medicine Course was held at the Centre de Médecine Aéronautique, Brussels. Seventeen representatives from seven NATO countries attended the course.

Theme of the course was Aviation Cardiology. Lecturers from the US, UK, France and Belgium covered the cardiological problems of selection and screening, the epidemiology and prevention aspects and the problems of ageing.

During two round table discussions, one on selection and screening aspects, the other on cardiovascular problems throughout the pilots career, the actual criteria and rules were reviewed and new solutions were proposed.

Special emphasis was put on the cardiovascular problems in relation to the selection and the medical follow-up of pilots, who have to fly the new generation, high performance aircraft, such as the F15, the F16, the Mirage 2000 and the Tornado.

The Participants in the course visited the Centre de Médecine Aéronautique and also the Department of Cardiology of the Université Catholique de Louvain at Woluwe, where they had the opportunity to be familiarised with the newest expertise and techniques in the field of cardiology.

I would like to thank especially the lecturers for their outstanding and to the point presentations, and all the participants for their very active participation in the round table discussions and for the innumerable questions throughout the course.

I would like to acknowledge the considerable help I received from the Staff of the Centre de Médecine Aéronautique and VSM, and in particular the projectionist Adjt Dossche, my secretary Adjt Demeester, and his assistant Cpl Christiane Lataire.

Dr J.BANDE
Med.Col.
Course Director

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CONTENTS

* Presented but not available at time of printing.

NON-INVASIVE EVALUATION OF THE CORONARY CIRCULATION

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The non-invasive diagnosis of coronary artery disease (CAD) is based at first on the history of the patient : in asymptomatic subjects, the probability of CAD is low while CAD is very likely in men with typical angina pectoris. This pre-test evaluation of the likelihood of disease is important since it determines the value of the data provided by all subsequent tests : false positive responses are frequent when the disease is unlikely while false negative responses are frequent when the disease is likely .

Exercise testing is the second diagnostic step : an abnormal ECG response (ST segment depression $\geq$ 0.1 mV) is a sensitive and specific sign of CAD . The exercise ECG should be interpreted very cautiously when it does not confirm the data provided by the history .

The diagnostic value of exercise testing is further improved when it is combined with a Thallium^{201} myocardial scintigraphy ; the specificity of this method is excellent . Finally, radionuclide angiography during exercise permits an accurate evaluation of the left ventricular function and this new method brings additional useful information .

Coronary artery disease (CAD) is a major medical problem since it is the first cause of mortality and morbidity in the middle-aged active population. The early detection of CAD is important since subjects with latent CAD have a much higher incidence of unexpected coronary events as compared to the normal population :as far as occupational medicine is concerned, these subjects should be identified since they may be suddenly incapacitated while on essential duties such as taking off or landing a plane .

Coronary arteriography is certainly the best way to ascertain or to exclude the presence of significant coronary lesions . This invasive procedure is however expensive and it involves a small incidence of fatal complications . For these reasons, coronary arteriography should be performed mostly in patients who are candidates for coronary bypass surgery : in these patients, the diagnosis of CAD has always been established first from non-invasive data . As far as the diagnosis of CAD itself is concerned, the place of coronary arteriography is very small and it is indicated only in those few subjects whose diagnosis is mandatory but remains unclear after use of all available non-invasive methods .

Among non-invasive diagnostic methods, we will examine the role of the history, the value of the exertional ECG and the additional information given by Thallium scintigraphy and radionuclide angiography .

1. IMPORTANCE OF THE HISTORY

Before testing a patient, his history will always be taken carefully since it brings important diagnostic informations (10, 14, 16, 18, 34, 44). The prevalence of CAD, also expressed as the pretest likelihood ratio, is indeed clearly influenced by the history (table 1) . In men, coronary lesions

Table 1 - Prevalence of coronary artery disease in 432 patients studied by coronary arteriography (13, 14, 27, 28, 29) .

History	Sex			
	Men		Women*	
	n	%	n	%
Previous MI	145/145	100	46	76-95
No Previous MI : Typical AP	152/164	93	14/26	54
Atypical AP	14/70	20	3/27	11

* : The data in women with previous MI are from Welch et al. (45) .
MI = myocardial infarction ; AP = angina pectoris .

are practically always present when there is a history of previous myocardial infarction - MI - (33); in such cases, the exercise test has per se no diagnostic value and it will be performed only for functional evaluation or detection of severe coronary lesions (14) . In the absence of a previous MI, the history has a great value in men since typical anginal complaints are associated with coronary lesions in more than 90% of the patients while significant CAD is found in only 20% of the patients

with atypical chest complaints (14, 33, 44, 46) . In women, a history of typical angina pectoris (AP) has a limited value since only half of these patients have significant CAD; when the history is atypical, CAD is very uncommon in women (45) . As logically expected, other factors such as the age and the presence of risk factors also considerably influence the prevalence of the disease (16, 17, 28) .

The pre-testing estimation of the prevalence of the disease is also essential in the interpretation of the results of a diagnostic test ; according to the Bayes theorem, a low prevalence of the disease is indeed attended by a high incidence of false positive responses while a high prevalence of the disease is accompanied by a high incidence of false negative responses (14, 16, 34).

2. DIAGNOSTIC VALUE OF EXERCISE ECG .

Exercise testing of patients suspected of CAD is based on the observation that patients with documented CAD often develop during exercise ECG abnormalities, namely a depression and/or an elevation of the ST segment . These ECG modifications during exercise reflect the presence of myocardial ischemia and they are now routinely used as an indirect indication of the presence of significant coronary lesions . Since patients with multivessel CAD and critical coronary lesions often exhibit the most abnormal responses to exercise, it is logic to try to predict the severity of CAD from the data collected during exercise .

Multistage testing with a low initial workload and subsequent stepwise increase in the exercise intensity should be recommended ; the exercise will be continued until the onset of symptoms or until exhaustion of the patients . These tests of maximal exercise provide the most complete ECG information and they also allow to estimate the severity of the symptoms and to measure the physical working capacity ; this chapter deals only with this type of maximal exercise tests .

The diagnostic value of exertional ECG will be reviewed taking into account recent studies which have indicated the importance of clinical data - sex, classification of chest pain - in the interpretation of the ECG response to exercise (10, 14, 16, 18, 34, 44). We will then examine the contribution of exertional ECG to the non-invasive prediction of the extent and severity of CAD . All the data presented in this paragraph have been collected in 432 patients who underwent a maximal exercise test and an arteriographic study (13, 14, 27, 28, 29); CAD was defined as a diameter stenosis of 50% of at least one major coronary vessel

2.1. Sensitivity and specificity of exercise ECG .

The best ECG criterion for the diagnosis of CAD is the onset of a horizontal ST segment depression $\geqslant$ 0.1 mV (12); an ST segment elevation $\geqslant$ 0.1 mV is also a reliable criterion but it is rarely observed in the absence of a previous MI and it is then highly suggestive of a Prinzmetal syndrome (15) . The significance of a slowly upsloping ST segment depression is still unclear unless the ST segment remains 2 mm below the baseline 0.08 sec after the J point (40) .

Table 2 - Diagnostic value of maximal exercise ECG in patients suspected of coronary artery disease but without previous myocardial infarction (13, 14, 29).

	Men (n = 234)		Women (n = 53)	
	n	%	n	%
Sensitivity	153/166	92	15/17	88
Specificity	53/68	78	29/36	81
False positives	15/168	9	7/22	32
False negatives	13/66	10	2/31	6
Prevalence of CAD	71%		32%	

In our experience, the sensitivity of the exercise ECG is ± 90% while its specificity is ± 80%; these numbers which reflect the true diagnostic value of exercise ECG are similar in men and in women (Table 2) . These scores are higher than those usually reported in the literature for several reasons : 1) use of a maximal exercise test rather than a test interrupted at 80 - 90% of the predicted maximal heart rate ; 2) recording of a 12 lead ECG rather than a single bipolar V_5 ; 3) exclusion of all patients with a previous MI; 4) exclusion of patients with valvular disease, ECG left ventricular hypertrophy or bundle branch block and taking drugs known to influence the ECG response to exercise .

The false positive ECG responses (table 2) are frequent in women (32%) and this finding is likely due to the low prevalence of CAD among women (13, 14) . These responses are indeed not characteristic of women since they are also very frequent (50%) in men with atypical complaints, a group of patients with a low prevalence of CAD (20%) .

The false negative ECG responses are seen mostly in patients with a high prevalence of CAD; in men with typical AP, 56% of the negative responses to exercise are falsely negative (14, 44).

These figures would still have been much higher if patients taking beta-blockers had not been excluded (37) .

2.2. Combination of history and exercise ECG .

In men with typical anginal complaints, the exercise ECG is most often positive (table 3) and this abnormal response is an important confirmation of the clinical diagnosis (97% of true positives); in these patients a negative response to exercise is difficult to interpret, due to the many false

Table 3 - Combination of history and maximal exercise ECG in 234 men suspected of coronary artery disease but without previous myocardial infarction (14, 29) .

History	Exercise ECG	n	Incidence of CHD n	%	False pos. %	False neg. %
Angina pectoris 16	Abnormal	148	143	97	3	-
	Normal	16	9	56	-	56
Atypical complaints 70	Abnormal	20	10	50	50	-
	Normal	50	4	8	-	8

negative responses to exercise (56%) . In men with atypical complaints, the exercise ECG is usually normal and this response is attended by a very low probability of CAD (92% of true negatives); but in these patients an abnormal response to exercise has no diagnostic value since 50% of these responses are falsely positive (14, 19, 20, 44). The same comments apply to the women where the significance of the ECG response is also determined by the prevalence of the disease (13, 14, 44) .

Table 4 - Schematic approach of the diagnosis of coronary artery disease .

History Is CAD likely ?	Exercise test Abnormal	Normal
Yes	Disease confirmed	?
No	?	Disease excluded

Table 4 summarizes the diagnostic information provided by exercise ECG and emphasizes the importance of the history . This schematic presentation should not make overlook other important data provided by exercise testing, namely the degree of the ECG abnormalities, the onset of AP during the test itself, a low maximal heart rate, a low exercise capacity, a poor blood pressure response, etc... : all these findings enhance the probability of CAD but their sensitivity is lower than that one of an ST segment depression $\geqslant$ 0.1 mV .

2.3. Prediction of extent and severity of CAD .

The prognosis of CAD is determined by the number of diseased vessels and by the extent of myocardial damage (7) ; since coronary arteriography cannot be performed routinely in all symptomatic patients, it is important to identify non-invasively the patients who have the most severe lesions and could eventually benefit from coronary bypass surgery . These patients are those with a left main disease (LMD) and possibly those with a multivessel disease (MVD). The interest of maximal exercise tests in men will be reviewed in that perspective; but, it is clear that the final decision to perform an arteriographic study and to bypass varies from an institution to another and is mainly determined by the "surgical or non-surgical" attitude of the medical staff .

2.3.1. After a myocardial infarction .

Men with a previous MI always have significant coronary lesions although a large subset of these patients have stenotic rather than occlusive lesions (2, 15, 28, 33); after MI, the majority (79%) of the patients have MVD .

The response to exercise in chronic stable MI (2 months or more after MI) is determined by the extent of the disease (table 5) ; the maximal heart rate and the maximal workload (physical capacity) are highest in patients with single VD and lowest in patients with 3 VD (27) . Also AP during exercise (10%) and ST segment depression (23%) are uncommon in single VD and frequent in patients with 2 and 3 VD ; When present, the ST segment depression is minimal in single VD but important in patients with 2 or 3 VD . It is thus obvious that an abnormal response to exercise is suggestive of severe CAD but, unfortunately, the patients with 2 or 3 VD cannot be distinguished from each other ; also, the patients with LMD cannot be separated from the other patients with

Table 5 - Maximal exercise data in 145 men with a previous myocardial infarction (14, 27)

	Coronary arteriography				
	1 VD (n = 30)	P	2 VD (n = 49)	P	3 VD (n = 66)
Heart rate (bpm)	160	0.02	146	NS	139
Workload (Watts)	168	0.02	146	NS	138
Angina (%)	10	0.05	41	0.01	67
ECG : - Normal (%)	37	NS	18	NS	12
- ST $\geqslant$ + 0.1 mV (1) (%)	40	NS	20	NS	11
- ST $\geqslant$ - 0.1 mV (2) (%)	23	0.005	61	NS	77
- ST depression (mm)	0.7	0.005	2.1	NS	2.4

(1) Isolated ST segment elevation
(2) ST segment depression with or without reciprocal ST elevation .

2 or 3 VD.

Multivessel disease after MI can adequately be predicted from an abnormal response to exercise (18, 22, 28) . The predictive value for MVD (% of true positives, i.e. % of patients with the given response who have MVD) is indeed 93% when the response to exercise is abnormal (table 6) . In order to eventually increase the predictive value of exercise testing for MVD, progressively more abnormal and less frequent findings have been listed in table 6 : they go from an ST segment depression $\geqslant$ 0.1 mV to the association of exertional induced AP with an ST segment depression $\geqslant$ 0.3 mV. The predictive value of an abnormal response to exercise increases with the degree of the required abnormality : it is 100% when AP is associated to an ST segment depression $\geqslant$ 0.3 mV . However, this type of abnormality is very uncommon (26 patients only) and 75% of the patients with MVD do not exhibit it (75% of false negatives) .

Table 6 - Detection of multivessel disease (n = 115) from maximal exercise data in 145 men with a previous myocardial infarction (14, 27) .

Exercise response	n	True positives %	True positives n	False negatives %	False negatives n
Abnormal response (1)	100	93	93	49	22
ST $\geqslant$ -0.1 mV (2)	88	92	81	60	34
AP	67	96	64	65	51
AP and ST $\geqslant$ -0.1 mV	53	96	51	69	64
ST $\geqslant$ -0.3 mV	44	98	43	71	72
AP and ST $\geqslant$ -0.3 mV	26	100	26	75	89
History of AP	80	87	70	56	45

(1) AP and/or ST depression $\geqslant$ -0.1 mV ; strictly isolated ST segment elevations considered here as a "normal" response .
(2) Includes patients with a "reciprocal" ST segment depression .

A normal response to exercise after MI does not rule out MVD since 49% of the patients with this response have MVD (table 6) ; in this table, the definition of a normal response is rather wide since it includes patients with an isolated ST segment elevation . A strictly normal response to exercise (no AP and no ST changes) is still less frequent after MI (16% of the present group) : this normal response remains difficult to interpret since half of the patients have a single VD and half have MVD (9, 27, 31) .

An ST segment elevation is commonly observed during exercise testing of post-MI patients. this abnormality is highly specific (96%) for the existence of severe myocardial damage (akinetic or dyskinetic ventricular zones) but it is not a very sensitive sign - 43% - (14, 27, 38) . This ECG response can be isolated or associated to a reciprocal ST segment depression ; when it is isolated, the ST segment elevation is frequently associated to a single vessel disease (41%) . On the other hand, the combination of ST segment depression and elevation is highly suggestive of MVD - 100% - (27, 43).

After MI, 55% of the patients are complaining of angina pectoris ; the predictive value of an history of AP is 87% (table 6) and thus less than the predictive value of the data collected during exercise testing (27) .

In summary, MVD is frequent after MI and exercise testing is very useful for its detection ;

an abnormal response to exercise is observed in approximately 2/3 of all post-MI patients and from those, 93 have MVD . The probability of a more extensive CAD increases with the degree of the observed abnormality but very abnormal findings are unfrequent and therefore lack sensitivity ; also, from exercise data, is it impossible to separate the patients with 2 VD from those with 3 VD. After MI, a normal response to exercise does not allow any firm conclusion except that MVD is present in ± 50% of the patients .

2.3.2. Symptomatic patients without previous MI .

Atypical complaints

In male patients with atypical complaints, the probability of significant coronary lesions is low (20%, table 1) and consequently, severe coronary lesions are uncommon (10,14,17,44); in a group of 70 such patients, 8 (11%) had a single VD, 6 (9%) had MVD and none had LMD . Due to the high incidence of false positive ECG responses in this group (table 3), an abnormal response to exercise does not allow to predict correctly nor the presence, nor the extent of CAD . On the other hand, in men with atypical AP, a normal ECG response to exercise is rarely associated to significant coronary lesions (8%, table 3) and in these cases, MVD is exceptional (only 1 out of 50 patients).

Typical angina pectoris .

In male patients with typical AP, a single VD is rather uncommon (19%) and the majority of these patients have a double (33%) or a triple (41%) vessel disease (table 7) . The prevalence of MVD is therefore high (74%) in these patients and a simple history of typical AP has a good predictive value for the presence of MVD ; the probability of having MVD also increases with the age of the patient and the duration of its symptoms (14,44,46) .

Table 7 - Maximal exercise data in 164 men with typical angina pectoris but no previous myocardial infarction (14,29) .

	Coronary arteriography						
	Normal (n = 12)	P	1 VD (n = 31)	P	2 VD (n = 54)	P	3 VD (n = 67)
Heart rate (bpm)	167	0.05	149	NS	143	NS	137
Workload (Watts	201	0.02	165	0.001	139	NS	139
Angina (%)	33	NS	52	0.01	81	NS	79
ECG : - Normal (%)	58	0.005	13	NS	2	NS	8
- ST -0.1 mV (%)	42	0.01	87	NS	98	NS	91
- ST depression (mm)	-0.7	0.01	-1.8	0.005	-2.7	NS	-2.6

The response to exercise of these patients with AP appears to be also determined by the severity of CAD (table 7) ; as far as maximal heart rate, maximal workload, incidence of AP and importance of the ST segment changes are concerned, the data become more abnormal when one goes from patients with 1 VD to patients with 3 VD . This trend is however less clear than it was in the patients with a previous MI (table 5) ; particularly, the incidence of ST segment abnormalities is similar in all groups . Also, as previously noted in patients with a previous MI, the response to exercise of patients with 2 VD is similar to the response of patients with 3 VD ; the information provided by exercise testing can therefore be used only for the prediction of MVD and not for the separation of patients with 2 and 3 VD .

Table 8 - Detection of multivessel disease (n = 121) from maximal exercise data in 164 men with typical angina pectoris but no previous myocardial infarction (14,29) .

Exercise response		True positives		False negatives	
	n	%	n	%	n
AP and/or ST $\geq$ -0.1 mV	155	76	118	33	3
ST $\geq$ -0.1 mV	146	78	114	39	7
AP	117	83	97	51	24
AP and ST $\geq$ -0.1 mV	114	82	93	56	28
ST $\geq$ -0.2 mV	111	83	92	55	29
ST $\geq$ -0.3 mV	63	83	52	68	69
HR $\leq$ 135 bpm	59	86	51	67	70
AP and ST $\geq$ -0.3 mV	53	85	45	68	76
WL $\leq$ 120 Watts	39	90	35	69	86
History of AP	164	74	121	-	-

In patients with typical AP, the most commonly observed abnormality is an ST segment depression $\geq$ 0.1 mV ; the predictive value for MVD (% of true positives) of this abnormality is only 78% (table 8) while it was 92% in patients with a previous MI . This means that among anginal patients with an ST segment depression $\geq$ 0.1 mV, 78% have MVD while 22% have a single VD ; this abnormality is however very sensitive to MVD since it is present in 94% of the patients with MVD but it is poorly specific since it is present in 74% of the patients with single VD or normal coronary arteries . The predictive value for MVD of more severe abnormalities increases with the degree of the abnormality (table 8) while simultaneously, the incidence of false negative responses increases markedly (24, 25) ; the trend is the same as in patients with a previous MI but here, the predictive value remains low and never reaches 100% . From a practical point of view, the best predictor for MVD is simply a history of angina pectoris .

It is therefore difficult to predict accurately and in a significant proportion of these patients the presence of MVD ; this situation is due to the fact that many patients with a single VD have an abnormal response to exercise . Among these patients with a single VD and an abnormal response to exercise, 60% have significant lesions of the left anterior descending artery and their response to exercise is similar to that one of other patients with single VD .

In patients with typical AP, a negative response to exercise is difficult to interpret since among such patients, 39% still have MVD (table 8) .

An ST segment elevation is rarely found in patients with AP but no previous MI ; this abnormal finding has been observed in only 11 cases, i.e. 7% of the patients . In every such case, the ST segment elevation was attended by an ST segment depression in reciprocal leads . These responses are mostly found in patients suffering from variant AP (15) and in our patients they were always attended by significant coronary lesions ; the spastic origin of these ECG abnormalities has been suggested and demonstrated in a few cases (47) .

In summary, patients with AP but no previous MI have MVD in $\pm$ 75% of the cases and single VD in $\pm$ 20% of the cases . Because anginal patients with a single VD often respond abnormally to exercise, it is difficult to predict accurately the presence of MVD from an abnormal response to exercise . Also, in anginal patients, a normal response to exercise does not permit to rule out MVD since it is present in 40% of these negative responders . As in patients with a previous MI , exercise testing of angina patients cannot separate the patients with 2 VD from those with 3 VD . In groups of symptomatic patients, the exercise testing data do not provide much more information for the prediction of MVD than the data given by the history (i.e. the presence or the absence of typical AP) ; in an individual patient however, the probability of having MVD increases drastically with the importance of the abnormalities induced by exercise .

2.3.3. Left main disease .

The prognosis of LMD is very poor (2) and these patients should be detected since their symptoms and survival are improved by coronary artery bypass surgery (8) .

Among patients suffering from AP (no previous MI), 30 patients (18%) had a significant lesion of the left main artery ; 8 of these patients had a 2 VD and 22 had a 3 VD . After MI, 16 patients (11%) had a left main stenosis and they had all a 3 VD . Among symptomatic patients (AP or MI), the frequency of LMD is thus about 15% (10, 29) . This frequency is much higher than usually reported (3.6%) but on one hand, our series includes only those patients who had both an exercise test and an angiographic study and on the other hand, we have excluded patients with atypical complaints, valvular disease or cardiomyopathies .

The data collected during exercise in LMD patients are the most abnormal (11, 29) but none of the parameters differ significantly from the data collected in patients with 2 or 3 VD . From their average response to exercise, these patients cannot therefore be distinguished within the group of patients with MVD (29) . From a clinical point of view, LMD is more likely in those patients with the most abnormal response to exercise but, as for MVD, any increase in the predictive accuracy will be attended by a drastic increase in the incidence of false negative responders .

3. NUCLEAR CARDIOLOGY .

During the last 10 years, exercise testing has increasingly been combined with radionuclide imaging of the heart ; this recent development has significantly contributed to a better non-invasive evaluation of the coronary circulation . Two methods are now available, namely the post-exercise myocardial Thallium scintigraphy and the gated blood-pool radionuclide angiography .

3.1. Thallium scintigraphy .

Thallium^{201} is an analog to the potassium , the major intracellular cation . After intravenous injection, Thallium^{201} is taken up by the myocardium and its distribution within the left ventricular wall precisely reflects the distribution of coronary blood flow . The unperfused areas (old myocardial infarction) do not fix any tracer and they appear as a defect on the scintigraphic image . The transient myocardial ischemia induced by exercise is attended by a relative decrease in coronary blood flow within the ischemic zones : these zones have a relatively lower myocardial uptake of Thallium^{201} and on the scintigraphic image, they appear as a zone of hypofixation or even as a defect . The localisation of these hypoperfused areas permits to predict the localization of the

coronary stenotic lesions . This myocardial hypofixation of Thallium persists during one hour after exercise and progressively disappears afterwards : the scintigrams recorded a few hours later are similar to those obtained at rest (redistribution imaging; 3) .

Thallium^{201} (1.5 to 2 millicuries) has to be injected one minute before the end of the exercise test and scintigraphic images are usually recorded in three positions : anterior, left oblique anterior 45° and left lateral . Each image is divided in several segments which correspond to the several regions of the left ventricular wall . The visual analysis of the polaroid images is sufficient for clinical purposes but several computer programs for acquisition of the data, display and analysis are now available (26) .

3.1.1. Sensitivity and specificity of exercise myocardial scintigraphy .

The sensitivity of Thallium^{201} scintigraphy is between 75 and 80% (table 9) and in many studies similar to the sensitivity of the exercise ECG ; noteworthy, myocardial scintigraphy can be interpreted in presence of an abnormal resting ECG (bundle branch block, left ventricular hypertrophy, ...) .

Table 9 - Thallium exercise scintigraphy, exercise ECG and their combination in the diagnosis of coronary artery disease .

Authors	Number of cases	Sensitivity (%)			Specificity (%)	
		Thallium	ECG	Thallium and ECG	Thallium	ECG
Ritchie et al. (36)	101	76	65	91	92	84
Hamilton et al. (21)	137	77	66	90	93	83
Verani et al. (42)	82	79	88	94	97	62
Turner et al. (41)	75	68	71	85	97	79
Melin et al. (30)	110	88	75	96	87	75

The high specificity (±95%) of stress myocardial scintigraphy is the major advantage of this diagnostic approach (21, 36, 41, 42) .

3.1.2. Combination of history, exercise ECG and scintigraphy .

A myocardial scintigraphy should always be interpreted taking into account the additional information provided by exercise testing, namely the ECG abnormalities and the complaints during the test : this approach increases the sensitivity of exercise testing up to 90 to 95% without any loss in specificity (table 9) .

Table 10 - Incidence of CAD according to the history and the maximal exercise ECG and scintigraphic data in 89 men suspected of coronary artery disease but without previous myocardial infarction (30) .

	Angina pectoris (n = 65)	Atypical complaints (n = 24)
History	91	12
Exercise data		
T+	98	40
E+	96	40
T-	58	5
E-	78	5
T- E-	50	0
T- E+	67	25
T+ E-	92	25
T+ E+	100	100

T = Thallium^{201} scintigraphy ; E = exercise ECG;
+ and - refer to an abnormal or normal response to the test.

The prevalence of CAD , which is mainly determined by the sex and the characteristics of the complaints (typical angina pectoris or atypical complaints), also influences the data provided by

Thallium^{201} scintigraphy (21, 30) . When the complaints are typical of angina pectoris, an abnormal ECG or an abnormal scintigraphy are highly predictive of CAD (table 10) ; when both tests are abnormal, 100% of angina patients have significant CAD . In these anginal men, a normal response to exercise testing has no diagnostic value since CAD is still present in 50% of the patients with a normal ECG combined to a normal scintigraphy ; part of these false negative scintigraphies are explained by a generalized hypoperfusion due to severe lesions of the three vessels .

In presence of atypical chest pain (low prevalence of CAD) a normal response to exercise testing has a great diagnostic value and CAD is never found when both ECG and the scintigraphy are normal (table 10) . In these patients, an abnormal response to exercise testing has a low predictive value except when both tests are abnormal (30) .

3.1.3. Prediction of the localization of coronary lesions .

Several studies have demonstrated a significant relationship between the localization of the scintigraphic abnormalities and the localization of the coronary lesions (23, 35) . This finding is a major contribution of Thallium^{201} scintigraphy : the predictive value is good for the left anterior descending artery , intermediate for the right coronary artery and poor for the left circumflex artery .

3.2. Exercise radionuclide angiography .

The global or regional left ventricular function can be studied by imaging the cardiac blood pool after its labelling with a radioactive tracer (Technetium) . The cyclic variation in intra-ventricular volume permits to measure the ejection fraction from a time-activity curve of the left ventricular region ; by sophisticated computer processing of the data, it is possible to obtain images at different intervals within the cardiac cycle and so to analyse the wall motion (39) .

3.2.1. Ejection fraction .

In normal subjects, the left ventricular ejection fraction increases from rest to maximal exercise (4) . In CAD patients, the ejection fraction is often normal at rest but it does not increase or even decreases during maximal exercise : this abnormal ejection fraction during exercise is highly sensitive for CAD (±95%) but this is a poorly specific sign since it is also observed in all diseases affecting the left ventricular function (valvular disease, hypertension, cardiomyopathies,... ; 5, 6) .

3.2.2. Ventricular wall motion abnormalities .

The onset during exercise of a localized abnormal wall motion is a very sensitive sign of CAD (±90%) and it permits to predict the localization of the coronary lesions (1, 4, 22) . Normal subjects practically never show such abnormalities and such findings are therefore highly specific of CAD ; as for ejection fraction, this high specificity is obtained only when all patients with valvular or myocardial disease are excluded from the calculations (1, 4, 22) . Anyhow, one can except that in the future, the combination of gated blood pool studies with exercise ECG will further improve the non-invasive evaluation of the coronary circulation .

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NATO REGULATIONS ON THE CARDIO - VASCULAR SYSTEM

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The official regulations are the juridical base of all our medical decisions concerning fitness for flying duties. More and more frequently, the applicants and the trained flyers, when declared unfit, do not hesitate to introduce claims against these medical decisions of unfitness. It may be that it is in accordance with the atmosphere of contestation or revolt of our time. Any deviation from the juridical texts is exploited by lawyers. Therefore, we have good medical and juridical reasons to direct our attention on these regulations.

In 1974, at the request of the AGARD Aerospace Medical Panel, I have been asked to undertake a comparative study on the current standards for assessing fitness for flying duties in the Air Forces of the North Atlantic Treaty Countries. I received the official regulations from seven countries. For various reasons, the regulations concerning standards of fitness for flying duties applicable to military flying personnel in the other countries represented in AGARD were not available in due time. It has been said or written to me that these regulations, most of them twenty-five years old, were at that time under revision by the authorities of the countries concerned.

Although the ideal scope of such a comparative study would have been a report on all the military requirements for fitness for flying duties in force in all the NATO countries, it is believed that the gaps resulting from this situation will not greatly detract from its practical conclusions. After three years of study on this very complex matter, the result has been published in 1977, in the form of an Agardograph, in English and in French : Agardograph N° 213. "Comparative study of regulations on standards of medical fitness for flying duties in nine Air Forces covering seven countries of the North Atlantic Treaty Organization." We are now in 1980. It may be that during the period between the beginning of the study and to-day, important modifications have been brought, in some countries, to some points I intend to discuss. If it is so, it will be a good opportunity for some of you, to give, after my concise presentation, a complement of documentation concerning texts which have been added or completely modified since 1975.

My present objective, during this short presentation, is to indicate the main lines of the content of the Chapter IV of the Agardograph N° 213, so that you may obtain - it is my hope - a clear view of the official regulations, as they were five years ago and as they are very likely to-day, concerning the fitness for flying duties in matters regarding the cardio - vascular system. Are they still valid in all details ? Are they uncompleted ? Is it a need for modifications or complements in some aspects ? I think that it is a good subject for your discussions. My objective is to present a synthesis of the official and juridical base of any decision concerning fitness or unfitness for flying duties, in the cardio-vascular field : a terrible power in your hands, considering the consequences for the future of the carreer of a pilot.

GENERAL PRINCIPLES

1. All the regulations require the circulatory system to be sound, as checked by clinical, radiological and electrocardiographic examination.

2. An electrocardiographic trace in all the peripheral and precordial derivations is required both for the initial examination and at each subsequent periodic examination.

Only, the Canadian regulations are less exacting : an electrocardiogram is required :
(a) on enrolment
(b) every four years up to the age of 35
(c) every year after the age of 35

3. Teleradiography of the heart is required if there is any appreciable enlargement of the cardiac area, as revealed by a clinical or X-ray examination.

The American, Canadian and Belgian regulations state that subjects whose transverse cardiac diameter exceeds the normal value by more than 15% must be disqualified.

4. Aircrew applicants and aircrew in service undergo special examinations and exercice tests to enable the cardiac functional responses to be assessed - Why ?

Under the French regulations, these responses must be distinctly satisfactory and compatible with prolonged physical exertion, even at altitude. Under the Belgian regulations, they must be such as to enable subjects to withstand, without difficulty any exacting conditions resulting from flying. The German regulations require these responses to show that the heart is capable of withstanding high stress loads.

For this purpose, a few tests are laid down in all the regulations, but the latter rarely indicate the interpretation to be placed on the results of such tests in order to reach a decision in regard to fitness or unfitness for flying duties.

In actual fact, the techniques of the tests and the interpretation of the results are more frequently dealt with in special technical instructions. A description of the various tests currently used by the medical services of the NATO Air Forces to assess the cardiovascular function in applicants for aircrew duties or in aircrew members has been given in Agardograph N° 196, published in December 1974, under the direction of Professor A. SCANO, to which reference should be made.

5. All the regulations give a more or less detailed list of the diseases constituting grounds for disqualification : the presence of such diseases means that the circulatory system no longer meets the basic requirement prescribing that the system should be organically and functionally sound.

Such a list provides an opportunity of indicating any authorized departures from the regulations or the precautions to be taken because of the existence of a past history of such diseases.

We intend to consider, first, the selection examination of applicants and, after that, the periodic medical examination of aircrew.

A. SELECTION EXAMINATION OF APPLICANTS OR INITIAL EXAMINATION.

We will consider :

1. The factors on which an assessment of the cardiovascular function is based.
2. A list of groups of diseases providing grounds for unfitness for flying duties, in the selection examination.

1. Factors on which an assessment of the cardiovascular function is based.

The factors used in assessing the cardiovascular function and referred to in all the regulations are the following :

(1) pulse rate

(2) blood pressure

(3) electrocardiogram

(4) cardiac tolerance to physical exertion, although the regulations are much less precise on this point.

(1) Pulse rate

In all the regulations, pulse readings are interpreted in very similar ways, which can be considered as practically the same. Some regulations underline the purely indicative character to be attributed to the values quoted as the normal levels.

Generally speaking, any abnormalities are assessed in relation to the clinical examination, and any disturbances of the cardiac rhytm, which are of pathological significance, are disqualifying factors.

The French regulations provide that "borderline cases require a period of observation in a specialized medical department before a decision to accept them can be taken".

What are the threshold values of the pulse rate in the official texts of the regulations ? There is a general agreement that the resting pulse rate in lying position, must not exceed 100 beats per minute -

- Tachycardia constitutes grounds for rejection of the applicant, if the resting pulse rate exceeds 100 beats per minute, irrespective of the cause, in the US Navy and the US Army. In the other regulations, there are some conditions allowing some tolerance.

For instance : In the USAF regulations, tachycardia constitutes grounds for rejection, if the resting pulse rate exceeds 100 beats per minute, unless the examiner can establish that such tachycardia is a psychic reaction and is not caused by a pathological condition.

The French regulations provide that certain types of neurotonic tachycardia not exceeding 100 beats per minute (subject seated) and reacting favourably to the exercise and hypoxia tests may be admitted. It seems that the general opinion, on a practical ground, is summarized in the RAF regulations : "It is never advisable to accept a candidate whose sitting pulse rate is persistently more than 100 beats per minute. It is rarely advisable to accept a candidate with a sitting pulse rate which is persistently over 90, after due care has been taken to allow the pulse to settle and to eliminate the emotional factor, the subject's temperature being normal. When persistent tachycardia is the only abnormal element in the medical examination, the applicant is asseesed as temporarily unfit and then re-examined after an appropriate interval. The standing pulse rate should not exceed the sitting rate by more than 24 beats per minute".

- Bradycardia : The references to bradycardia do not include a threshold rate below which the applicant would have to be rejected. Only the German regulation mentions that bradycardia of 60 beats or less a minute is a ground for rejection, when a clinical examination or an electrocardiogram shows that this is caused by an organic heart disease.

I think that the USAF regulation concisely expresses the common way of thinking : the applicant presenting bradycardia is declared unfit whenever any pathological conditions related to fainting are observed.

On the reverse, three regulations present also a positive aspect :

(a) in the French regulations : sinusal bradycardia not associated with any subjective disorders and reacting favourably to the exercise and hypoxia tests are frequently compatible with flying.

(b) the RAF regulations : it is merely referred to the fact that rates of 48 beats per minute and below may occasionally be found in very athletic persons who go in for strenuous sports.

(c) The Canadian regulations are on the same line : bradycardia associated with a pathological condition constitutes grounds for disqualification. However, bradycardia not due to any disease condition and associated with moderate enlargement of the cardiac area, such as it is frequently found in an athlete who has undergone extensive training is not a cause for rejection.

(2) Blood pressure

The various regulations draw examiners' attention to the need for care in interpreting applicants' blood pressure. In cases of doubt, it should be measured on several occasions, if necessary at intervals of a few days, since an emotional factor, which is a normal occurence at the time of examination, may temporarily affect the actual blood pressure values. Nevertheless, in spite of these calls for cautiousness, all the regulations, except those of the RAF, have indicated threshold values for the acceptance of applicants, the pressure being measured in the sitting position. The levels for these threshold values are similar or very close in all the various regulations.

- Upper limits

(a) threshold value of 150 mm Hg for the systolic pressure and 90 mm Hg for the diastolic pressure are mentionned in the following regulations : Belgium, France, Germany (the diastolic threshold is 95 mm Hg), Canada.

(b) USAF, US Navy, US Army and Norway have adopted a lower threshold value for the systolic pressure : 140 mm Hg, but the threshold of diastolic pressure is similar to the value admitted by other regulations : 90 mm Hg.

(c) The RAF regulations, although they do not expressly mention a systolic threshold value, accept as diastolic threshold, the common value : 90 mm Hg. It can be presumed that they accept also, practically, the systolic threshold of 150 mm Hg, as deduced from the following provision mentionned in the official text : systolic pressures of 160 mm Hg in conjunction with tachycardia can be ignored, by reason of emotional factors, if there are no symptoms of cardiovascular or renal disease, if the body temperature is normal and if the diastolic pressure remains between 70 and 90 mm Hg.

- Lower limits

Six regulations have fixed 100 mm Hg - 60 mm Hg as lowest acceptable values, respectively for the systolic and the diastolic values : Belgium, Germany, USAF, US Navy, Canada, Norway. - France and UK have fixed a higher systolic level : 110 mm Hg - 60 mm Hg. US Army is the most tolerant : 90 mm Hg - 60 mm Hg.

French and US regulations call attention on the need for a systematic investigation of orthostatic hypotension on applicants presenting a tall and underweight body-build, who have a tendency to be particularly sensitive to acceleration. UK regulations express the degree of flexibility acceptable, when the threshold values are not obtained : "Systolic pressures of 105 mm Hg or even lower are sometimes found in healthy individuals. However, the combination of a low normal systolic pressure with a low diastolic pressure is an indication of a liability to syncopal episodes. A diastolic pressure of over 90 mm Hg in a candidate can be ignored if the remainder of the examination is satisfactory and if, in particular, renal function proves to be normal. A diastolic pressure below 70 mm Hg, associated with low systolic pressure, is not in itself sufficient to warrant an assessment of unfitness, but calls for a great deal of caution. Diastolic pressure below 60 mm Hg should be regarded, if they persist, as grounds for the rejection of candidates for flying duties, as they are rarely found in normally robust individuals".

Summarizing, it can be said that there exists a large agreement on the threshold values :

Upper limits : 150 mm Hg - 90 mm Hg with an exception for the US regulations : 140 mm Hg - 90 mm Hg.

Lower limits : 110 mm Hg or 100 mm Hg - 60 mm Hg with an exception for the US Army regulations : 90 mm Hg - 60 mm Hg.

(3) Electrocardiogram

The electrocardiogram is dealt with in all the regulations by a precise enumeration of the abnormalities which are causes for rejection and those which are compatible with fitness. There is an exception : the RAF regulations, as the regulations of the other Air Forces, require an electrocardiogram to be recorded for all candidates for flying duties, but make no special comment on the electrocardiographic abnormalities which would be a cause for rejection.

As general rule for interpretation of electrocardiographic abnormalities, the French regulations mention that isolated electrocardiographic abnormalities of repolarisation must be very carefully investigated in relation to the age of the candidate, his history and results of functional tests.

There is a general agreement on the electrocardiographic abnormalities indicating serious conduction defects and, therefore to be considered as causes for rejection :

(a) Major arrhythmias, such as atrial flutter or fibrillation, ventricular fibrillation, multifocal premature ventricular contractions.

(b) first degree atrioventricular block, unless the clinical examination reveals no other cardiac abnormality, and if reduced during exercise, particularly if observed in athletic subjects.

(c) second and third degree atrioventricular block

(d) complete left bundle branch block

(e) complete right bundle branch block

(f) Wolff - Parkinson - White syndrome

Are compatible with fitness :

(a) incomplete and isolated right bundle branch block

(b) isolated and sporadic extrasystoles, which disappear after exercise.

As expressed in the German regulations, any other electrocardiographic findings (e.g. mild excitability abnormalities, left anterior hemi - block, incomplete block) must be interpreted within the framework of the whole cardiological examination.

(4) Exercise tests

In all regulations, there are mentions, in general terms, about exercise or functional tests. The assessment examination must therefore include them as current and sometimes mandatory elements. Technical instructions regarding examination methods occasionally specify precisely the tests which should be performed, and in such cases, they also indicate how the results are to be interpreted. More often, the regulations make no mention of methods of examination, although these are covered by separate special instructions (see Agardograph N° 196, quoted above).

I intend to review the contents of the official regulations on this matter in 9 Air Forces under study.

1. Belgium

The regulations require each candidate to undergo an exercise test at the initial selection examination in order to assess the extent of cardiovascular tolerance to prolonged and exhausting exercise. The type of test used is not mentionned. However, the Harvard step-test, of five minutes duration, has in fact been used since 1946 up to 1970 and subjects with an index of less than 70 are disqualified. This disqualifying index is reached whenever the total number of beats recorded for 30 seconds, at the start of the second minute, of the third minute and of the fourth minute following the completion of the test exceeds 220.

Now, tests on ergocycle are used.

2. France

The French regulations make it a requirement that at the initial examination the cardiac functional responses should be absolutely satisfactory and compatible with prolonged physical stress, even at altitude. In connection with subjects presenting a tall and underweight body-build, it is pointed out that because of possible intolerance to acceleration, orthostatichypotension should be systematically investigated. The tests advocated or prescribed for these two purposes are not mentionned. In the same way, the regulations mention that isolated electrocardiographic abnormalities of repolarisation must be considered in terms of several factors, one of the most important being the results of functional tests. A technical notice gives some general lines on exercise tests. It mentions that some functional tests, usual in the past, have to-day fallen into disuse, e.g. hypoxia test in low pressure chamber at an altitude of 5000 m for 20 minutes, ergotamin tartrate test, potassic load test.

The test, described in the technical notice, are carried out for the diagnosis of coronary disease, and also for the assessment of the physical condition of the healthy or ill subject. Comments are given on the Master Exercise Test, (single two-step test, double two-step test), exercises on bicycle ergometers, treadmill tests. The technical notice adds that these exercise tests must only be carried out in the department of a hospital, having at its disposal resuscitation equipment, as they can be dangerous for some individuals. But, I presume that it is not the case for individuals submitted to the initial examination.

I hope that this question will be clarified by our French colleagues, during the discussion following this lecture.

3. Germany

According to the regulations of 1969, a Master test is always carried out for a period of 3 minutes on every candidate for entry into the Air Force. But, in the regulations of 1976, this test is not any more mentioned. An electrocardiogram is made before the exercise, the subject being at rest, then immediately on completion of the exercise, and finally two and four minutes after the end of the exercise.

If the past medical history and the results of the clinical examinations show the possibility of orthostatic disturbances, an orthostatic tolerance test (tilt table test) must be carried out, with a recording of pulse rate and blood pressure.

A dynamic tolerance test, during which the pulse and blood pressure are read, is performed whenever hypertensive circulatory disorders are suspected.

Exercise tests to determine functional performance in hypoxia conditions are not mandatory. They are carried out at the German Institute of Aviation Medicine as part of the initial medical examination,

if there are any particular signs of aeromedical importance present, such as signs of circulatory disorders, orthostatic insufficiency accompanied by syncopal tendencies, or excessive dysfunctioning of the automatic nervous system.

Any reduction in performance capacity is measured quantitatively in a low pressure chamber at a simulated altitude of 7500 metres, using the ball test. This test consists in placing 30 round objects in the appropriate holes. The heart rate, blood pressure and respiratory rate are recorded before the test, and during the test while the subject is breathing 100 % oxygen, and then while breathing the normal air in the chamber. The results are assessed according to the type of response given by the subject and the type of deterioration in performance in low oxygen conditions.

4. United Kingdom

The regulations prescribe an exercise test for investigation of the cardiac function. With reference to this "exercise tolerance test", the RAF manual states that a test of this kind rarely provides information which cannot be obtaining during the general medical examination, that it is of no value in detecting heart disease, but is useful in special cases, usually to confirm the results of other parts of the examination. The test is a step-test, lasting for one minute ; the chair which has to be climbed twenty times is 15 inches high. The pulse is taken before the test, then immediately after the test and, finally, one minute after completion of the test.

The pulse rate immediately after the test should not exceed by more than 36 beats per minute the sitting pulse registered on the subject at rest before the exercise. One minute after completion of the exercise, the heart rate must have returned approximately to normal level.

Abnormal results are found in the case of emotional subjects, and as a result of some functional defects, such as insufficiency of systolic output, poor vasomotor tone or functional insufficiency of the circulatory system as a whole.

5. Canada

Candidates for aircrew duties and trained aircrew who do not fully meet the fitness standards are referred for decision or opinion to the Defence and Civil Institute of Environmental Medicine. The regulations mention that this Institute has a low pressure chamber, a human centrifuge, and various devices for testing cardiovascular stress. A description of these tests is not, however, included in the regulations on fitness standards for aircrew.

6. United States

The exercise test prescribed in the regulations of the three US Forces consists in hopping 100 times on one foot, raising it about one inch from the floor at each hop. The sitting pulse rate is recorded before exercise, then immediately after, and finally two minutes after completion of the test. Blood pressure is read before the exercise and two minutes after the exercise. The degree of dyspnea, the possible existence of a murmur, as detected during auscultation, and any symptoms of circulatory failure are also noted.

The regulations,again, add that if other test are carried out, their results should be noted.

No other exercise tests are specially recommended in the regulations of USAF, the US Army and the US Navy. But, from Agardograph 196, it can be deduced that the tests mentioned in the French regulations are also in common use in the US Forces, as they are in the other NATO Air Forces.

The US Navy Manual mentions that the neuro-circulatory efficiency test (Schneider index) is no longer required. There is no objections to its being applied and noted, but it is no longer mandatory for assessing fitness for flying duties.

2. Diseases providing grounds for unfitness for flying duties in the selection examination.

Generally speaking and without paying too much attention to details which are not essential importance, it can be said that there is good agreement between the various regulations in listing the diseases which provide causes for the rejection of candidates.

The following are causes for rejection :

1. Arterial or arteriovenous aneurysm

2. Well characterized organic diseases of the heart and vessels; well characterized functional disorders of the heart.

In addition to diseases of the pericardium, the myocardium and the endocardium, this leading should also include, in particular, orthostatic tachycardia and hypotension, neurocirculatory asthenia, cardiac rhythm disturbances and intracardiac conduction disorders of pathological significance (See "Electrocardiogram" above).

Marked differences between the requirements of the various regulations should, however, be pointed out in the following causes :

(1) Rheumatic fever (BOUILLAUD'S disease)

Disagreements between the various texts relate to the decision to be taken in the absence of any cardiac sequela after one or more attacks of rheumatic fever.

Three regulations state that, even in the absence of any cardiac sequelae, subjects must be

assessed as unfit for a minimum period of two years during which they must remain free from any symptoms. The regulations referred to are those of the USAF, the US Navy and Belgium.

Norway, generally speaking, follows also the USAF regulations : I presume that it is the case in this matter.

The US Army regulations require a candidate to be assessed as unfit until a period of five years has elapsed without the appearance of any symptoms.

The UK regulations lay down a dinstinct and clear rule for such cases. If a candidate has a history of rheumatic fever, without cardiac or other sequelae, he can be accepted for flying duties if any of the following conditions apply :

- he is 25 years old or over

- he is under the age of 25 years, but has received for five years continuous penicillin prophylaxis, or 10 years or more have elapsed since the attack, no treatment having been given.

The French and the Canadian regulations are not explicit about the action to be taken in the absence of any cardiac sequelae. They simply state that cases of rheumatic fever with cardiac complications must be assessed as unfit.

The German regulations are similarly imprecise : they specify that a history of acute or chronic rheumatoid arthritis is a cause of disqualification, either temporarily, or permanently, but no mention is made of the decision to be taken in the specific case of the absence of cardiac sequelae in subjects with a history of rheumatic fever.

(2) Congenital diseases of the heart and heart surgery

Three degrees of strictness are found.

(a) First group : candidates to be assessed as unfit, without any exception

The Belgian, French and German regulations and the US Army regulations have similar provisions : congenital or acquired cardiopathy and malformation of the aorta and the major vessels, of whatever type, even after surgery, are grounds for permanent unfitness. The Belgian regulations add that there is an exception : dextrocardia with complete situs inversus is considered as an anomaly and not a malformation : the healthy candidates having such anomaly can be considered as fit for flying.

(b) Second group : candidates to be assessed as unfit, except in the case of minor congenital diseases, but these are not specified.

The USAF and US Navy regulations stipulate a decision of unfitness for any history of heart surgery and any serious congenital anomaly. Uncomplicated dextrocardia and other minor asymptomatic anomalies are acceptable.

It should, however, be observed that neither of these two regulations defines what is to be understood by "minor asymptomatic anomaly". But, candidates must be assessed as temporarily unfit for a period of at least six months after undergoing surgery for these minor anomalies.

The Canadian regulations require an assessment of unfitness for cases of major congenital cardiopathy. Minor congenital diseases, however, which have been treated surgically, with results considered by a cardiologist to be satisfactory, are acceptable.

(c) Third group : candidates to be assessed as unfit except in the case of some well-defined minor congenital diseases corrected by surgery.

The RAF regulations are very precise. Congenital malformations of the heart and of the majors vessels are, as a general rule, causes for rejection. Certain congenital malformations of the heart are, how , compatible with acceptance for flying duties if a surgical operation has successfully eliminated their effects. The anomalies included in this category are the following :

(1) Patent ductus arteriosus

If the patent ductus arteriosus has been permanently closed, either by ligation alone, or by ligation and division, the candidate can be accepted.

(2) Atrial septum defect

The primary type is always unacceptable. In the secundary type, if the interatrial communicating orifice has been closed and there is no pulmonary hypertension or cardiac enlargement, the candidate can be accepted.

(3) Coarctation of the aorta

A candidate who has undergone a surgical operation for coarctation of the aorta can be considered fit for acceptance for flying duties only if the following requirements are met :

- the surgical operation was performed successfully more than 5 years previously;

- the clinical examination reveals no anomalies in regard to blood pressure, ECG and heart size;

- the femoral pulse is palpable and not delayed

(3) Diseases indicating serious functional insufficiency of the venous system

The texts on varicose veins in the lower limbs are the subject of descriptive comments in some of the regulations, in order to determine the fitness requirements. We must state that there is a large degree of discrepancy between these regulations.

The Belgian regulations provide that to constitute grounds for an assessment of unfitness for flying duties, varicose veins in the lower limbs must have at least one of the following characteristics :

(1) be predisposed to rupture, either as a result of a trauma, or of haemodynamic changes during flying;

(2) be sinuous or voluminous to the point of forming a tumour;

(3) come at least halfway up to the leg or to extend beyond the knee.

The French regulations do not go into these details, but are confined to a statement that marked disorders of the peripheral venous circulation are causes of unfitness. They do, however, add an important detail which is missing from the Belgian regulations : varicose veins which have been treated surgically are not compatible with fitness for functions requiring the general medical aptitude standard N° 1, that means standard for candidate pilot all categories.

We will see, further, that varicose veins which have been treated surgically are only compatible with the general aptitude standard N° 2, that means : trained flighter, reconnaissance, bomber, transport pilot, navigator or radio, if any functional or trophic troubles are absent and if they have no tendency to recurrence.

The USAF regulations do not state what is meant by "serious disorders" which constitute grounds for rejection. They only enumerate some consequences arising out of these marked disorders : oedema, skin ulceration or scars resulting from previous ulceration. They make no mention whatsoever of what happens if the varicose veins have been treated surgically.

The US Army and US Navy requirements are exactly the same as those of the USAF.

Germany and Canada simply quote varicose veins to a marked degree among the causes for rejection, and similarly in the case of varicose ulcers. In parallel with the American regulations these countries provide no guidance for the assessor when confronted with a candidate whose varicose veins have undergone surgical treatment.

The RAF regulations, on the other hand, do envisage this hypothesis, but the decision involved is the opposite of that in the French regulations. Any candidate whose veins show varices to any marked degree is assessed as unfit for flying duties untill such time as this condition has been successfully corrected by means of surgery.

In conclusion, it is surprising to note that in regard to this condition, fortunately not frequent amongst the candidates, (but relatively current amongst trained aircrew), the regulations do not agree on important details, though they all certainly prescribe rejection of a candidate when the varicose condition is very marked. Precise criteria in regard to this "marked degree" are given in the Belgian regulations. The other regulations do not define the marked degree which is the cause of unfitness; only the USAF regulations add a reference to a few complications which are a frequent attribute to a marked degree of the varicose condition. Surgical treatment of the varicose condition is mentioned in two regulations only, although they differ in the requirements laid down.

In the French regulations, such treatment does not affect in any way the decision : the candidate pilot remains unfit. In the RAF regulations, it makes the candidate fit for flying duties, provided that the operation is cinsidered to have been successful.

I think, however, that, at the age of eighteen, twenty years, the incidence of such cases is very low.

B. PERIODIC MEDICAL EXAMINATION OF TRAINED AIRCREW

1. Basic factors for assessing the circulatory function

a. Pulse rate, ECG and physical exercise tests are not covered by any particular requirements which are fundamentally different from those for the initial examination.

Referring to electrocardiography, it should be pointed out, however, that the USAF regulations state a very wise precaution, clearly intended to avoid premature or insufficiently founded decisions or too radical decisions in regard to trained aircrew : all borderline tracings, those which differ markedly from those recorded during previous periodic examinations and those considered to be abnormal by the USAF Central Electrocardiographic Library are causes for declaring the candidate temporarily unfit and require detailed investigation. An assessment of fitness is restored only if the results of such an investigation carried out by the USAF School of Aerospace Medicine eliminate the existence of any cardiac disease.

b. Blood pressure

The area of normality for blood pressure is widened in the majority of the regulations which fix numerical values to indicate the hypertensive condition boundary.

The maximum systolic and diastolic pressures are not considered to be abnormally excessive unless they are higher than the following values :

(1) USAF US Army US Navy

140 mm Hg - 90 mm Hg if the subject is 35 years old or under
150 mm Hg - 90 mm Hg if the subject is over 35 years old

(2) French and Canadian regulations

150 mm Hg - 90 mm Hg

(3) RAF regulations

150 mm Hg -90 mm Hg

In fact, no specific value is quoted, but it can be inferred from the explanatory notes that the maximum values are 150 mm Hg - 90 mm Hg.

(4) German regulations

150 mm Hg - 95 mm Hg, if the subject is 35 years old or under

160 mm Hg - 95 mm Hg, if the subject is over 35 years old

(5) Belgian regulations

160 mm Hg - 90 mm Hg

c. Exercise tests

With reference to the exercise tests, no precise statement of mandatory nature is made, in the regulations, that they should be modified in relation to the age of the subject or to the particular conditions of the periodic examinations. Of all the functional tests quoted in connection with the initial examination, only the very strenuous endurance tests (as the 5 minutes Harvard step test) would, in fact, need to be adapted in relation to the specific purpose of the investigation for which they are being performed. The other functional tests (3 minute Master step test, 1 minute Harvard step test, orthostatism test, tilt table test, performance capability in low oxygen conditions, tests using ergocycles or treadmill) are suitable both for the periodic and the initial examinations, in the sense that they can be performed, after suitable adaptation, without running excessive risks in the case of subjects who have minor defects or who experience difficulties due to age.

d. Detection of atheroma and degenerative vascular diseases associated with metabolic disturbances, without clinical symptomatology

In all the Air Forces, it is clear that the initial clinical examination and the annual or periodic examinations include not only urine and haematological tests, but also various biochemical tests, although a list of these does not necessarily appear in the text of the regulations.

A systematic biological examination for detecting atheroma and degenerative vascular diseases associated with metabolic disturbances (obesity, diabetes, lithiasis, gout) is carried out. But, at our knowledge, only two regulations, the French regulations and the German regulations, contain precise texts which make it compulsory, for all the candidates and for all flying personnel, to undergo a systematic biological examination.

1. The French regulations require the following blood tests to be carried out, in connection with detection or prevention of degenerative vascular diseases :

- total lipids in serum
- total cholesterol in serum and lipidogram
- triglycerides in serum and lipidogram
- glycemia
- uricaemia

At the initial examinations, dyslipidaemia is a cause of rejection, not by reason of an immediate incompability with flying, but because it means a very great atherogenous risk in the future. To justify a decision of unfitness, the laboratory results must be confirmed several times and must exceed the following limits :

- total lipids : 9 grams
- total cholesterol : 3 grams
- triglycerides : 2 grams

At the periodic examinations, the above tests are compulsory every five years, before the age of 40. From the age of 40 on, they are carried out at each yearly examination.

Biochemical disturbances (hypercholesterolaemia, hyperlipaemia) associated with clinical or radiological stigmata or artherosclerosis (e.g. arterial calcification) are a cause of unfitness.

The German regulations require the same tests to be carried out at the initial examination and at each periodic examination. Hyperlipoproteinaemia is a cause of rejection.

Biological tests of this kind are, in fact, very likely performed in all the other Air Forces and is to be assumed that they are indicated in special technical instructions. The question therefore arises of the reason which prevents their compulsory inclusion, in a short but precise form, in all the regulations on fitness for flying duties. Perhaps, some of you have an answer.

It would seem abvisable for juridical reasons, in case of decision of unfitness, to lay down in the regulations the minimum content of the biological evaluation which should be carried out at the periodic examinations, in the frame of the early detection of atheroma and degenerative vascular diseases associated with metabolic disturbances, without clinical symptomatology.

2. Diseases constituting grounds for unfitness for flying duties at periodic medical examination.

The position admitted by all regulations can be summarized by quoting the German regulations on the standards required for the periodic examinations. These standards are most frequently the same as the selection standards; some are less stringent, providing flight safety is not endangered and the pathological conditions revealed are marginal and not liable to be aggravated by flying.

Some comments on a few diseases should now be made.

1. Coronary artery disease. Myocardial infarction

All the regulations require disqualification of aircrew who have suffered coronary artery disease or myocardial infarction. Electrocardiographic evidence of sequelae constitute a sufficient basis for an assessment of unfitness.

2. Sequelae of rheumatic fever

The same standards are applied as for the initial examination.

3. Heart surgery

The standards for the initial examination also apply to the periodic examinations.

4. Varicose conditions

The standards for the periodic examinations are exactly the same as for the initial examination, except in the French regulations which run parallel in this respect, with the RAF regulations.

In the French regulations, contrary to the requirements for candidate pilots at the initial examinations, it is accepted that varicose veins which have been operated on, are compatible with the maintenance of fitness for flying duties in trained aircrew providing there is no associated functional or trophic disorder and no tendency to recurrence of the varicose condition.

CONCLUSION

1. Concerning the methods or tests used in the clinical examination, no serious divergence exists in the points of view expressed in the various regulations.

Pulse and blood pressure are interpreted in very similar ways, which can be considered as practically the same. Some regulations lay great stress on the purely indicative character to be attributed to the values quoted as the normal levels.

The electrocardiogram is dealt with in all the regulations, except in the RAF regulations, by a precise enumeration of the abnormalities which give cause for rejection and those which are compatible with fitness. There is no discrepancy between the various regulations.

The use of exercise tests is mentioned in all the regulations. Very often, the regulations make no mention of the tests which should be performed and how the results are to be interpreted in matter of fitness or unfitness for flying duties.

It has always been difficult to state categorically which types of circulatory functional tests should be adopted. The lack of precision found in this connection, in the official regulations, is therefore not surprising. - The essential point has, at least, been achieved : the principle of the inclusion of functional tests in the medical fitness examination. - Furthermore, the warning given by the US Navy when referring to the Schneider test is a wise one. This test, like many others, has its limitation; it assesses in particular the effect of the automatic nervous system on the control of the cardiac centres rather than the functional value of the myocardiac fibre. The regulations rightly instruct the medical examiner not to rely on the quantitative results of the test alone in order to support a decision of unfitness. At the same time, the medical officer is reminded, as also in the case of the RAF regulations, that the clinical examination of an individual constitutes a complete picture, of which it is often not easy to make an overall assessment, and that this difficulty cannot be made to dissapear by the expedient of the results of a single exercise test, sometimes of disputable or doubtfull significance. A functional test provides an additional element, among many others, in a complete whole; it must not be interpreted, on its own, within its limits alone, but in the complete clinical picture.

2. With regard to the effect of some diseases on flying duties, this is clearly an area offering possibilities for greater standardisation in the decisions made by medical experts, on the basis of the texts of the official regulations. I have presented some examples : rheumatic fever, with and without cardiac sequelae, congenital heart diseases, sequelae of heart surgery and such ordinary diseases as varices. Present day development in the design of combat aircraft may affect the significance of morphological or physiological anomalies or insufficiencies of the cardio-vascular system, with the result that some of them may be felt to be less significant, and others more significant.

This very important concept must not be ignored during future revisions of medical fitness standards.

This very quick comparative review of nine sets of regulations has indicated some differences of opinion, or some techniques of doubtful value which should be re-examined. Some standards traditional concepts of the medical fitness examination may totter as a result of such a revision but this is often the way in which progress is achieved.

It is natural that the official texts, prepared with the full guarantee of official medical experts and with the approval of higher authorities, should give the users of such texts an impression of unshakable assurance and fully achieved perfection. Such an impression is always illusory to a certain degree.

The problems arising out of a comparaison of the various medical fitness regulations are there as

a reminder that some concepts are relative and constantly changing, and that there are a large number of subjects matters in this field which still require continuous investigation by qualified researchers and experienced medical experts.

I hope that this revision, in spite of its severe and arid aspects, will be useful for your discussions and exchanges of ideas.

APPORT DES MECANOGRAMMES CARDIAQUES DANS L'EXPERTISE DU PERSONNEL NAVIGANT

par

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I - INTRODUCTION

L'idée d'enregistrer graphiquement les pulsations carotidiennes ou l'apexogramme n'est pas récente puisqu'elle avait été déjà réalisée au XIX° siècle par CHAUVEAU, MAREY et MACKENSY. Mais di de tels enregistrements avaient été précieux pour les physiologistes, ils n'avaient été que peu d'utilité pratique pour le clinicien. C'est la possibilité de transformer les phénomènes à étudier en variations électriques sans inertie qui a permis de reprendre l'étude des mécanogrammes et d'en tirer des indications précieuses pour le clinicien et pour nous expert du personnel navigant.

Ce sont des techniques non sanglantes, facilement reproductibles à chaque expertise ; en plus ce sont des tracés que l'on inclut dans le dossier de chaque pilote permettant ainsi la comparaison d'une expertise à l'autre.

Les mécanogrammes cardiaques nous apportent les renseignements de trois ordres :

1) analyse des souffles cardiaques précisant la variété de la cardiopathie par la phonocardiographie,

2) étude de la distensibilité artérielle par le carotidogramme,

3) mesure chronocardiographique mesurant un index de débit systolique et la contraction du muscle myocardique.

II - ANALYSE DES SOUFFLES CARDIAQUES

L'auscultation cardiaque aidée des examens complémentaires que sont l'électrocardiogramme et la radiographie cardiaque permet d'affirmer l'organicité d'un souffle diastolique et parvient, dans la majorité des cas, à affirmer l'organicité ou l'anorganicité d'un souffle systolique. Dans quelques cas, vu l'importance du diagnostic d'organicité pour la détermination de l'aptitude au personnel navigant, il paraît utile de s'aider de techniques non sanglantes que sont les mécanogrammes cardiaques. Les techniques mécanographiques employées dans le service sont les suivantes :

a) phonocardiogramme avec 4 bandes de fréquence (35 Hz, 70 Hz, 140 Hz, 280 Hz) pris au niveau d'auscultation du souffle systolique ;

b) l'étude du carotidogramme porte sur deux éléments :

- étude de la morphologie du tracé,
- étude des chronologies des divers accidents de la courbe, temps d'ascension, temps de 1/2 ascension et durée de l'éjection ventriculaire gauche.

Mais ces temps doivent être corrigés en fonction du rythme par l'abaque de PERNOD et CARRE.

c) apexogramme,

d) épreuves dynamiques comprenant :

1 - la manoeuvre de Valsalva permet d'affirmer que le souffle systolique est d'origine gauche ou droite. Dans le souffle d'origine droite, le souffle prend à la fin de l'épreuve son intensité maximum, alors qu'à l'inverse, pour le souffle d'origine gauche, il ne devient maximum que cinq systoles suivant l'arrêt de l'épreuve.

2 - épreuves pharmacodynamiques avec prise de tracés après : épreuve au nitre d'amyle ou l'isuprel complétée par les épreuves aux sybstances vasopressives (aramines, méthoxamine).

Donc, à la fin de nos tracés, il est possible de conclure schématiquement si le souffle est d'obstruction ou de régurgitation, s'il est droit ou gauche.

	Souffle d'obstruction ou antérograde	Souffle de régurgitation ou rétrograde
Morphologie	- losangique	. rectangulaire
Chronologie	- naît à distance de B 1 - n'atteint pas B 2	. hylosystolique va de B 1 à B 2
Après pause extrasystolique	- renforcé	non renforcé
nitrite d'amyle	- renforcé	diminué
isuprel	- renforcé	diminué
aramine ou méthoxamine	- diminué	augmenté

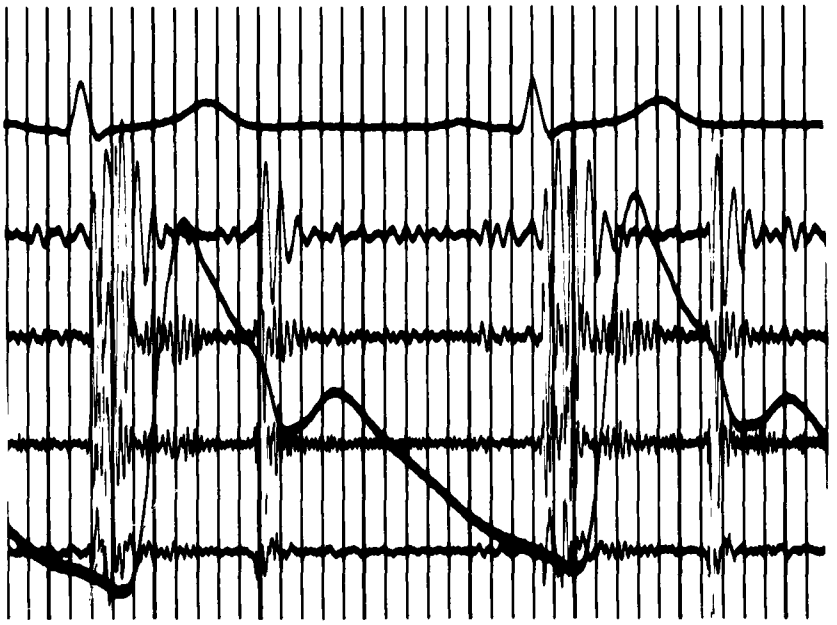
Etudions les différents types de souffle systolique que l'on peut rencontrer en visite d'admission ou en visite révisionnelles.

A/ LES SOUFFLES SYSTOLIQUES ANORGANIQUES

1) Le souffle infundibulopulmonaire ou souffle de TRIFIER-DEVIS est très fréquemment rencontré chez les jeunes candidats ayant une élasticité artérielle très grande. C'est un souffle systolique siégeant au foyer pulmonaire dans la région parasternale gauche à la partie interne du 2° ou 3° espace intercostal gauche. Le mécanisme du souffle est l'engouffrement du sang dans un orifice pulmonaire jouant le rôle de rétrécissement fonctionnel.

Les critères mécanographiques seront ceux d'un souffle d'obstruction droit.

Du point de vue morphologique, on remarquera que le souffle est protosystolique accolé au 1° bruit, decrescendo et laisse libre la méso et la télésystole.



2) Les souffles cardiopulmonaires (souffle de Potain), rencontrés plus rarement, ne naissent pas au niveau d'un orifice du coeur et varient considérablement avec les phases du cycle respiratoire et la position du patient.

Ils sont perçus dans la région endopexienne. Ils peuvent être inspiratoires et expiratoires ou uniquement inspiratoires.

B/ LES SOUFFLES SYSTOLIQUES ORGANIQUES

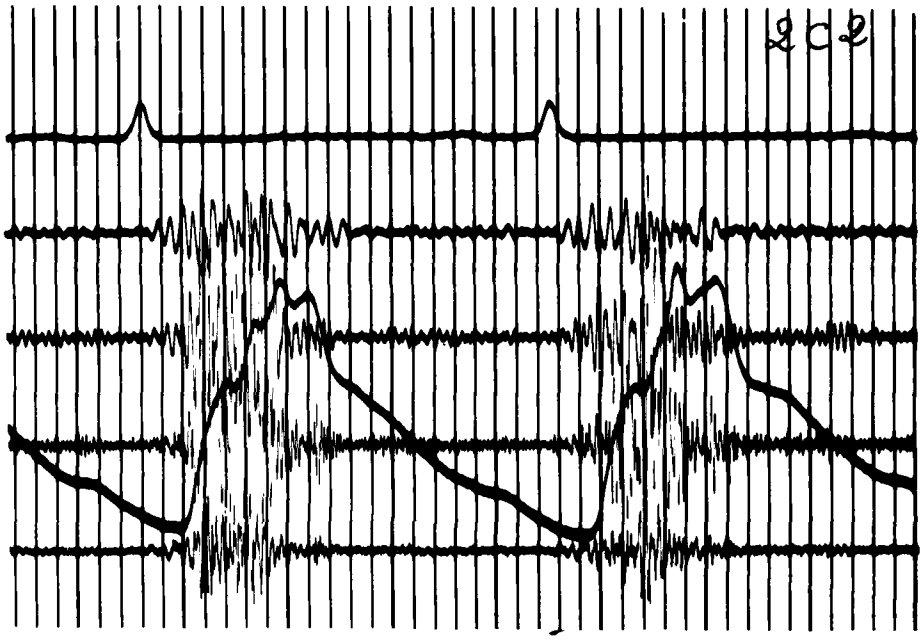
1) Le rétrécissement aortique

Le phonocardiogramme montre que c'est un souffle d'obstruction gauche avec les critères que nous avons décrits plus haut.

Quelques nuances phonocardiographiques sont propres à la sténose aortique :

- disparition de la composante aortique du 2° bruit,
- constatation d'un claquement protosystolique (ou click) d'éjection qui se rencontre dans certains cas.

Le carotidogramme du rétrécissement aortique présente du point de vue morphologique une série de crénelures (image en crêtes de coq ou en dent de scie) à la partie terminale de la branche ascendante et une disparition de l'incisure catacrote. Du point de vue chronologique, on note une augmentation du temps d'ascension, du temps de demi-ascension et du t emps d'éjection systolique. Sur l'apexogramme du rétrécissement aortique, on remarque une augmentation de l'onde A. On peut même aller plus loin, des corrélations les plus précises entre l'importance du gradient ventriculo-aortique et le carotidogramme ont été établies dans lequel le temps de demi-ascension et le temps d'éjection vaient significativement en raison directe du gradient. Ici, cinq critères de sévérité ont pu être proposés : extinction de B 1 au foyer aortique, présence d'un B 4, chronologie tardive des vibrations maxima du souffle, allongement du temps d'éjection ventriculaire gauche et allongement du temps de demi-ascension au-delà de 0,06 seconde. Le rétrécissement est d'autant plus serré que l'enregistrement comporte un nombre plus grand de ces critères.

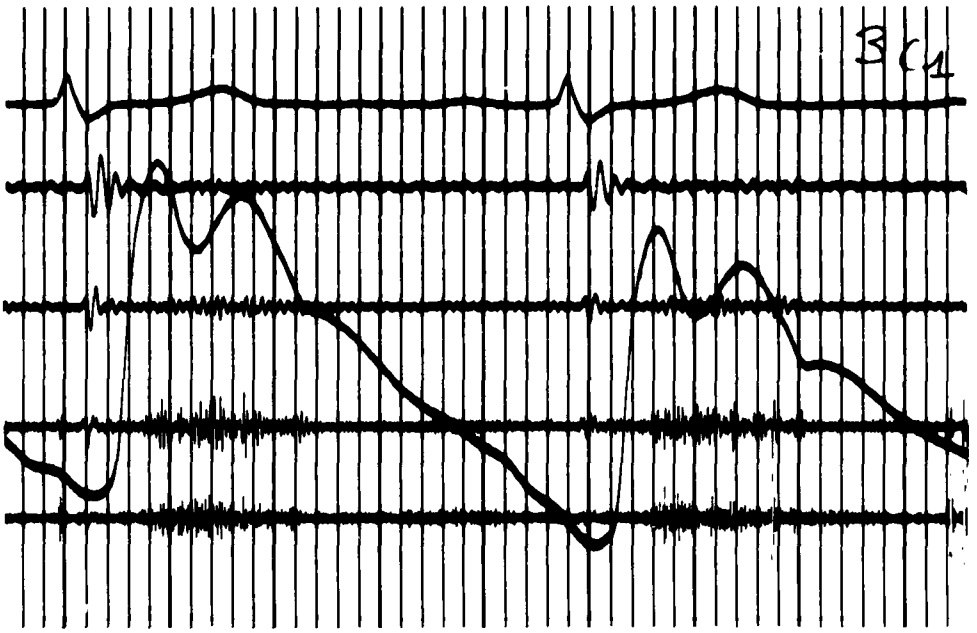


2) La cardiomyopathie obstructive réalisant un obstacle à l'éjection ventriculaire gauche doit être systématiquement recherchée à la visite d'admission en raison de la fréquence des morts subites chez le jet jeune porteur de cette cardiopathie.

Le tracé du phonocardiogramme visualisera un souffle d'obstruction du type gauche.

Le carotidogramme joue un rôle essentiel dans le diagnostic. Il comporte sur la partie descendante après une brusque descente suivie d'un creux, une nouvelle onde positive moins élevée que la première surnommée par BRAUNWALD "systolic bulge". Ce signe n'est pas pathognomonique puisqu'en étudiant les tracés de 1000 pilotes nous l'avons rencontré chez 25 sujets indemnes de toute anomalie. L'apexogramme présente une onde A et une bifidité du plateau systolique et c'est un argument important pour le diagnostic.

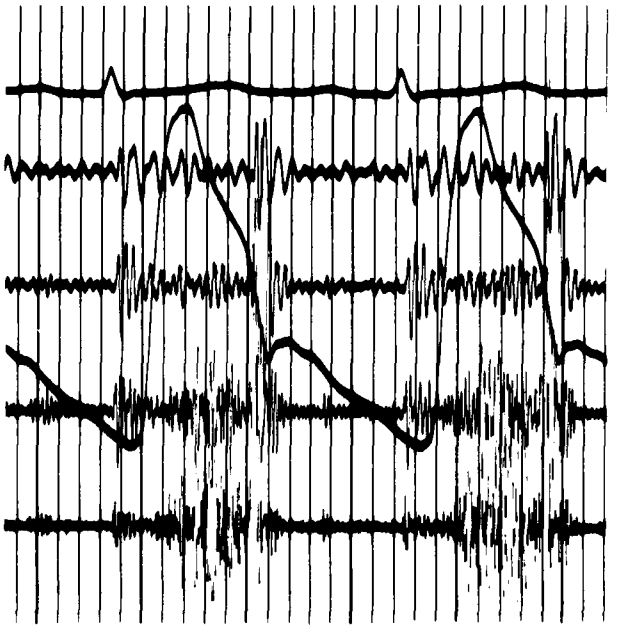
Mais nous voudions insister sur la pharmacodynamie ; un sujet ne peut rien avoir à l'état basal et l'épreuve au nitrite d'amyle fait découvrir les anomalies mécanographiques. Nous prendrons pour exemple un pilote de MIRAGE III porteur d'une onde Q ample, inexpliquée, en D2, D3, VF et sur le précordium gauche. Seule l'épreuve au nitrite d'amyle a fait apparaître le souffle systolique et l'anomalie au carotidogramme.



3) L'insuffisance mitrale . Les caractères phonocardiographiques sont ceux d'un souffle de régurgitation gauche. Ce souffle enregistré à la pointe est de tonalité aiguë, ce qui explique souvent la difficulté de son enregistrement. Il existe des variations morphologiques en particulier : le souffle au lieu d'être holosystolique peut être decrescendo et très souvent il n'est que télésystolique laissant libre la proto et la mésosystole. Devant tout souffle télésystolique, il faut penser à l'insuffisance mitrale.

Le carotidogramme est normal et à l'apexogramme on enregistre une onde F aiguë, pointue contemporaire d'un B 3 au phonocardiogramme.

Nous voudrions placer ici les triolets, bruits ou clics mésosystoliques suivis ou non d'un souffle télésystolique. Les épreuves pharmacodynamiques permettent de reverser dans la pathologie mitrale ces clics mésosystoliques longtemps attribués à une origine extracardiaque. Ces clics mésosystoliques sont souvent ignorés et pris pour un dédoublement du 2° bruit. L'intérêt de la phonocardiographie est de pouvoir les visualiser.



4) Le souffle systolique de la communication interventriculaire enregistré au niveau de l'endapex est un souffle de régurgitation gauche. Il existe quelquefois un dédoublement de B2 traduisant un retard de la composante pulmonaire P2 sur la composante aortique A 2. Pour LEATHAM, la durée de l'intervalle A 2 - P2 traduit le volume du shunt. Pour FISHLEDER, l'importance du shunt gauche droit est proportionnelle à la longeur de l'intervalle Q M 1 et inversement proportionnelle à celle de l'intervalle A2-B3.

5) Le phonocardiogramme du souffle de la communication interauriculaire est celui d'un souffle d'obstruction droit traduisant une sténose pulmonaire fonctionnelle. Il existe un dédoublement du deuxième bruit dont le caractère principal est sa fixité par rapport aux mouvements respiratoires.

6) La sténose pulmonaire isolée, c'est à dire avec septum interauriculaire et interventriculaire intacts donne un souffle d'obstruction droit maximum aux 2° et 3° espaces intercostaux gauches. Mais la morphologie est différente du souffle d'obstruction droit des souffles infundibulopulmonaires ; ici il est à maximum méso et télésystolique dépassant A 2 qui peut être noyé dans le souffle mais n'atteint pas P2.

Il existe dans la sténose pulmonaire un clic systolique d'éjection au foyer pulmonaire, un dédoublement du 2° bruit et parfois un B 1 . Au jugulogramme, on relève une onde A augmentée de volume.

L'appréciation de la gravité hémodynamique se base sur la distance séparant le maximum du souffle au 1° bruit, la présence de B4, l'augmentation de l'onde A du jugulogramme, l'écart A2 - P2 (en plus l'écart A2-P2 en centième de seconde multiplié par 10 donnent le chiffre de la pression ventriculaire droite).

7) Les mécanogrammes sont bien en retrait par rapport à la clinique dans le diagnostic d'une coarctation aortique. LA clinique est riche avec un souffle systolique endapexien et entendu dans l'espace interscapulovertébral, augmentation de la tension artérielle aux membres supérieurs, artères fémorales faiblement perçues, développement d'une circulation anastomotique décelable cliniquement se traduisant par des érosions costales sur la radiographie pulmonaire.

Les mécanogrammes peuvent individualiser deux souffles : l'un est un souffle de débit donc protosystolique, l'autre celui de l'obstacle est télésystolique mais d'obstruction augmenté par l'épreuve au nitrite d'amyle qui le déplace dans la protosystole.

Le tracé du pouls fémoral est retardé par rapport au pouls radial.

Nous voyons que l'oreille est souvent prise en défaut pour affirmer l'origine d'un souffle systolique : l'expert du personnel navigant doit, devant tout souffle systolique pratiquer des mécanogrammes cardiaques. Ceux-ci permettent de typer le souffle et peuvent dans certains cas apprécier le degré du retentissement.

	Souffle infundibulo pulmonaire	Souffle cardio pulmonaire	R.A.	C.M.G.	I.M.	C.I.A	C.I.V.	R.P.
Phonocardiogramme	Obstruction droit	Variabilité	Obstruction gauche	Obstruction gauche	Régurgitation	Obstruction droit	Régurgitation gauche	Obstruction droit
Carotidogramme	N	N	1) Anomalies morphologiques 2) Anomalies chronologiques	Bulge	N	N	N	N
Apexogramme	N	N	Onde A	1) Bifidité 2) Onde A	Onde F	N	N	N

III - Le CAROTIDOGRAMME TEMOIN DE LA DISTENSIBILITE ARTERIELLE

Il paraît séduisant d'essayer d'apprécier la distensibilité de la paroi artérielle par un procédé physique tel que le carotidogramme.

Le carotidogramme est recueilli grâce à un capteur à variation d'inductance. Cette technique est facile, non sanglante et de ce fait facilement reproductible à chaque expertise semestrielle du personnel navigant. Le carotidogramme normal est fait d'une montée rapide (onde pulsion) suivie d'une descente (onde de réflexion) se terminant par l'incisure catacrote, l'incisure étant suivie d'une deuxième onde ou onde dicrote.

Avec l'âge, nous avons constaté deux éléments : d'une part des variations morphologiques et d'autare part des variations du rapport I/A.

a) Variations morphologiques

Avec l'âge, la morphologie de la courbe du carotidogramme se modifie, la montée se fait moins rapidement et le deuxième sommet systolique progresse le long du segment descendant jusqu'à dépasser le premier sommet et aboutir au tracé type anacrote.

Sur 1000 pilotes, avec PERNOD, nous avons étudié par tranche d'âge de 10 ans, 1000 carotidogrammes. Ce type anacrote est peu fréquent dans le groupe de sujets âgés de 18 à 29 ans puisqu'il est rencontré 0,34 %.

Ce type augmente légèrement dans le groupe des sujets âgés de 30 à 39 ans puisqu'il est de 2,80 %. Mais dans le groupe de 40 à 50 ans, le tracé anacrote est de 14,25 %. Donc 15 % des pilotes âgés de 40 ans ont un tracé de type anacrote, témoin d'une modification de l'élasticité de la paroi artérielle.

b) Etude du rapport $\frac{1}{A}$

En même temps que surviennent ces modifications avec l'âge, le rapport hauteur de l'incisure (1) sur l'amplitude de l'onde pulsatile (A) augmente. Avec NOGUES, nous avons mesuré chez 250 pilotes, le rapport $\frac{1}{A}$. Dans les trois groupes d'âge moyen différent, le rapport progresse avec l'âge.

Premier groupe : nombre de sujets : 100 (âge 17 à 29 ans)
Moyenne d'âge : 21 ans.

$$\frac{1}{A} = m\ 21 \pm 2\ \sqrt{\ }\ m\ 21 = 0{,}437 \pm 0{,}020$$

Deuxième groupe : nombre de sujets : 70 (âge 30 à 52 ans)
Moyenne d'âge : 41 ans.

$$\frac{1}{A} = m\ 41 \pm 2\ \sqrt{\ }\ m\ 41 = 0{,}569 \pm 0{,}023$$

Troisième groupe : nombre de sujets : 80 (âge 32 à 78 ans)
Moyenne d'âge : 53 ans

$$\frac{1}{A} = m\ 53 \pm 2\ \sqrt{\ }\ m\ 53 = 0{,}586 \pm 0{,}020$$

NOGUES grâce à une étude sur modèle hydraulique a pu montrer que le rapport $\frac{1}{A}$ du carotidogramme, rapport de la hauteur de l'incisure catacrote sur l'amplitude de l'onde pulsatile est un reflet de la distensibilité artérielle.

Expérimentalement, ce rapport augmente lorsque l'élasticité du système hydraulique diminue ou lorsque les résistances périphériques augmentent ; pour une même pression diastolique, le rapport $\frac{1}{A}$ augmente lorsqu'on diminue l'élasticité des parois du modèle ou lorsque les résistances à l'éjection augmentent. La perte de la distensibilité artérielle apparaît ainsi comme pouvant être liée.

- soit à un facteur dégénératif pariétal propre au segment interrogé,
- soit à un facteur périphérique, obstacle à l'écoulement liquidien.

Par ailleurs, sur le modèle, l'amplitude de l'onde dicrote apparaît d'autant plus faible que la distensibilité artérielle est diminuée.

Ainsi est soulignée à nouveau l'intérêt de l'étude du rapport $\frac{1}{A}$ du carotidogramme qui permet au clinicien de se faire rapidement une idée de la distensibilité du système artériel.

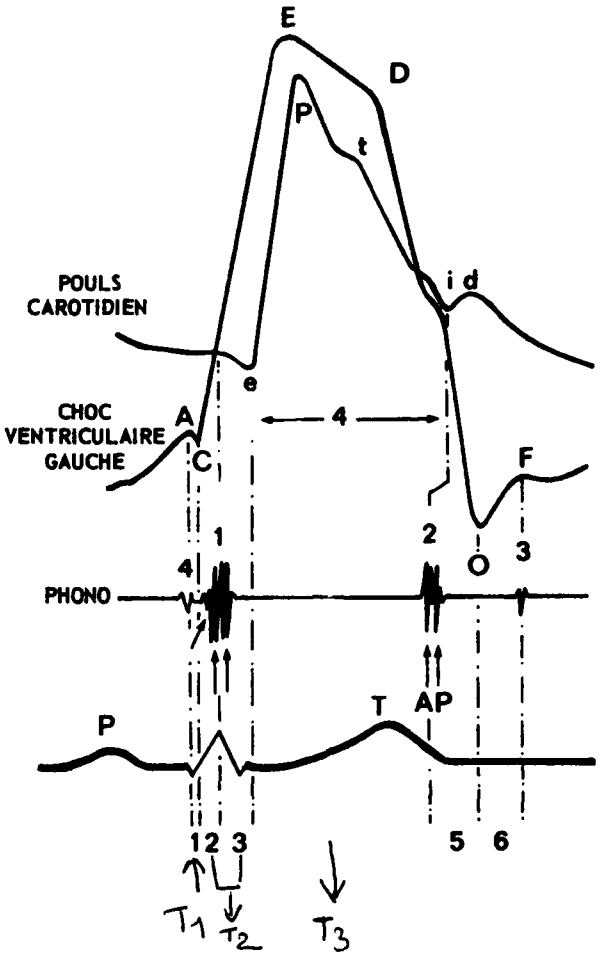
IV - ETUDES CHRONOCARDIOGRAPHIQUES

Puisque les intervalles du chronocardiogramme varient selon l'importance de l'atteinte myocardique, il était logique de chercher à savoir s'il existait une corrélation entre ces différents intervalles et les données hémodynamiques apportées par le cathétérisme cardiaque et la cinéangiographie ventriculaire. C'est ce qu'ont fait :

- WEISSLER (1970) ARONOW (1971) pour l'étude de la contraction du muscle myocardique.

Mais auparavant, il nous faut rappeler les différentes mesures que l'on pratique en chronocardiographie.

- T.1 : intervalle électromécanique allant du point Q de l'électrocardiogramme au point C de l'apexogramme.
- T.2 : ou intervalle préexpulsive allant du point C de l'apexogramme au point E de la courbe carotidienne. Cet intervalle préexpulsive de divise en deux parties : T2A ou contraction préisométrique du point C de l'apexogramme à la fermeture des valves mitrales, c'est à dire sur le phonocardiogramme aux premières composantes rapides de B1 et T2B ou contaction isométrique de la fermeture mitrale ou point E de la courbe carotidienne.
- T.3 : ou temps d'éjection systolique du point E à l'incisure catacrote du carotidogramme. Mais ces mesures doivent être corélées en fonction du rythme cardiaque.



Le T3 varie en fonction inverse de la fréquence cardiaque. En utilisant les équations de régression de WEISSLER, on peut calculer :

$$T\,3^{C} = T\,3 + 1{,}7\ R\,R.$$

Avec cette formule, T3 normal est de 4I3 ± 10 ms (valeur normale extrapolée pour une fréquence cardiaque nulle). On utilise également l'abaque de PERNOD et CARRE qui est basée sur la relation linéaire entre T 3 et R.R.

$$T\,3^{C} = 1{,}02\ T\,3 + 195{,}4.$$

Cependant, en étudiant la relation entre HR et T3 sur de nombreux sujets sains, COLIN et CARRE ont de façon constante observé une corrélation linéaire différente de celle obtenue par WEISSLER. Ils ont proposé en 1978, la formule de correction suivante :

$$T\,3^{C} = T + 1{,}4\ R\,R$$

$T\,3^{C}$ normal est alors de $3 + \pm\ 13{,}3$ ms

Ces trois différents temps mesurés par mécanographie externe classique ont été validés par comparaison avec les méthodes sanglantes. Travaux exécutés par de nombreux auteurs avec des résultats similaires :

T 3 externe et T 3 sanglant ont été étudiés en particulier pour BORSH, MARTIN, Van der MERF. Le T 3 mesuré sur le carotidogramme a été comparé à l'enregistrement simultané de la pression sanguine à la base de l'aorte descendante par cathétérisme. Les coefficients de corrélation varient de 0,97 à 0,99 suivant les auteurs, le T 3 sanglant est généralement plus court de 3 à 4,5 ms que le T 3 non sanglant.

La validité de la mesure de la systole électromécanique totale par l'intervalle T1 + T2 + T 3 a été démontrée par Anastassides et Brough (expérimentation sur des chiens, coefficient de corrélation 2 = 0,90.

Enfin la validité de la mesure de T 2 par voie externe a aussi été établie par rapport à sa mesure par voie sanglante par BUSH et METZGER avec des coefficients de corrélation de 0,94 à 0,98. Par ailleurs, l'intérêt de ces intervalles de temps systolique a été mis en évidence :

- METZGER a établi que la période de pré-éjection est en relation étroite avec le temps de contraction isovolumétrique, le délai électromécanique étant relativement constant entre 30 et 40 ms. AHMED a, de plus, montré qu'il existait une bonne corrélation entre la valeur de T 2 et la vitesse maximum de variation de pression dans le ventricule gauche. Le rapport $\frac{T2}{T3}$ est très important dans l'évaluation de la contractilité myocardique. D'après WEISSLER, il présente une forte corrélation avec l'index cardiaque. Il est d'ailleurs plus sensible que ce dernier et peut se révèler normal alors que l'index cardiaque est encore dans les limites de la normale (LEWIS).

Enfin GARRAND a montré que le rapport $\frac{T2}{T3}$ présente aussi une excellente corrélation (2 = 0,90) avec la fraction d'éjection angiographique.

La mesure des intervalles de temps systolique ainsi appliquée et analysée permet une évaluation clinique sensible, facilement reproductible et quantitative au degré de détérioration des performances du ventricule gauche.

Cette méthode a été utilisée en médecine aéronautique. STAFFORT s'en est servi pour étudier les modifications circulatoires provoquées par des changements de position du corps, GRAYBOYS pour étudier les réponses cardiovasculaires au test de pression négative sur la moitié inférieure du corps et aux accélérations + G 2 (la fréquence cardiaque, le T 3, T 2 et le rapport $\frac{T2}{T3}$ augmenteront proportionnellement au niveau d'accélération atteint et rarement à des valeurs normales après 60 sec de repos). Avec PITOUSSI nous avons utilisé cette méthode au cours de l'exercice physique et montré l'intérêt du rapport $\frac{T2}{T3}$ pour apprécier la forme physique du point de vue cardiovasculaire. Mais cette méthode bien codifiée présente quelques inconvénients : difficulté de mise en place du capteur carotidien, étude du coeur gauche seulement. C'est la raison pour laquelle COLIN, après corrélation avec les mécanogrammes cardiaque propose de mesurer ces intervalles de temps systoliques grâce à la pléthysmographie cardiaque par impédance électrique. Cette méthode élégante, facile, non sanglante en cours de validation est appelée à un grand avenir en médecine aéronautique et spatiale.

ECHOCARDIOGRAPHIE EN MEDECINE AERONAUTIQUE

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MOTS-CLEFS. ECHOCARDIOGRAPHIE - C.M.O. - PROLAPSUS MITRAL - CONTRACTILITE MYOCARDIQUE - MEDECINE AEROSPATIALE.

RESUME

Les techniques d'échocardiographie sont de plus en plus développées et perfectionnées.

Si le mode T.M. (Temps-Mouvement) reste le plus utilisé, l'échocardiographie bi-dimensionnelle, et avec Doppler pulsé, s'avère également d'un grand intérêt.

Les applications de l'échocardiographie sont multiples en Médecine Aérospatiale. Sont plus longuement étudiés :

la cardiomyopathie obstructive, le prolapsus mitral, l'étude de la valeur fonctionnelle du myocarde.

Les progrès en Cardiologie ont été marqués, au cours de ces quinze dernières années, par le développement de méthodes d'investigations non sanglantes.

Parmi celles-ci, l'échocardiographie tient une place de choix.

Nous en rappellerons brièvement le principe et les diverses modalités techniques, puis nous envisagerons quelques cas où son utilisation est particulièrement intéressante en Médecine Aéronautique.

PRINCIPES ET TECHNIQUES.

L'échocardiographie résulte de l'application et del'utilisation au niveau du coeur des propriétés des ultra-sons.

Un faisceau d'ultra-sons traverse un milieu homogène (liquide ou solide) mais se réflêchit (donne un écho) lorsqu'il arrive à l'interface de deux structures différentes.

Les ultra-sons, cependant, ne se propagent pas dans l'air. Il est donc possible, grâce à une sonde ou transducteur, fonctionnant à la fois comme émetteur et récepteur sur une fréquence de 2,25 à 5 Megahertz, de recueillir les échos provenant de la réflexion d'ultra-sons sur les différentes structures cardiaques. Ces échos peuvent être projetés soit simplement sur un scope, soit sur différents systèmes d'enregistrements.

La sonde est appliquée à la partie interne du 3ème, 4ème ou 5ème espace intercostal gauche, et en modifiant l'orientation du transducteur, donc du

.../...

faisceau d'ultra-sons, on peut visualiser les différentes structures cardiaques.

Il faut, bien entendu, éviter toute interposition osseuse costale ou sternale, et établir un contact étroit entre la paroi et la sonde grâce à une pâte inerte (les ultra-sons ne se propagent pas, ou très mal, dans l'air).

Plusieurs modalités techniques se sont développées en échocardiographie.

I - TECHNIQUES UNI-DIMENSIONNELLES (MONOSCAN).

Ces techniques utilisent un seul capteur (un seul faisceau).

1 . En échographie A (A pour Amplitude). Les différentes structures du coeur traversées par le faisceau donnent naissance à des échos verticaux dont l'intensité est proportionnelle à l'intensité de la réflexion

La distance séparant deux échos peut être facilement mesurée. Ce mode échocardiographique n'est plus guère utilisé actuellement.

Il s'agit essentiellement d'une technique de repérage.

2 . En échocardiographie T.M. (pour Temps-Mouvement ou Time-Motion). Ces échos sont représentés par un point plus ou moins brillant selon l'intensité de l'écho. Mais, de plus, ces points sont visualisés en fonction du temps, sous forme de courbe. Les structures cardiaques peuvent ainsi être visualisées durant les différentes phases de la révolution cardiaque (systole-diastole).

On a donc un aspect dynamique des structures cardiaques étudiées

La chronologie des phénomènes peut être précisée par l'enregistrement simultané sur le meme document d'une dérivation de l'E.C.G. ou du carotidogramme.

Le Mode T.M. reste le plus couramment utilisé en Cardiologie.

L'image visualisée en échocardiographie mono-dimensionnelle est une image punctiforme obtenue à l'endroit où le faisceau ultra-sonique rencontre la structure cardiaque étudiée. La méthode ne donne donc pas une image réelle du coeur. Cette image doit être interprétée.

II - LES TECHNIQUES BI-DIMENSIONNELLES (MULTISCAN - SECTORSCAN).

Ces techniques sont nées de cette insuffisance. Elles permettent de visualiser non pas selon un point, mais selon un plan (en deux dimensions) une partie du coeur réalisant l'équivalent d'une coupe tomographique.

De plus, cette échotomographie cardiaque n'est pas fixe (comme une tomographie radiographique) mais dynamique, donnant une véritable image en temps réel du plan de coupe cardiaque étudié.

Dans cette technique, on utilise non plus un, mais une série de microcapteurs placés les uns à côté des autres. Un balayage électronique les fait fonctionner successivement dans des temps très courts comme émetteurs et récepteurs.

3 . En échographie Multiscan, le plan de coupe est rectangulaire. Les capteurs sont disposés en ligne sur une barrette qui peut déborder l'espace intercostal. Dans ce cas, l'interposition de matériel osseux va gêner l'examen.

Par contre, la définition de l'image est bonne avec cette méthode.

4 . En echographie Sectorscan, le plan de coupe est réduit à un secteur angulaire de 30, 60 ou 90° selon les appareils. Le sommet de l'angle se trouve, bien entendu, au niveau des transducteurs. L'avantage de cette technique, qui est la plus utilisée, est que la sonde , de plus petit volume, trouve facilement place dans un espace intercostal ou même au creux épigastrique.

Deux incidences sont particulièrement étudiées en échocardiographie bi-dimensionnelle.

- La coupe longitudinale donne une coupe du coeur selon son grand axe. On y visualise particulièrement la naissance de l'aorte, l'orifice aortique avec, en arrière, l'oreillette gauche, l'orifice mitral, les valves mitrales; les cavités ventriculaires et le septum qui les sépare.

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Le mouvement des valves mitrales peut particulièrement être apprécié dans cette incidence. Chez le sujet normal, l'anneau aortique et l'anneau mitral font un angle de 100 à 110° ouvert vers la pointe.

En systole, les feuillets mitraux sont accolés en faisant un angle aigu voisin de 90°, ouvert vers l'oreillette.

En diastole, les deux feuillets mitraux rejoignent les parois antérieure ou postérieure ou en restent séparés de quelques millimètres.

- La coupe transversale permet d'obtenir des plans de secteurs horizontaux à différents niveaux du ventricule gauche et du septum surtout, et de la naissance des gros vaisseaux.

- La coupe des quatre cavités s'obtient en plaçant le transducteur à la pointe du coeur, les faisceaux ultra-soniques sont dirigés vers la base.

On visualise bien ainsi les deux ventricules et les appareils mitral et tricuspidien

III - DOPPLER PULSE ET ECHOCARDIOGRAPHIE.

Lorsqu'on envoie un flux d'ultra-sons sur un vaisseau sanguin, celui-ci se réflèchit sur les hématies. Comme celles-ci se déplacent, il va en résulter un effet Doppler, c'est-à-dire la production d'un son continu, d'autant plus aigu que la vitesse de circulation des hématies est rapide.

Le signal sonore qui témoigne du flux sanguin peut être transformé en une courbe.

Cette méthode est très utilisée en pathologie vasculaire pour explorer artères et veines. C'est un apport important au diagnostic des artérites.

Habituellement, le faisceau d'ultra-sons ne peut explorer que les artères proches de la surface cutanée et explore la masse des hématies circulant dans le vaisseau sous-jacent.

Dans la technique de Doppler pulsé, on peut focaliser le Doppler, non pas seulement dans un axe donné, mais aussi à une profondeur donnée. L'exploration est donc alors ponctuelle.

En Cardiologie, on peut coupler échocardiographie et Doppler pulsé.

On commence par visualiser les différentes structures cardiaques, en général en mode T.M. (on peut aussi utiliser le mode A). Puis, à l'aide d'un spot lumineux, on détermine sur le scope l'emplacement que va électivement explorer le faisceau d'ultra-sons pulsé. On peut ainsi placer cette "fenêtre" en regard d'un orifice (aortique, mitral, etc..., du septum, etc...).

Le flux des hématies est ainsi enregistré au niveau de l'orifice considéré et on peut ainsi le visualiser sur le scope. Cette méthode permet en particulier de mettre en évidence de petites fuites ou de petits shunts difficiles à affirmer par ailleurs, sauf par méthode endocavitaire.

INTERETS EN MEDECINE AERONAUTIQUE

L'intérêt de l'échocardiographie en Cardiologie n'est plus à démontrer. Les applications et les indications en sont multiples, et il est hors de propos de vouloir tous les aborder.

En Médecine Aérospatiale, on retrouve un grand nombre de ces indications. Nous voudrions nous limiter à trois chapitres qui nous paraissent avoir un intérêt particulier.

1. Le diagnostic des cardiomyopathies obstructives (C.M.O.) parce qu'il s'inscrit dans le vaste chapitre du diagnostic des souffles systoliques. Ce problème est un des plus importants que l'on rencontre au moment de la sélection.

2. Le diagnostic du prolapsus mitral, parce que cette affection pose des problèmes aéronautiques spécifiques.

3. L'appréciation de la valeur contractile du myocarde. Ce dernier point reste encore très difficile à appréhender mais semble appelé à un développement certain, aussi bien en Médecine Aéronautique qu'en Médecine Spatiale.

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I - LA CARDIOMYOPATHIE OBSTRUCTIVE.

La cardiomyopathie obstructive (C.M.O.) s'exprime dans ses formes évoluées par des anomalies auscultatoires dominées par le souffle systolique méso-systolique, des anomalies électro-cardiographiques et éventuellement radiologiques.

Dans la population de jeunes adultes qui caractérise le Personnel Navigant (P.N.), tout peut se résumer à un souffle systolique qui, à l'auscultation, doit se différencier d'un souffle innocent.

Le phonocardiogramme et les mécanogrammes externes (carotidogramme, apexogramme) sont d'un appoint très précieux au diagnostic ,surtout couplés aux épreuves pharmaco-dynamiques, mais peuvent être en défaut.

L'échocardiographie va apporter une aide complémentaire au diagnostic, et dans certains cas, quelques éléments d'appréciation de degré de sévèrité de l'obstruction.

1. L'ECHOCARDIOGRAPHIE T.M. dans la C.M.O.

La séméiologie échocardiographique de la C.M.O. en mode T.M. porte sur cinq points essentiels. Si l'observation des signes reste valable avec le temps, leur signification physiopathologique, leur valeur diagnostique, voire pronostique, reste très discutable.

Les principaux signes sont :

- Une augmentation de l'épaisseur du Septum Inter-ventriculaire. Cette hypertrophie septale"asymétrique"(H.S.A.) se fait essentiellement aux dépens de la cavité ventriculaire gauche.

  La paroi postérieure reste d'épaisseur normale, ou peu hypertrophiée. Il en résulte que le rapport épaisseur du sertum sur épaisseur de la paroi postérieure est augmenté, supérieur ou égal à 1,3 (normal : 1 à 1,2).

- La réduction du diamètre transversal de la cavité ventriculaire gauche (en-dessous de 40 millimètres) est en partie liée à l'H.S.A.

- Le soulèvement systolique antérieur de la"grande valve mitrale"(S.A.M.) a été initialement tenu pour un des signes essentiels de la C.M.O. On a même essayé de corréler le degré de soulèvement avec le degré du gradient systolique enregistré dans la chambre de chasse ventriculaire gauche.

  Des études plus récentes, en particulier en échographie bi-dimensionnelle, ont montré qu'en réalité le S.A.M. correspondait plutôt à une image des cordages qu'à celle du feuillet mitral antérieur.

- La butée proto-diastolique de la grande valve mitrale. Cette butée peut durer pendant toute la diastole.

- La fermeture précoce des sigmoides aortiques suivie d'une réouverture, plus rare, est tenue pour un bon signe diagnostique. Elle serait l'explication de l'aspect, ou bulge, du carotidogramme observé dans la C.M.O.

Aucun des signes pris isolément n'est pathognomonique ni même constant.

Dans une série de 68 cas de C.M.O. affirmées par cathétérisme sélectif du ventricule dans le Service de Cardiologie de l'Armée , les signes suivants sont retrouvés avec la fréquence suivante :

- épaisseur du septum supérieure ou égale à 15 mm.....	90 %
- butée septale.....	78 %
- vitesse mitrale diminuée (inférieure à 70 mm/sec).....	75 %
- diamètre ventriculaire gauche inférieur ou égal à 40 mm.....	73,5 %
- S.A.M. supérieur ou égal à 20 %.....	73,5 %

2. L'échocardiogramme bi-dimensionnelle dans la C.M.O.

L'échocardiographie bi-dimensionnelle permet d'apprécier la morphologie du ventricule gauche, surtout en coupe longitudinale, et les mouvements de l'appareil mitral.

- Sur le plan morphologique, la méthode permet de visualiser l'hypertrophie et son retentissement sur la cavité. Elle permet de distinguer :

  . des hypertrophies prédominant sur la partie haute du septum interventriculaire ;
  . des hypertrophies intéressant surtout les piliers;

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Elle permet également de visualiser les modifications de fonctionnement du ventricule gauche, où l'on peut le plus souvent distinguer :

- la désaxation de la cavité ventriculaire
- l'apparition de deux zones de fonctionnement distinct :
  . la zone apicale hypercinétique,
  . la zone basale, de cinétique réduite.

Parfois apparaît une véritable biloculation du ventricule.

Les coupes transversales montrent la réduction de la cavité du ventricule gauche par la saillie septale.

- Appareil mitral.

En coupe longitudinale, on observe bien les mouvements des deux feuillets mitraux, en particulier la butée du feuillet antérieur en diastole.

Il est possible de voir que le "soulèvement antérieur mitral" est, en fait, probablement formé en majeure partie par des cordages et leur inserteurs sur la grande valve.

L'échocardiographie peut apporter une aide au diagnostic des souffles systoliques dans bien d'autres cas : rétrécissements aortiques sous-valvulaires, ou peu serrés, insuffisance tricuspidienne, shunts, etc... mais qui sont moins souvent rencontrés.

II - LE PROLAPSUS MITRAL.

Le dépistage de la C.M.O. s'inscrit essentiellement dans le cadre de la sélection et du diagnostic des souffles systoliques. Son intérêt tient, en grande partie, au risque de mort subite fréquemment observé dans la maladie.

Le dépistage du prolapsus mitral répond au même souci d'écarter les sujets porteurs d'une affection qui comporte des risques d'incapacité brutale en vol. Mais cette affection semble, de plus, avoir un intérêt plus spécifiquement aéronautique.

1 - Rappel.

L'appareil mitral comporte plusieurs éléments :

- un anneau délimitant l'orifice ;
- sur lequel s'insèrent deux valves ; la grande antérieure, la petite postérieure. Durant la systole, la grande valve vient prendre appui sur la petite pour fermer l'orifice.
- pour que les valves ne s'éversent pas dans l'oreillette lors de la poussée systolique, elles sont sous-tendues par des cordages, eux-mêmes amarrés à des piliers musculaires.
- ceux-ci sont indissociables de la paroi ventriculaire sur laquelle ils s'insèrent.

Un des phénomènes importants à considérer est qu'au moment de la systole la pointe du ventricule gauche tend à se rapporcher de l'anneau mitral. C'est alors la contraction des piliers qui, en retendant les cordages, assure l'étanchéité de l'orifice mitral occlus par les valves.

Le prolapsus mitral, ou plus exactement ballonisation mitrale, décrite par BARLOW est caractérisée par un bombement de la petite valve, le plus souvent, dans l'oreillette. Il peut en résulter un défaut d'accolement des deux valves et donc une insuffisance mitrale.

Parmi les complications du prolapsus mitral, il faut souligner les troubles du rythme pouvant être cause de mort subite.

2 - En quoi le pilote est-il concerné par le prolapsus mitral ?

Toute réduction du volume ventriculaire gauche, et de la distance pointe-base, est un facteur favorisant le prolapsus.

Or, les accélérations, qu'elles soient + Gz ou + Gx entrainent une réduction du volume ventriculaire et tendent donc à favoriser le prolapsus.

Mais les accélérations peuvent agir par d'autres mécanismes.

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Il a été démontré, chez l'animal d'expérience, que les accélérations de haut niveau (+ 6 Gz) et de longue durée (15 sec.) pouvaient induire des lésions décrites sous le terme d'hémorragies sous-endocardiques et de cardiomyopathies de stress. Ces lésions intéressent en particulier les piliers dont le dysfonctionnement favorisera le prolapsus mitral.

Les pilotes des avions de combat à haute performance poseront donc peut-être un problème de sélection vis-à-vis du prolapsus mitral et mériteront peut-être une sélection particulière à l'égard de cette affection qui peut être aggravée par le vol.

Le diagnostic du prolapsus,en effet, n'est pas toujours aisé.

Il se traduit à l'auscultation par un click proto ou télé-systolique, accompagné ou non d'un souffle télé-systolique qui traduit l'insuffisance mitrale qui l'accompagne.

La phonocardiographie et les variations obtenues sous pharmacodynamie sont un bon appoint au diagnostic mais l'échocardiographie apporte plus de précisions.

3 - L'échocardiographie T.M. dans le prolapsus mitral.

Cette méthode va objectiver la ballonisation mitrale qui intéresse le plus souvent la petite valve, mais parfois la grande.

Deux aspects sont très caractéristiques : l'image en cupule et l'image en hamac.

- L'image en cupule. Les deux valves ont un aspect normal en miroir pendant la diastole. Au début de la systole, elles sont unies, réalisant une trace unique, puis vers le milieu de la systole la petite valve a un brusque mouvement de retrait vers l'arrière. Elle se décolle de la grande valve qu'elle ne rejoint qu'à la fin de la systole réalisant l'aspect en cupule. On peut voir juste avant une image de soulèvement systolique antérieur.

- L'image en"hamac" ou en U. L'aspect est le même, mais le mouvement en arrière de la petite valve se fait dès le début de la systole. Il est maximum au niveau de la méso-systole.

- D'autres aspects , moins typiques, ont été décrits, tels les échos multiples superposés en systole. Ils ne peuvent être retenus qu'en présence d'un contexte clinique et para-clinique très évocateur.

4 - L'échocardiographie bi-dimensionnelle dans le prolapsus mitral.

Beaucoup plus fiable, elle apporte des données sur les conditions anatomiques et les mécanismes du prolapsus mitral.

La coupe longitudinale passant par le grand axe du coeur semble la plus intéressante (certains Auteurs accordent également leur attention à la coupe dite des quatre cavités).

- Dans les formes qui paraissent correspondre à l'image en cupule en T.M., on observe un mouvement antérieur de la petite valve qui, en quelque sorte, se verticalise, alors que la valve elle-même prend un aspect concave qui dépasse le plan de l'anneau mitral.

- Dans les formes qui paraissent correspondre à l'image en hamac en T.M., le jeu de la grande valve est augmenté. Dès le début de la systole, le feuillet antérieur se rabat sur le postérieur, le refoulant sur la paroi ventriculaire postérieure.

  Puis, à la méso-systole, les deux feuillets réalisent un aspect arciforme dont le feuillet le plus postérieur dépasse le plan de l'anneau mitral.

  Il importe d'examiner avec soin le bord libre des valves. C'est lorsque ce bord dépasse le plan de l'anneau mitral que sont réalisées les formes les plus sévères avec fuite mitrale importante. Ce sont ces seules formes qui devraient mériter le terme de "prolapsus mitral".

  En fait, les cinétiques des deux feuillets mitraux sont très interdépendantes et la ballonisation intéresse souvent les deux valves.

L'échocardiographie bi-dimensionnelle renseigne en outre parfois sur les anomalies des structures responsables du mauvais fonctionnement des valves : valves elles-mêmes remaniées, myxoïdes, anomalies des cordages ou des piliers, existence de signes ventriculaires gauches.

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III - EVALUATION DE LA FONCTION VENTRICULAIRE GAUCHE.

L'évaluation de la valeur fonctionnelle du myocarde reste difficile, soit parce que les techniques mises en jeu sont traumatiques (angiographie bi-dimensionnelle) soit parce qu'elles donnent des résultats dont la fiabilité reste discutée (Mesure des Intervalles de Temps Systolique).

L'échocardiographie permet une nouvelle approche non traumatique d'évaluation de la fonction ventriculaire gauche. Elle permet de mesurer avec précision le diamètre transversal du ventricule gauche. Ce diamètre est mesuré du bord gauche du septum à l'endocarde postérieur. Il faut, pour cela, avoir des enregistrements de bonne qualité (en technique T.M.).

A partir du diamètre ventriculaire, plusieurs indices peuvent être calculés.

1 - La fraction d'éjection.

Cet indice permet d'évaluer la FONCTION POMPE du ventricule gauche. Son calcul, à partir des diamètres systolique et diastolique repose sur une hypothèse concernant la forme géométrique du ventricule gauche. Ce dernier est assimilé à un ellipsoide de révolution dont le grand axe est le double du petit. Dans ces conditions, le volume est égal au cube du diamètre transversal.

Après mesure des diamètres transversaux télédiastolique (D.D.) télésystolique (D.S.), il est facile de calculer le volume d'éjection systolique :

$$\Delta V = DD^3 - DS^3$$

La fraction d'éjection exprime le pourcentage du volume télédiastolique mobilisé lors de la systole :

$$\frac{\Delta V}{V D} = \frac{DD^3 - DS^3}{DD^3}$$

Elle voisine 75 %.

2 - Variations systolo-diastoliques du diamètre transversal.

La formule appliquée au calcul du volume ventriculaire est discutable et approximative, et de plus elle suppose que la contraction cardiaque soit homogène pendant la totalité du cycle cardiaque.

Le calcul de la fraction d'éjection ne peut donc être considéré comme une mesure mais comme une simple estimation.

Dans ces conditions, on peut se contenter d'une estimation grossière, plus simple et ne faisant pas intervenir d'hypothèse sur la forme géométrique du ventricule.

On apprécie le pourcentage de variation du diamètre transversal par rapport au diamètre diastolique.

$$\frac{\Delta D}{D D} = \frac{D D - D S}{D D}$$

Ce rapport a été estimé comme voisin de 38 %.

3 - Vitesse moyenne de raccourcissement du diamètre.

Elle est égale à la variation du diamètre transversal $\Delta D = DD - DS$ divisée par le temps correspondant (t). Tous ces éléments sont directement mesurables sur les tracés. Cette vitesse est proportionnelle, à un facteur Pi près, à la vitesse de raccourcissement des fibres circonférentielles du myocarde (VCF) déterminée par angiocardiographie et considérée par KARLINER comme un bon indice de contractilité.

Normalisée et exprimée en diamètre télédiastolique par seconde pour tenir compte des dimensions du ventricule, elle fournit les mêmes valeurs que la VCF, exprimée en circonférences par seconde. Sa valeur moyenne a été estimée à 1,3 DD (PERNOD, DRONIOU et Coll.) et diffère significativement des valeurs calculées chez les sujets porteurs de cardiopathies.

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4 - La vitesse maxima de raccourcissement du diamètre.

C'est un indice de contractilité encore plus sensible, mais dont la détermination faite manuellement est encore plus longue que la précédente.

L'appréciation de la fonction ventriculaire gauche chez le Personnel Navigant est utile dans plusieurs circonstances mais surtout dans deux cas observés assez fréquemment et posant de difficiles problèmes d'aptitude.

- Chez les sujets porteurs d'extra-systoles ventriculaires importantes où l'on suspecte une cardiomyopathie primitive débutante. L'échocardiographie peut d'ailleurs apporter en outre des éléments morphologiques ou cinétiques en faveur d'une cardiomyopathie primitive (hypertrophie septale asymétrique non obstructive, zone dyskinétique ou akinétique, etc...).

- Le problème est un peu le même chez les sujets porteurs d'un trouble primaire de la repolarisation dont toutes les explorations non sanglantes sont restées normales.

Dans les deux cas, une évaluation échographique péjorative de la fonction ventriculaire (les découvertes de zones dyskinétiques), retrouvée de façon constante, peut être un élément intéressant et important à prendre en compte dans la décision d'aptitude.

- L'intérêt fonctionnel de l'échocardiographie peut être intéressant également lorsqu'il s'agit de soumettre des Navigants à des contraintes cardiaques très éprouvantes. Ce sera peut-être le cas des pilotes des futurs avions de combat à haute performance.

Un bon exemple en a été donné par les Cosmonautes et le test de pression négative des membres inférieurs (L.B.N.P. = Lower Body Negative Pression).

Chez les Cosmonautes du programme SKYLAB IV, une échocardiographie mode T.M. fut enregistrée avant le vol, juste après le retour, et plusieurs fois dans les mois qui suivirent (J1-J2-J4-J11-J31-J68).

De même, les données échocardiographiques furent recueillies au cours du L.B.N.P. à la fin de chaque étape de pression (- 8 mm Hg ; - 16 mm Hg ; - 30 mm Hg ; - 40 mm Hg ; - 50 mm Hg).

Après le vol, on constate, chez deux des trois cosmonautes, une réduction significative du volume d'éjection systolique (par rapport au volume avant le vol) et aussi du volume ventriculaire gauche.

Il est intéressant de noter que ces deux courbes varient de façon parallèle, ce qui laisse penser que la chute du volume systolique est surtout liée à la diminution du volume ventriculaire.

Au cours du test L.B.N.P., on voit le volume systolique diminuer avec la dépression. Mais on voit aussi la courbe du volume ventriculaire gauche diminuer de façon parallèle.

Ces courbes ont un grand intérêt méthodologique. Elles sont l'occasion de rappeler que la plupart des paramètres qui étudient la fonction cardiaque dépendent du volume télédiastolique.

A cet égard, l'échocardiographie constitue une méthode de choix, et fournit des résultats plus faciles à interprêter que d'autres méthodes comme la mesure radiologique du volume cardiaque ou les intervalles de temps systoliques.

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Nous n'avons pu citer et développer toutes les indications de l'échocardiographie à la Médecine Aérospatiale. Mais ces quelques exemples suffiront probablement à prouver l'intérêt d'une telle méthode. Totalement indolore, atraumatique, elle demande cependant du temps, et parfois à être répétée. Aussi ne saurait-elle s'appliquer à tous les personnels, mais seulement à ceux présentant une anomalie cardiaque faisant discuter l'aptitude, ou à ceux qui vont être exposés à des stress particulièrement éprouvants pour le coeur. Il s'agirait alors là d'une véritable sélection au deuxième degré.

PRINCIPALES ANOMALIES ELECTROCARDIOGRAPHIQUES DANS L'EXPERTISE DU PERSONNEL NAVIGANT

PAR LE MEDECIN EN CHEF CARRE RAYMOND

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CENTRE PRINCIPAL D'EXPERTISE MEDICALE DU
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Le pilotage d'avion à très haute performance type Mirage 2000 ou 4000, exige que le personnel navigant soit choisi de façon à ce que la sécurité en vol soit au maximum. Au cours de ces vols l'appareil cardiovasculaire est l'appareil le plus sollicité par le stress aérien.

Les réglements militaires régissant l'aptitude médicale du personnel navigant requièrent l'intégrité absolue organique et fonctionnelle de l'appareil circulatoire.

L'électrocardiogramme avec les 6 dérivations périphériques et précordiales est pratiqué à chaque visite d'admission ou révisionnelle du personnel navigant.

L'inaptitude du personnel navigant est facilement prononcée quand on rencontre :

- des troubles du rythme : flutter, fibrillation auriculaire, troubles de conduction évidents.

- des blocs de branche droit complets ou blocs de branche gauche complets.

- des séquelles d'infarctus du myocarde, certaines connues par les interessés, mais d'autres méconnues par les pilotes. Nous avons relevé en 10 ans, 8 infarctus du myocarde méconnus, passés inaperçus et découverts de façon systématique à la visite révisionnelle. Dans certains cas difficiles on peut s'aider du vectocardiogramme.

Mais des tracés électrocardiographiques prêtent à discussion ; nous envisageons l'étude de :

1) Certains troubles du rythme.
2) Le syndrome de Woff Parkinson White
3) Les blocs de branche droit incomplets
4) les déviations axiales gauches et leur rapports avec le concept d'hémibloc antérieur gauche
5) Les atypies de la repolarisation ventriculaire.

I LES TROUBLES DU RYTHME.

a) les troubles de l'excitabilité sont fréquemment rencontrés. Les extrasystoles auriculaires, nodales et ventriculaires sont de constatation journalière ; des enregistrements électrocardiographiques de 24 heures montrent leur fréquence. Il est difficile de savoir quel est le nombre tolérable dans un nycthémère. Nous sommes satisfaits de voir que beaucoup de troubles du rythme disparaissent à certaines épreuves de contrainte (épreuve d'effort). Mais à l'opposé nous émettons un avis réservé au pilotage quand nous voyons apparaitre ces extrasystoles soit au cours ou à la fin d'une épreuve d'effort, soit aux épreuves de contraintes aéronautiques (centrifugeuse, tests d'orthostatisme, test au Lower Body Negative Pressure).

b) les troubles de conduction auriculo-ventriculaire, sont évidemment éliminatoires au poste de personnel navigant. Mais l'allongement de l'intervalle PR pose des problèmes ; il faut d'abord définir la normalité ; grâce à des histogrammes sur 200 sujets, nous ne parlons d'allongement d'intervalle PR qu'après 24/100 de seconde.

Mais par ailleurs, il n'est pas rare d'observer des troubles de la conduction cardiaque, surtout de la conduction auriculoventriculaire, chez des sujets jeunes, volontiers sportifs. On invoque alors la possibilité d'un trouble fonctionnel d'origine vagale. Une telle éventualité pose de difficiles problèmes d'aptitude chez les membres du personnel navigant. Leguay, dans la thèse de Delcoustal a rapporté 9 observations ; ce sont des pilotes de chasse très grands sportifs. L'enregistrement endo-cavitaire du faisceau de His sous stimulation, stimulation sous atropine et épreuve à l' ajmaline, permettent de conclure à un trouble de conduction supra hisien, avec des éléments en faveur d'une participation vagale ; mais il est quelquefois très difficile d'éliminer chez le jeune une fragilité congénitale sous-jacente, susceptible de s'aggraver et chez le sujet mûr, le début d'une atteinte dégénérative du tissu spécifique de conduction.

Il est toujours nécessaire de s'assurer que le trouble se corrige lors des épreuves de stress, en particulier aéronautiques (hypoxie, dépression, accélération) avant de se prononcer sur l'aptitude. Leguay, en faisant des enregistrements électrocardiographiques de 24 heures, trouve fréquemment la nuit, des troubles de conduction d'origine vagale. Mais la signification même de la vagotonie n'est pas toujours invoquée ; elle peut apparaitre comme un mécanisme d'adaptation aux stress répétés comme chez le sportif, ou comme un dérèglement de ces mêmes mécanismes d'adaptation neuro-végétative. Dans ces derniers cas responsable de malaises, voire de pertes de connaissance, la vagotonie apparait nocive et peut entrainer l'inaptitude professionnelle.

II LE SYNDROME DE WOLFF PARKINSON WHITE.

Nous trouvons le même pourcentage de cette anomalie électrique en France, 1,5 °/. , que les auteurs anglosaxons, Searset Manning trouvent sur 15.000 membres d'équipage dans l'aviation canadienne, 46 sujets porteurs d'un Wolff Parkinson White (soit 3°/..). Les statistiques de l'aviation américaine sont plus importantes, 187 WPW sur 156 sujets pour His et Lamb dans l'U.S Air Force (soit 1,5 °/.), 27 WPW sur 28295 sujets (soit 0,99 °/.) dans l'aviation navale U.S.

Nous éliminons les candidats porteurs d'un Wolff Parkinson White, non seulement en raison du risque non négligeable de crises de tachycardie paroxystique, mais en raison de la coexistance possible, d'affections familiales de diagnostic difficile, comme la cardiomégalie familiale et surtout de la cardiomyopathie obstructive.

Le syndrome de Wolff Parkinson White ne prête pas à discussion quand il existe les trois caractères :

a) raccourcissement de l'intervalle PR inférieur à 11/100 de seconde.

b) élargissement apparent du complexe QRS supérieur à 12/100 de seconde.

c) empatement du début de QRS désigné sous le nom d'onde delta.

Braunwald admet que le syndrome de préexitation existe quand il y a présence de deux ou un seul des trois critères classiques. Doit-on éliminer les candidats porteurs d'un PR court inférieur à 11/100 de seconde en le faisant entrer dans le syndrome de WPW ?.

Nous éliminons 2°/. des candidats, cette question du PR court est contreverser; en France nous les déclarons aptes au personnel navigant et nous n'avons eu depuis 15 ans aucune crise de tachycardie paroxystique.

III LES BLOCS DE BRANCHE DROITS INCOMPLETS.

Les aspects de bloc droit incomplets fréquemment rencontrés nous paraissent compatibles avec l'aviation si la durée totale de QRS ne dépasse pas 12/100 de seconde, si l'aspect de bloc en VI du type rSr' reste immuable ou disparaît lors de l'épreuve de Flack ou d'endurance, test à 40 mm de mercure.

En effet, une étude statistique faite au Centre Principale d'Expertise Médicale du Personnel Navigant de Paris a montré que ces aspects de bloc droit incomplet étaient retrouvés chez 12 °/. des candidats à l'admission, que cette fréquence était d'autant plus grande que le groupe des sujets examinés était jeune. Aussi, peut-on considérer que très souvent ces aspects de bloc droit incomplet, susceptibles de disparaître sous l'influence de la rotation de Flack,ne sont qu'un aspect purement physiologique de l'électrocardiogramme juvénile. Il serait donc abusif d'éliminer automatiquement les sujets porteurs de ces aspects, d'autant que les enregistrements simultanés multiples en plusieurs dérivations tendent à grouper sous le nom de bloc de branche droit incomplet des images morphologiques semblables, mais dans certaines d'entre elles le sommet r' ne correspond manifestement pas à la contraction du coeur droit retardée.

IV LA DEVIATION GAUCHE DE L'AXE DE QRS.

La détermination de l'axe moyen du complexe QRS dans le plan frontal, est l'un des éléments fondamentaux de l'analyse d'un électrocardiogramme.

Cet axe est considéré comme normal chez les individus adultes, lorqu'il est situé entre - 30° et + 110 °. On admet que en dhors de toute cause pathologique, l'axe électrique du coeur varie entre ces limites, selon sa position anatomique dans le thorax. Une franche déviation à gauche de l'axe de QRS au delà de - 30° , a souvent une signification pathologique : elle s'observe dans certaines cardiopathies congénitales, et fait penser surtout à une hypertrophie ventriculaire gauche. Depuis les travaux de Grant en 1956, et surtout de Rosenbaum, en 1968, un nouveau concept physiopathologique est apparu, celui des hémiblocs de la branche gauche de division du faisceau de His qui s'est rapidement imposé comme étant à l'origine, d'importantes déviations axiales de QRS.

Nous avons déjà rapporté 60 observations, ayant en commun une déviation à gauche de l'axe de QRS, la majorité étaient des longilignes marqués. Toutes ces anomalies sont de découverte systématique, aucun de ces sujets n'accusant de signe fonctionnel. Grâce à notre fichier nous avons pu retrouver dans une majorité des cas, des documents antérieurs qui permettent d'affirmer que l'aspect dit anormal de l'électrocardiogramme, existait avant l'âge de 25 ans et que cet aspect dit anormal est resté stable pendant de nombreuses années (8 cas avec un recul de plus de 15 ans).

Avec Lancaster nous considérons que cet aspect se situe à l'extrême gauche de l'électrocardiogramme normal et que à l'extrême, l'activation de tout le ventricule gauche peut dépendre exclusivement des filets postérieurs comme dans l'hémibloc gauche antérieur, tout se passe alors comme si le faisceau antérieur gauche était peu ou pas du tout fonctionnel. Il s'agit là de variétés non pathologiques du mode d'activation ventriculaire et nous proposons l'aptitude aux fonctions du personnel navigant. Rabkin de l'armée de l'air canadienne en 1979 est arrivé à la même conclusion que nous.

Lorsque nous sommes en présence d'un bloc de branche droit complet et d'une déviation axiale gauche, nous pensons que :

a) l'inaptitude à l'admission dans le personnel navigant est une proposition qui s'impose à l'évidence .

b) lors d'une expertise périodique révisionnelle, la découverte de telles anomalies doit faire envisager deux éventualités :

- la première concerne les sujets dont on sait que le tracé électrocardiographique antérieur, comportait une déviation axiale gauche ; ces cas à notre avis doivent être envisagés comme des blocs isolés de la branche droite, on en sait le pronostic classiquement favorable.

- la deuxième éventualité concerne les personnels dont le tracé ECG était strictement normal selon les critères classiques, chez lesquels apparait l'association bloc de branche droit complet et hémibloc gauche antérieur simultanément. On doit considérer ces cas comme des blocs bifasciculaires et réserver le pronostic, à notre avis l'inaptitude aux emplois du personnel navigant doit être proposés.

V LES TROUBLES DE LA REPOLARISATION.

Les troubles de la repolarisation asymptomatiques découverts à la visite du personnel navigant sont fréquents. Vous comprenez notre anxiété devant la découverte d'une atypie de la repolarisation. S'agit-il d'une asthénie neurocirculatoire ? ou d'une insuffisance coronarienne asymptomatique ? ou de douleurs angineuses, cachées sciemment par le pilote ?.

Il suffit de rappeler le décès par infarctus du myocarde survenu il y a quelques semaines du commandant de bord d'un Boeing 747 de la Braniff. Heureusement il ne s'est rien passé, les 280 passagers du vol Honolulu-Dallas ne s'étaient aperçus de rien, le copilote James Cunningham avait posé sans encombre son boeing à Dallas. Cette observation illustre l'importance pour l'expert de médecine aéronautique d'affirmer s'il existe ou non une insuffisance coronarienne. Les anciennes épreuves fonctionnelles ou pharmacodynamiques (épreuves d'hypoxie, montée au caisson à dépression à 5 000 mètres sans oxygène, épreuve au gynergène, épreuve au chlorure de potassium) sont abandonnées au profit des épreuves d'effort.

1) les différentes méthodes.

Les épreuves au nombre de trois, continuent d'être pratiquées :

. Le test de Master, Il consiste à faire gravir à une cadence donnée un escabeau de deux marches pendant 1,30 mn (test simple) ou 3 mn (test double).

Malgrè sa simplicité, cette épreuve à l'inconvénient de provoquer un effort brutal et de courte durée, d'être peu compatible avec un enregistrement de qualité au cours de l'effort et d'être critiquable malgrè un essai de standardisation fondé sur le poids, la taille et le sexe, les sujets minces ayant une consommation d'oxygène / kg supérieure à celle des sujets obèses.

. Le tapis roulant. Utilisé surtout aux U.S.A. L'effort physiologique de marche qu'il réclame, évite, souvent l'apparition trop précoce d'une fatigue musculaire. En revanche , il est coûteux, bruyant et procure des enregistrements de qualités inégales.

. Les cycloergomètres. Le sujet doit vaincre une résistance au pédalage, obtenue par un freinage mécanique ou électromagnétique.
Lors d'un freinage mécanique, le travail est fonction de la vitesse de pédalage. La vitesse doit donc être maintenue constante. Peu onéreux, ces cycloergomètres sont suffisants pour les épreuves de diagnostic ou de réadaptation mais deviennent imprécis lorsqu'il s'agit de comparer des tracés successifs obtenus chez un même sujet.

Le freinage électromagnétique, en revanche, n'exige pas une vitesse de rotation constante, l'intensité du freinage étant inversement proportionnelle à la fréquence du pédalage. Cette méthode simple, reproductible, adaptée aux capacités du sujet, permet un bon recueil des paramètres avant, pendant et après l'effort.

En définitive, l'évolution des idées et des techniques s'est faite :

. vers une codification plus précise des épreuves, visant à les rendre fiables, reproductibles et non dangereuses ;

. vers l'élargissement des indications, notamment du dépistage de l'insuffisance coronaire latente ; dépistage qui sera peut-être facilité dans l'avenir par l'analyse automatique des tracés ;

. vers la recherche d'autres épreuves dynamiques visant soit à éliminer un diagnostic d'insuffisance coronarienne (test d'hyperventilation, épreuve pharmacodynamique), soit à l'affirmer (test d'hypoxie, au glucose, à l'isoprotérénol, enfin, test de tachycardie provoquée par stimulation de l'oreillette droite, encore appelé "pacing"). Parmi toutes ces épreuves, seule la dernière présente un intérêt certain et se place directement après l'épreuve d'effort.

2) <u>le déroulement de l'épreuve</u>.

1. Une épreuve d'effort est toujours précédée d'un examen complet.
Celui-ci vise :
. A rechercher une contre indication absolue ou temporaire.
. A rechercher une prise médicamenteuse susceptible de modifier l'E.C.G (digitaline, bêta-bloquants, quinidine ...) L'épreuve doit, en outre, se situer deux heures après la prise d'un repas et 24 heures après un travail important.
. Cet examen permet en outre de préciser les caractères de la douleur accusée par le sujet et d'informer ce dernier sur les buts poursuivis, afin de prévenir un arrêt trop précoce de l'épreuve.
. Un enregistrement E.C.G complet termine cet examen.

2. Installation.
Le recueil de trois paramètres est indispensable : fréquence cardiaque (mesurée sur les tracés E.C.G), tension artérielle (l'un et l'autre éléments étant recueillis toutes les deux minutes), E.C.G (qui sera surveillé en permanence, afin de dépister les troubles du rythme ou les anomalies ischémiques prononcées).
Ce recueil sera poursuivi pendant la période de récupération jusqu'à normalisation (en moyenne 15 à 30 mn). En effet, certaines modifications peuvent n'apparaître qu'après l'effort.
. Le choix des dérivations.
On peut utiliser les 12 dérivations classiques, à la condition de fixer les électrodes des membres au niveau des acromions et des crêtes iliaques, afin d'éliminer un parasitage d'origine musculaire.
On peut aussi tenter de simplifier le protocole en limitant le nombre des dérivations. C'est ainsi que Blackburn a montré d'une part que le nombre de résultats positifs s'accroît avec le nombre des dérivations, et a préconisé d'autre part comme la plus sensible (85 p 200 de résultats positifs) la dérivation CM5 ("chest-manubrium"). Mais cette dérivation est susceptible de donner des faux positifs.
Il semble bien qu'un optimum puisse être obtenu par l'enregistrement de D1 - VF et une précordiale gauche (V5 ou V6).
.
. La fixation des électrodes.
Elle nécessite une bonne préparation de la peau qui sera soigneusement décapée à l'aide d'une compresse (pouvoir abrasif) imbibée d'éther jusqu'à rubéfaction. On enduit ensuite chaque zone de pâte conductrice et l'on enlève le surplus à l'éther lorsque la pâte a été suffisamment absorbée. En effet, la peau doit être parfaitement sèche pour une bonne fixation des électrodes autocollantes, qui remplacent avantageusement la fixation par sangle. On enduit d'un minimum de pâte l'électrode avant fixation.

3. Intensité et modalité de l'effort.

Au cours d'un effort d'intensité croissante, la consommatinn d'oxygène et la fréquence cardiaque s'accroissent jusqu'à un palier qui définit la V02 maximum d'une part et la fréquence maximum d'autre part. Au-delà de cette charge, l'effort ne peut être maintenu plus d'une à deux minutes sans qu'apparaissent des manifestations d'intolérance. Or,comme l'a montré Astrand, la fréquence maximum est fonction de l'âge et elle peut être calculée par la formule 220 âge avec une dispersion de 15 p.100.

L'épreuve est dite maximale lorsque le sujet atteint au moins 95 p.100 de la valeur théorique maximale. Elle est dite sous-maximale lorsque la valeur atteinte égale 70 à 85 p.100 de la fréquence maximale théorique (à titre d'exemple : 150/mn pour un homme de 50 ans).

Mais signalons dès à présent que le nombre d'épreuves faussement négatives s'accroit lorsqu'on s'éloigne des valeurs maximales.

L'effort peut être soit de type rectangulaire (une charge constante est appliquée pendant un temps donné. Elle entraine souvent une fatique précoce) ; soit par paliers successifs (on peut proposer une augmentation de 30 watts toutes les minutes).

La charge de départ est modulée en fonction de l'aptitude du sujet à l'effort : 60 W en général, 30 W en cas d'aptitude limitée, 100 W ou plus chez les sujets robustes ou sportifs.

4. Arrêt de l'épreuve.

Lors d'une épreuve à visée diagnostique on peut l'interrompre :

. De principe, lorsqu'apparaissent des signes suffisants pour affirmer le diagnostic, et ceci si l'on ne désire pas associer à l'épreuve diagnostique une évaluation de la capacité d'effort.

. Lorsque la fréquence cardiaque maximale ou sous-maximale est atteinte.

Mais soulignons qu'il est très discutable d'interrompre de façon systématique l'examen en l'absence de signe pathologique. En effet, si l'on peut admettre qu'un sujet n'est pas coronarien lorsqu'il a pu soutenir sans trouble sa fréquence maximale pendant quelques minutes, en revanche, le nombre de faux négatifs s'accroît d'autant plus que la fréquence cardiaque atteinte est plus faible.

Si elle est bien tolérée il est donc souhaitable de réaliser des épreuves maximales, ce qui réduit les faux négatifs (la sensibilité de l'épreuve augmente) et assure des critères E.C.G moins discutables (la spécificité de l'épreuve s'accroît).

Mais c'est rappeler l'importance de la surveillance permanente de ce type d'épreuve par une équipe compétente.

. Devant les troubles cliniques ou E.C.G.

La douleur. Si elle est de type angineux avec ST sus-décalé, elle doit faire interrompre l'épreuve ; elle cède le plus souvent spontanément ou avec une dragée de trinitrine : bien que son obtention ne soit pas souhaitable, elle a une grande valeur diagnostique et détermine la valeur de la capacité maximale d'effort. Si elle est atypique, sans modification E.C.G elle peut permettre de poursuivre l'épreuve ; mais il faut savoir que l'aspect ischémique peut n'apparaître que secondairement. En pratique, quel que soit l'aspect E.C.G, le sujet s'arrête spontanément.

La tension artérielle. Toute chute de pression en cours d'effort, même modérée (alors que normalement elle augmente), doit faire interrompre l'épreuve ; elle est à différencier de celle survenant en fin d'effort et que l'on peut prévenir par un arrêt progressif de l'épreuve. A l'inverse, un chiffre de 250 mm Hg paraît être la limite supérieure à ne pas dépasser.

Un galop gauche. Il sera systématiquement recherché dès que le segment ST se sous-décale.

Un certain nombre de troubles, qui conduisent à l'arrêt de l'épreuve : fatigue musculaire parfois prématurée, dyspnée, lipothymie, pâleur, sueurs froides, confusion, pouvant parfois apparaître pour des niveaux très bas.

La constatation de troubles du rythme ou de la conduction, qui impose également l'arrêt. Les extrasystoles isolées banales au cours de l'épreuve n'engagent qu'à redoubler de prudence. Mais si leur nombre s'accroit (plus de cinq par minute) ou si elles sont polymorphes, l'arrêt est impératif.

3) Incidents et accidents.

La mauvaise réputation dont jouit l'épreuve n'est pas justifiée dans la mesure où les contre-indications et les critères d'arrêt sont respectés, dans la mesure aussi où l'on a recours à des épreuves adaptées, progressives et surveillées par une équipe disposant d'un matériel de réanimation et d'un défibrillateur. En particulier, les épreuves pratiquées en unité ou en cabinet doivent être formellement proscrites.

La fréquence des incidents, essentiellement douleurs prolongées et troubles du rythme régressifs, reste dans la plupart des études publiées inférieure à 5 p.100.

Les accidents graves sont rares : infarctus du myocarde, tachycardie ou fibrillation ventriculaire, mort subite.

	Décès	Nombres d'épreuves
BLACKBURN	16	170.000
BRUCE	4	107.000
ROUSSEAU	4	114.350
JOUVE	2	19.000
BROUSTET	0	6.000

Même faible, la possibilité d'accidents engage la responsabilité du médecin, d'autant que la pratique, courante au Etats-Unis, consistant à faire signer par le patient une décharge,n'a en France aucune valeur légale. Il revient donc éventuellement aux tribunaux d'apprécier la nécessité de cette épreuve pour l'établissement d'une thérapeutique.

4) Les modifications de l'E.C.G à l'effort.

La tachycardie, l'augmentation de l'onde P, l'inclinaison du segment PQ, les variations d'amplitude de QRS, les modifications de ST, enfin la superposition partielle de l'onde T et P, les modifications habituelles au cours de l'effort, rendent difficile la lecture de l'E.C.G et l'appréciation de la ligne isoélectrique, pourtant indispensable à la mesure du point J. Sur ce tracé suffisamment stable, on trace une droite joignant le début de deux complexes QRS consécutifs. Certains auteurs préfèrent utiliser la droite descendante prolongeant le segment PQ.

Parmi les nombreuses altérations électriques liées à l'effort, deux méritent attention : les modifications du segment ST et celles de l'onde T.

1) Modifications de ST. On oppose schématiquement :

. La dépression ST dite fonctionnelle ou physiologique, où le point J sous-décalé est suivi d'un segment ST rapidement ascendant. Le rapport $\frac{Q\ X}{Q\ T}$ reste inférieur à 0,5.

. La dépression ST dite "ischémique" où, au sous-décalage de J succède un segment ST descendant ou horizontal. QX/QT est supérieur à 0,5. Bien souvent on retrouve des déformations descendant de ST, sans abaissement de J.

. Sous décalage faiblement ascendant de JST, avec cassure de raccordement de l'onde T. C'est l'aspect "Nearischemic" décrit par Master.
La pente de ST peut être évaluée en mV/sec.
On peut enfin observer un sus-décalage de JST.

2) Modification de T. Elles peuvent être de quatre types : augmentation d'amplitude, aplatissement, inversion, positivation d'une onde négative au repos.

5) Valeur diagnostique et pronostique.

Parmi les différentes modifications E.C.G; il est unanimement admis que seules, les modifications de JST méritent d'être retenues.

En ce qui concerne les autres critères , seul le surdécalage de ST aurait une bonne valeur, hormis le cas où son amplitude s'accroit du triple de sa valeur initiale.

1) L'OMS propose comme critère l'aspect ischémique de ST avec un sous-décalage de J, 0,1 mV, mais cette attitude par trop rigide doit être nuancée.

. Il convient d'abord de préciser quelle est la fréquence de ce critère lors d'épreuves chez des sujets "normaux" : 2 à 10 p.100 sont les chiffres les plus communément retrouvés dans la littérature ; chiffres d'autant plus élevés que l'on recourt à des épreuves maximales ou que l'on étudie des sujets plus âgés. Mais il semble, à partir des quelques études prospectives publiées, qu'il s'agisse dans bien des cas d'insuffisance coronaire encore latentes. Ainsi l'étude de Cloarec portant sur une population dont la moyenne d'âge est de 45 ans, retrouve 9 p.100 d'anomalies pathologiques. Dans les cinq ans, 60 p.100 de ces sujets ont présenté une manifestation clinique d'insuffisance coronaire. Dans ces observations,il existait de façon quasi constante une association de facteurs de risque clinique ou biologique.

. Il faut remarquer que l'importance du sous-décalage de JST, donc sa valeur diagnostique, varie selon le type de l'épreuve (test de Master ou cycloergomètre) et suivant la dérivation utilisée. (CM5 amplifie les modifications, qui sont plus importantes qu'en dérivations standard).

2) Les corrélations observées entre les apports de l'E.C.G d'effort et la coronarographie seront maintenant précisées.

. On obtient : soit des résultats concordants (l'épreuve d'effort est positive et la coronarographie montre des lésions athéromateuses) ; soit des résultats discordants (l'épreuve d'effort est négative mais il existe des lésions coronaires : faux négatifs ; l'épreuve est positive mais il n'y a pas de lésion des vaisseaux : faux positifs) ; soit enfin des épreuves douteuses ou ininterprétables.

Si l'on admet le critère classique (J 1mV St ImV/S avec aspect rigide) la concordance oscille autour de 80 p.100.

Auteurs	Concordances	Discordances	Douteux
FROMENT	82	9,25	8,75
SERRADIMIGNI	74	10,6	15,4
LESBRE	82,3	17,7	-

. Plus qu'un critère précis, certes nécessaire pour la confrontation de résultats, il faut reconnaitre que :

- d'une part, la valeur diagnostique, c'est-à-dire la spécificité, s'accroît d'autant plus que le point J est plus sous-décalé et que la pente de ST est plus négative.

- d'autre part, plus on exige des critères sévères de positivité, plus la sensibilité de l'épreuve baisse (les faux négatifs augmentent) et des coronariens indiscutables n'ayant présenté que des troubles E.C.G discrets seront méconnus. Il existe donc un balancement entre spécificité et sensibilité de l'épreuve.

. Les insuffisances de l'E.C.G d'effort ne sont pas toujours à mettre au passif de la méthode.

En effet, les "faux négatifs" peuvent être dus :

- à un arrêt trop précoce de l'épreuve par le malade ou par le médecin ceci explique la tendance actuelle à préférer les épreuves maximales qui ont, en outre, l'avantage d'évaluer la capacité d'effort ;

- à la bonne qualité d'un réseau anastomotique, assurant une compensation efficace.

Les "faux positifs" peuvent être liés :

- à une difficulté d'interprétation des modifications de JST ;

- à une pathologie artériolo-capillaire ou du métabolisme cellulaire (angor à coronaires normales), la coronarographie étant alors insuffisante.

. Signalons également qu'il n'existe aucune corrélation entre la topographie des lésions et le siège des altérations électriques.

. La coronarographie permet enfin d'attribuer à l'E.C.G d'effort une certaine valeur pronostique. En effet, les lésions ont d'autant plus de chance d'être modérées que la fréquence cardiaque atteinte a été plus élevée et que le degré du sous-décalage a été plus modéré.

DONC : l'électrocardiogramme d'effort apporte à l'expert de médecine aéronautique des informations de valeur :

- d'ordre fonctionnel

- surtout d'ordre diagnostique : on connait la relative faillite de l'électrocardiogramme enregistré au repos dans le diagnostic de l'insuffisance coronarienne ou dans l'interprétation des troubles non spécifiques de la repolarisation.

Mais il convient d'en connaitre les limites. Il restera toujours une dualité entre la spécificité de l'épreuve et sa sensibilité de même qu'à côté des résultats patents, on retrouvera toujours un lot d'épreuves douteuses ou ininterprétables et un lot d'épreuves faussement positives ou faussement négatives.

Multiplier ces épreuves codifiées à des valeurs maximales sous entend leur pratique dans des centres équipés, par des équipes compétentes et entrainées, respectueuses des contre-indications et des critères d'arrêt.

C'est à ce prix que l'épreuve d'effort perdra sa mauvaise réputation dont on peut dire qu'elle n'est plus justifiée.

TREADMILL TESTING FOR THE DETECTION OF ASYMPTOMATIC CORONARY DISEASE IN THE HEALTHY MALE

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INTRODUCTION

Treadmill testing has been shown to have a high degree of sensitivity and specificity in a population studied because of chest pain, previous myocardial infarction, or in other patients in whom the diagnosis of coronary artery disease was either evident or strongly suspected.(1,2,3) This paper will deal with treadmill testing in totally asymptomatic men, a group in whom the predictive accuracy of the treadmill test has been quite disappointing. (4) The major portion of this discussion will center around the problem of false positive exercise tests. Currently, there is an increasing tendency to place less reliance upon the treadmill test as a single, stand-alone test for the detection of latent coronary artery disease. Research is continuing in many centers in an attempt to define parameters other than just the ST segment response which may yield helpful information. However, the maximal amount of highly predictive information currently available in the treadmill tests of asymptomatic men is limited, and markedly diminishes their usefulness. The treadmill test should more aptly be regarded as a risk factor and as a part of the total risk factor mosaic rather than as a definitive test for coronary artery disease.

THE AEROMEDICAL IMPORTANCE OF CORONARY ARTERY DISEASE

A discussion of treadmill testing in asymptomatic men is essentially the discussion of coronary artery disease detection in the asymptomatic aircrewmember. Coronary artery disease (CAD) represents a major public health problem for most developed nations of the world. From an aeromedical standpoint, it continues as the major nontraumatic cause of death in U.S. Air Force aviators. Even mild degrees of coronary artery disease can lead to sudden incapacitation during positive G_z stress. We are all well aware that annual aviation physical examinations fail to detect significant CAD. Further, the use of cardiovascular screening tests in asymptomatic men is fraught with problems, and intensive study is required in this area. The problem of the early detection of asymptomatic CAD is becoming more urgent, now that aircrewmembers are being subjected to increasing workloads on the cardiovascular system with the new generation of high-performance aircraft.

METHODS AVAILABLE FOR THE DETECTION OF ASYMPTOMATIC CORONARY ARTERY DISEASE

TABLE 1

CORONARY ARTERY DISEASE DETECTION METHODS

History

Physical examination

Resting electrocardiogram

Holter monitoring

Exercise electrocardiography

Exercise scintigraphy

Echocardiography

Risk estimation

The methods available to the clinician to detect asymptomatic CAD are quite numerous. (Table 1) However, only treadmills combined with myocardial scintigraphy and risk estimation truly hold any degree of promise for disease detection in the asymptomatic male. Still, the routine treadmill test is not only useful for evaluation of the ST segment response to maximal exercise, but remains a valuable tool for the detection or provocation of significant stress arrhythmias, determination of functional capacity in mild valvular heart disease, and as a general indicator of cardiovascular fitness and oxygen consumption. While the treadmill exercise test has obvious limitations in the detection of asymptomatic CAD, an abnormal ST segment response is a potent epidemiological risk for coronary artery disease events in the asymptomatic population. Froelicher studied the natural histories of 1,640 asymptomatic aircrewmembers who received treadmill tests between December 1965 and January 1969.(5) Followup was obtained in 85% of the total group and in 95% of the group with abnormal treadmill tests. The followup period ranged from 4.1 to 8 years, mean followup of 6.6 years. Using epidemiological endpoints of acute myocardial infarction, angina pectoris, bypass surgery, coronary angiography or sudden death, marked differences were noted between those with normal and abnormal ST segment response to maximal exercise. Overall, an abnormal stress test identified a population with a 14-fold risk for subsequent coronary events. Thus, it can be seen that the treadmill test can properly be regarded as a potent risk factor, which cannot be ignored in the practice of aerospace medicine.

THE PROBLEM WITH FALSE POSITIVES

A basic concept in epidemiology is that of Bayes' theorem. Roughly paraphrased, this theorem states that the usefulness of a screening test is very heavily dependent upon the prevalence of the disease being tested for in the population. In other words, in a population with a low prevalence of CAD, almost any diagnostic test applied to detect coronary disease will result in a majority of the positive response being false positives. A few common biostatistical terms are listed in Table 2.

TABLE 2

Sensitivity = Percentage of positive results in patients with disease

$$Se = \frac{TP}{TP + FN} \times 100$$

Specificity = Percentage of negative results among those without disease

$$Sp = \frac{TN}{FP + TN} \times 100$$

Predictive value = Percentage of positive results which are true positives

$$PV = \frac{TP}{TP + FP} \times 100$$

Risk ratio = $\frac{\text{Percentage of subjects with an abnormal test who have disease}}{\text{Percentage of subjects with a normal test who have disease}}$

Abbreviations: TP = True Positives
FN = False Negatives
TN = True Negatives
FP = False Positives

Sensitivity is the percentage of positive results in patients with the disease. Specificity, on the other hand, is the percentage of negative results among those who do not have the disease. The predictive value, one of the most commonly used epidemiological terms, is the percentage of positive results which are true positives. The risk ratio (also called the relative risk) is the risk of disease with an abnormal test compared to the risk of disease with a normal test. The prevalence of a disease in the population has a strong bearing upon predictive value. Table 3 lists a hypothetical case in which a population with a 50% prevalence of disease is tested with a screening procedure which is 60% sensitive and 90% specific.

TABLE 3

PERFORMANCE OF A TEST WITH 60% SENSITIVITY AND 90% SPECIFICITY IN A POPULATION WITH 50% PREVALENCE OF DISEASE

Subjects	# Abnormal Tests	# Normal Tests
5000 diseased	3000 (TP)	2000 (FN)
5000 nondiseased	500 (FP)	4500 (TN)
Total	3500	6500

Predictive value of an abnormal test = $\frac{TP}{TP + FP} = \frac{3000}{3500} = 85.7\%$

If there were a total of 10,000 subjects in the population, then 5,000 would be diseased and 5,000 would be nondiseased. If the test is 60% sensitive, then 3,000 of the 5,000 subjects with disease would have an abnormal test. In the other 5,000 subjects without the disease, a 90% specific test would correctly classify 4,500 true negatives, while 500 of the nondiseased subjects would be false positives. Thus, the predictive value, that percentage of positive results which are true positives, would be 85.7% under such circumstances.

The prevalence of significant CAD in our asymptomatic population is between 3% and 5%. Table 4 outlines the performance of a test with a 60% sensitivity and 90% specificity in a population with a 5% prevalence of disease.

TABLE 4

PERFORMANCE OF A TEST WITH A 60% SENSITIVITY AND 90% SPECIFICITY IN A POPULATION WITH A 5% PREVALENCE OF DISEASE

Subjects	# Abnormal Tests	# Normal Tests
500 diseased	300 (TP)	200 (FN)
9500 nondiseased	950 (FP)	8550 (TN)
Total	1250	8750

$$\text{Predictive value of an abnormal test} = \frac{TP}{TP + FP} = \frac{300}{1250} = 24\%$$

In the 500 subjects with disease, 300 would have a positive test and 200 would have a negative test. In the 9,500 subjects without disease, 950 would have a positive test and 8,550 would have a negative test. Thus, the predictive value unde. such a low disease prevalence is only 24%. It is apparent from these two examples that the predictive value of a test with a 60% sensitivity and 90% specificity can be markedly different, depending upon the disease prevalence in the test population. Table 5 outlines the steady increase in predictive value and the steady decrease in false positive results as the disease prevalence increases.

TABLE 5

EFFECT OF INCIDENCE ON PREDICTIVE VALUE AND FALSE POSITIVE RATE IN TEST WITH 60% SENSITIVITY AND 90% SPECIFICITY

Prevalence %	Predictive value of abnormal test (%)	False positive rate (100%-predictive value)
1	5.7	94.3
5	24	76
10	40	60
50	85.7	14.3

A disease prevalence of 5%, with a predictive value of 24% and a false positive rate of 76%, is quite analogous to the situation of treadmill exercise testing in healthy asymptomatic men.

There are numerous cases of false positive exercise tests, including mitral valve prolapse, electrolyte abnormalities, cardiomyopathies, pericardial disease, anemia, left ventricular hypertrophy, pre-excitation, nonfasting state, vasoregularity abnormalities and coronary spasm. However, the great bulk of false positive exercise tests are of unknown etiology.

THE WIDE SPECTRUM OF ASYMPTOMATIC CORONARY ARTERY DISEASE

It must always be remembered that the absence of symptoms does not rule out the presence of severe obstructive CAD. Although CAD is usually far advanced when it becomes symptomatic,(6) severe asymptomatic CAD is by no means a rare finding.(7) On the other hand, ominous risk factor profiles as well as markedly abnormal exercise tests do not necessarily indicate the presence of latent CAD. We have observed virtually all possible combinations of risk factors, positivity of exercise tests and coronary angiographic results.

USAFSAM EXPERIENCE WITH TREADMILL TESTING IN ASYMPTOMATIC MEN

Table 6 outlines the results of a recently completed treadmill study at USAFSAM.(8)

TABLE 6

RESULTS OF TREADMILL STUDY

256 abnormal treadmill, asymptomatic

158 no CAD

98 any CAD

65 significant disease (≥50% lesions)

33 minimal disease (<50% lesions)

Predictive value of a positive treadmill for any CAD - 38%

Predictive value of a positive treadmill for significant CAD* - 25%

*Significant coronary disease means at least one lesion in a major vessel or branch which diminishes the luminal diameter by at least 50%.

256 left heart catheterizations with abnormal treadmill tests were reviewed. The ST segment criteria utilized were classical criteria (1 millimeter of ST segment depression with a horizontal slope, measured 80 milliseconds after the J point). Tests were also read as positive if they met Ellestad's criteria (1 millimeter of ST segment depression 80 milliseconds after the J point, irrespective of slope). All subjects in this study were totally asymptomatic. Subjects were excluded from this study if they had symptoms or chest pain syndromes, right bundle branch block, left bundle branch block, valvular heart disease (including mitral valve prolapse), or electrocardiographic and/or clinical documentation of myocardial infarction. The results of the treadmill study revealed that of 256 patients with abnormal treadmills, 158 had no CAD, 98 were found to have some degree of CAD, with 65 of those having significant disease at the 50% lesion level. Thirty-three subjects had minimal disease with lesions less than 50% of the luminal diameter. Thus, a positive treadmill test with any CAD was found 38% of the time, and a positive treadmill with significant CAD was found 25% of the time.

A number of risk factors were also evaluated in this population which received catheterization for positive treadmill exercise tests.(Table 7) The sensitivity, specificity and predictive value of these risk factors were calculated, as well as the relative risk. (9) The relative risk is the risk of CAD in a person with a given characteristic, as opposed to one in whom the characteristic is absent.

TABLE 7

CATHETERIZED FOR POSITIVE TREADMILL

		CAD	NORMAL
CHOLESTEROL			
Cholesterol $\geq$ 220 mg%		53	100
Normal cholesterol		12	90
Relative risk	= 2.9		
Sensitivity	= 82%		
Specificity	= 47%		
Predictive Value	= 35%		
SMOKING			
Yes		41	92
No		24	98
Relative risk	= 1.6		
Sensitivity	= 63%		
Specificity	= 52%		
Predictive Value	= 31%		
HYPERTENSION (140/90 mmHg)			
Present		19	37
Absent		46	153
Relative risk	= 1.5		
Sensitivity	= 29%		
Specificity	= 81%		
Predictive Value	= 34%		
FAMILY HISTORY			
Present		25	65
Absent		40	125
Relative risk	= 1.1		
Sensitivity	= 38%		
Specificity	= 66%		
Predictive Value	= 28%		
GLUCOSE INTOLERANCE			
Present		12	14
Absent		53	176
Relative risk	= 2.0		
Sensitivity	= 18%		
Specificity	= 93%		
Predictive Value	= 46%		

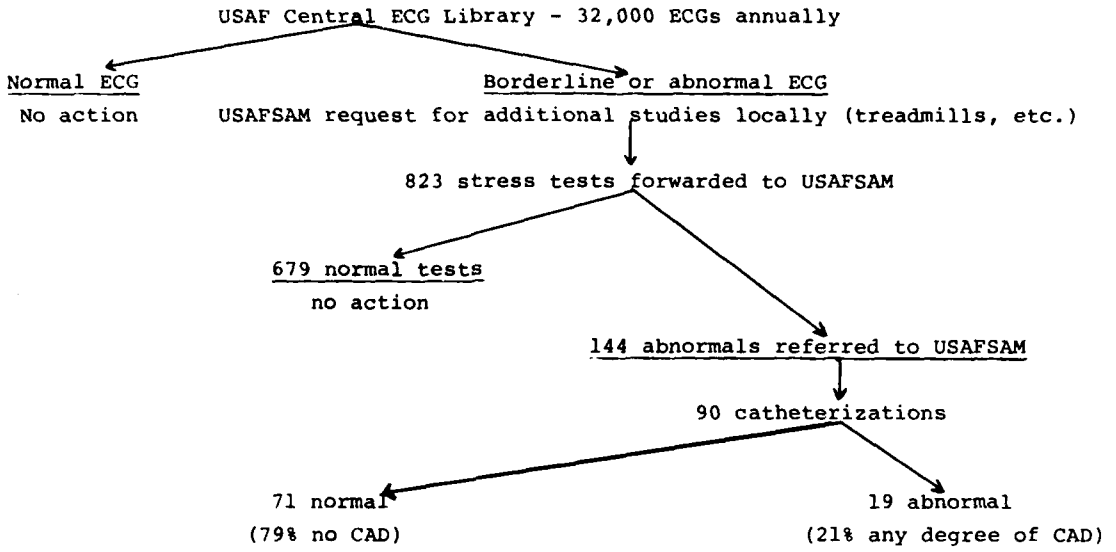
The highest relative risk in the entire group was that of a cholesterol greater than 220 milligrams percent, yielding a relative risk of 2.9 and a predictive value of 35%. The performance of the other cardiovascular risk factors, when considered singly, is unimpressive. The overall prevalence of hypertension in this highly selective population was so low that hypertension was of almost no assistance as a single risk factor. Thus, it can be seen that no initial risk factor is of great benefit when considered singly in an asymptomatic population with an abnormal treadmill.

SCREENING FOR CORONARY DISEASE WITH AN ANNUAL RESTING ELECTROCARDIOGRAM

Table 8 reveals the results of a one-year screening process using the annual electrocardiogram (ECG).

TABLE 8

DETECTION OF CORONARY ARTERY DISEASE BY ANNUAL ECG



From a total of 32,000 ECGs, 1,018 requests for additional studies were sent to various flight surgeons' offices. 823 stress tests which had been requested were referred to USAFSAM. 679 of these tests were normal and no further action was required. 144 abnormal stress tests were referred to USAFSAM, resulting in 90 catheterizations. 79% of the catheterizations were normal and coronary disease of any degree was found in 21%. The great majority of these exercise stress tests which were requested by the USAF Central ECG Library were due to acquired ST and T wave changes. Thus, treadmill tests which were requested due to an acquired serial ST or T wave change in the resting ECG revealed a predictive value of 21% in the general aviation population.

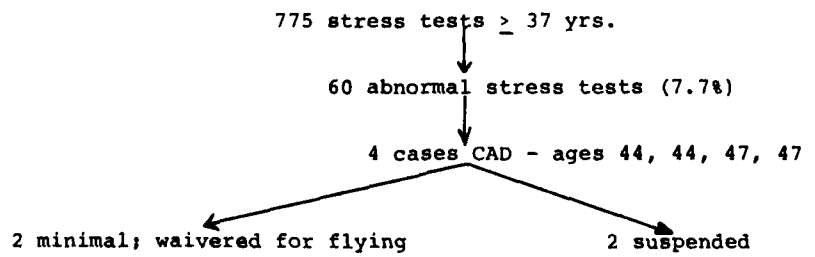
UNSTRUCTURED EXERCISE TESTING

An unstructured exercise testing program is one in which there is no previous stratification of individuals by risk factor analysis, resting electrocardiographic changes, or other factors which may raise the suspicion of asymptomatic CAD. During a one-year field trial, a major Air Force command conducted 775 stress tests in men over the age of 37 years, with an age of 37 years being the only stratification variable.(10)

TABLE 9

UNSTRUCTURED EXERCISE TESTING

A one-year field experience



The abnormal test rate was 7.7%. This screening process revealed 4 cases of coronary artery disease, ages 44, 44, 47, 47. Two cases of disease were minimal and two cases were

suspended from flying. Thus, the results of unstratified testing revealed an unacceptable yield of disease in view of the logistical expense involved.

COMPARISON OF STRATIFIED AND UNSTRATIFIED TREADMILL TESTING

TABLE 10

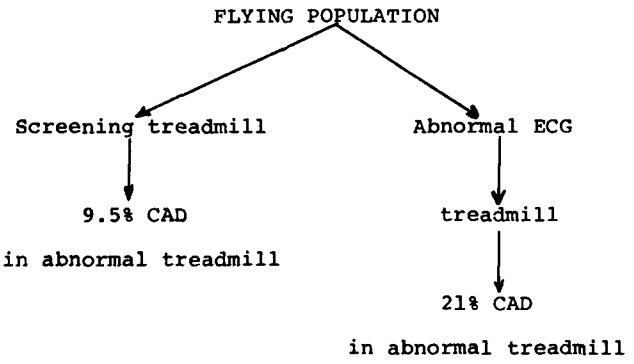
STRATIFICATION OF TREADMILL POPULATION

	ANY CAD	SIGNIFICANT CAD (lesion $\geq$50%)
USAFSAM treadmills (referral population)	38%	25%
ECG Library abnormal ECGs with followup abnormal treadmills (for year 1979)	21%	--
Unstructured testing in the field (normal ECG) screening treadmill abnormal	9.5%	--

Table 10 reveals the results of stratification of a treadmill population. A positive treadmill exercise test in the USAFSAM referral population, 67% of whom are referred for cardiovascular evaluations, results in some degree of CAD in 38% of the patients and significant CAD in 25% of the patients. The predictive value decreases from 38% to 21% if the treadmill test is done solely to followup a serial change in the ECG with no other factors suggesting cardiovascular disease. If one eliminates the screening process of an abnormal ECG and uses unstructured exercise testing in the field with no particular suspicion or reason for performing the test, then the predictive value decreases further to 9.5%. Thus, the limitations of the treadmill exercise test as a screening test for CAD, are further magnified if the population to be tested is not stratified in some manner.

As can be seen in Table 11, an annual ECG which is abnormal as a serial change increases the predictive value of an abnormal treadmill test from 9.5% to 21%. Still, this extremely low predictive value limits the treadmill test as a screening tool.

TABLE 11



PROBLEMS WITH THE TREADMILL TEST

The first and most obvious problem with the use of the treadmill as a screening tool is its excessive false positive rate. Further, it must be recognized that the false negative rate is unknown in an asymptomatic population, since individuals with negative exercise tests do not receive further screening tests or cardiac catheterizations. While a false positive test imposes additional testing upon those who do not have the disease, a false negative test has major aeromedical implications, because those with true disease are not identified or studied further. In spite of these two major shortcomings in the treadmill test, one cannot ignore the rather potent risk ratio of a positive test, which is 14-fold that of a negative test over a mean followup of 6.5 years. While an individual treadmill may be poorly predictive of the absence or presence of disease, it is nevertheless a potent epidemiological tool. A false positive rate for some cardiovascular screening tests may not impose a heavy burden on the screening system. For example, an elevated blood pressure reading which ultimately is identified as a spurious or "falsely positive" reading and not representative of true hypertension is not an extremely costly error. The followup test for an abnormal blood pressure is to simply repeat the blood pressure serially. However, the followup test for a positive treadmill test in an aviator (i.e., cardiac catheterization) is expensive, time consuming, and is not risk free. Thus, it follows that a surveillance program for coronary disease detection in aviators totally dependent upon the treadmill as a screening test will impose severe burdens upon the medical screening process.

If one examines the alternatives to a screening program based on the treadmill (Table 12), one is presented with a variety of choices. One may choose to totally abandon treadmill testing, but one then sacrifices the very valuable information contained in the treadmill as a physiologic indicator of functional capacity. The treadmill test is also a valuable test for the detection of stress-induced arrhythmias. Arrhythmias which are not produced under any other circumstances may become manifest during treadmill exercise. Further, the treadmill test is an extremely valuable epidemiological tool, and many of our aeromedical population studies are still heavily dependent upon the treadmill test as a stand-alone test. As a further alternative, one may choose to abandon the treadmill test as a "stand-alone" test. This implies that one intends to do a first-order screening test. One way to accomplish this end is to "change" the disease prevalence in the test population in order to increase the pretest likelihood of disease, thereby increasing the predictive value of the treadmill test. If one stratifies the population at risk to an extent that appreciably increases the prevalence of coronary disease in the test population, one will therefore increase the yield of a positive test. At USAFSAM, we have chosen to use a combination of alternatives 2, 3, 4, and 5 from Table 12 by utilizing a risk equation to single out those with a high risk of having or developing CAD. This risk equation has been formulated from the risk factor information obtained on asymptomatic Air Force aviators who have undergone coronary angiography. The risk equation is based upon age, cholesterol, blood pressure, smoking history, and family history. From the risk factors of this population of 500 asymptomatic men with coronary arteriograms, a risk index from 0 to 1.0 has been derived. The catheterization population has been divided into deciles of risk. The USAFSAM risk estimation equation is currently being evaluated in a prospective fashion.

TABLE 12

THE ALTERNATIVES TO A SCREENING PROGRAM BASED ON THE TREADMILL

1. Totally abandon treadmill testing, sacrificing important additional information:
   a. Functional capacity
   b. Arrhythmias
   c. Epidemiological use
2. Discontinue the treadmill as a "stand-alone" test
3. "Change" the disease prevalence in the test population to increase the predictive value of the test
4. Accomplish #3 by utilizing a risk equation to single out those with a high risk of having or developing CAD
5. Combine the treadmill with thallium-201 scintigraphy

The use of the exercise thallium myocardial scintigram for the detection of coronary disease is currently under evaluation at USAFSAM. The thallium scan, with high sensitivity and specificity in our population, holds great promise in aviation medicine.(11)

TABLE 13

THE "OLD" PLAN

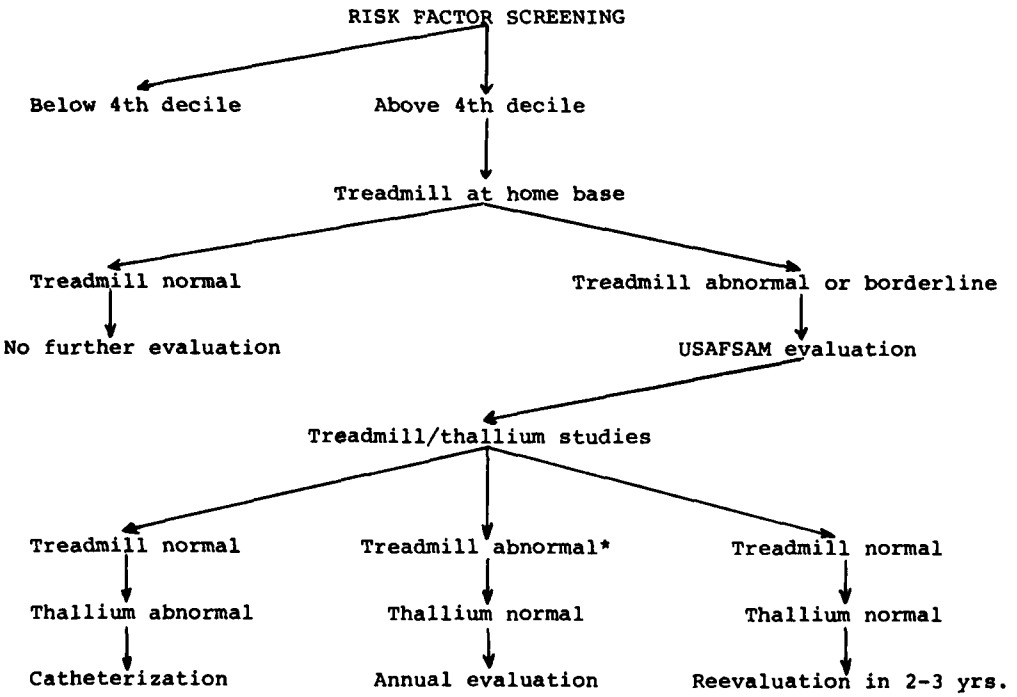
Annual ECG
↓
Serial change
↓
Request treadmill
↓
Abnormal or borderline treadmill test
↓
USAFSAM evaluation
↓
Abnormal treadmill
↓
Catheterization - approximately 80% false positives

The scheme in Table 13 defines the primary system by which CAD has been detected in the aviator population in the past. This plan consisted of an annual ECG beginning at age 35. If the annual ECG revealed a significant serial change, a treadmill test was performed in the field. If the treadmill test was abnormal or borderline, the individual was referred to USAFSAM where extensive cardiovascular evaluations were undertaken. Cardiac catheterizations were performed for abnormal exercise tolerance tests, yielding an approximately 80% false positive rate in recent years.

A risk identification program is currently under evaluation in certain portions of the U.S. Air Force flying population. This type of screening is accomplished at the time of the annual physical examination at the home base. For those who are below the fourth decile of risk, a treadmill test is performed. An abnormal or borderline treadmill test leads to a USAFSAM evaluation. A normal treadmill at the home base leads to no further action. At USAFSAM, a treadmill test plus a thallium exercise study are performed. A normal treadmill test plus an abnormal thallium scintigram requires a cardiac catheterization for delineation of the coronary arteries. If both the treadmill and thallium tests are normal, periodic noninvasive reevaluations are accomplished in the future. If the treadmill and thallium are both abnormal, cardiac catheterization is, of course, indicated. As indicated in Table 14, our future plans are to forego catheterization in those individuals with an abnormal treadmill test but a normal thallium scan. Currently, the decision to perform cardiac catheterization on aviators with the abnormal treadmill/normal thallium combination is dependent upon the age of the aviator. Current Air Force policy allows an abnormal treadmill in those with a normal thallium scan to be waivered for flying without catheterization if the aviator is 35 years of age or under with no risk factors. Obviously, any aviator identified by risk screening would not fall into this category. Still, many aviators 35 years of age or under receive treadmills for ST or T changes on the scalar ECG. In the U.S. Air Force, after an initial ECG, the next required ECG is due at age 35, and annually thereafter. Repolarization changes on this ECG at age 35 require a treadmill test. Other aviators under age 35 may receive a scalar ECG for special evaluations and assignments. Hence, the occasional aviator 35 years or under may yield an abnormal exercise test. Based upon the extremely poor yield of coronary disease at catheterization in men 35 years of age or under with abnormal exercise tests, we have chosen to waiver an abnormal treadmill as long as the thallium is normal and there are no coronary risks. Individuals thus waived are then followed with serial noninvasive tests. A decision rule to forego angiography in all aviators with the abnormal treadmill/normal thallium combination, irrespective of age, awaits additional experience with thallium scintigraphy. We are optimistic that the plan envisioned in Table 14 will become a reality.

TABLE 14

PROPOSED SCREENING PLAN



*USAF policy currently requires catheterization for an abnormal treadmill, even with a normal thallium. Above schema assumes that normal thallium scintigrams will replace coronary angiography in those with abnormal treadmills.

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ENREGISTREMENT CONTINU DE L'E.C.G. SELON LA METHODE DE HOLTER

(Modalités techniques - Choix d'un appareillage)

G. LEGUAY (+) - A. SEIGNEURIC (++)

La mise au point par HOLTER, en 1949, d'un procédé permettant l'enregistrement continu de l'E.C.G., en ambulatoire, permet non seulement de saisir plus qu'un instantané de l'activité électrique du coeur, mais semble, de plus, susceptible de modifier certains de nos concepts, en particulier des troubles du rythme.

Cette méthode, constamment améliorée, présente en cardiologie, deux grands pôles d'intérêt :

- étude des troubles du rythme et surveillance de leur traitement,
- étude des troubles de la repolarisation.

Les caractéristiques et les performances des différents appareils proposés sont très variables. Il en résulte parfois une certaine confusion sur les indications de la méthode, ses possibilités et ses limites.

Elles dépendent, en partie, des modalités techniques des différents systèmes que nous voudrions présenter dans leurs grandes lignes.

I. MODALITES TECHNIQUES DE LA METHODE DE HOLTER

Les caractéristiques et les performances des différents appareils sont très variables. Il en résulte parfois une certaine confusion sur les indications de la méthode, ses possibilités et ses limites.

Elles dépendent, en partie, des modalités techniques des différents systèmes que nous viendrons présenter dans leurs grandes lignes.

Tout ensemble d'enregistrement continu de l'E.C.G. comporte trois parties :

- l'enregistreur,
- le lecteur,
- le système informatique.

1° Enregistreur

L'enregistrement se fait sur un support magnétique, déroulé à vitesse constante et sur lequel on doit pouvoir inscrire, outre le signal électrocardiographique, une base de temps et un marqueur d'évènements.

a) Support magnétique

L'enregistrement peut se faire actuellement :

- soit sur bande magnétique,
- soit sur cassette.

Ce deuxième mode est de plus en plus répandu. Il a l'avantage d'une simplification de la manipulation. On lui reproche parfois, pour des enregistrements supérieurs à 18 heures, des difficultés de déroulement qui compromettent la lecture de la cassette.

Un des inconvénients du système à bande magnétique est l'usure des pignons du moteur. Actuellement, ils peuvent heureusement être changés. La mise en place de la bobine demande plus de soins que celle de la cassette. Une mauvaise mise en place peut entraîner une absence de déroulement.

Enfin, si l'on veut conserver les enregistrements, le système de la cassette est moins onéreux.

b) Alimentation électrique

Tous les appareils sont munis d'un dispositif d'alimentation électrique autonome qui doit durer plus de 24 heures :

- accus qui doivent être rechargés avant chaque usage. Ce qui nécessite l'achat d'un chargeur,
- piles alcalines,
- piles au mercure.

Certaines de ces piles sont rechargeables.

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Service de Médecine Interne Médecine Aéronautique
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78013 VERSAILLES

c) Vitesse de déroulement et marqueur de temps

Un des intérêts majeurs de la méthode est de confronter l'E.C.G. enregistré, à des moments précis de l'activité du malade. Par ailleurs, il importe d'avoir une vitesse de déroulement uniforme du support magnétique. Ceci est difficile car cette vitesse est très lente.

Dans les appareils les plus perfectionnés existe une horloge à quartz qui pilote, d'une part la vitesse de déroulement, d'autre part un marqueur de temps sur la bobine.

d) Marqueur d'évènements

Il est également intéressant que le sujet testé puisse imprimer, sur la bande d'enregistrement, la marque d'évènements précis et brefs (symptômes, émotions, thérapeutique, etc ...).

A la lecture, le signal peut être confronté avec l'E.C.G. et la base de temps.

Le marqueur d'évènements actionné par le sujet testé est soit incorporé au boitier, soit relié par un câble, ce qui permet de l'avoir à proximité de la main.

e) Nombre de pistes

L'enregistrement se fait par l'intermédiaire d'électrodes précordiales, placées le plus souvent dans l'axe du coeur de façon à recueillir le plus grand signal.

Les enregistreurs comportant deux pistes offrent une plus grande garantie. Ils permettent d'enregistrer deux dérivations, et de ce fait :

- de s'affranchir de certains parasites,
- de pallier au décollement d'une électrode qui peut toujours survenir chez un sujet à qui l'on demande d'avoir son activité habituelle.

f) Poids

Les enregistreurs pèsent entre 500 et 750 grammes, ce qui est souvent admis comme le poids maximum tolérable. Les enregistreurs à cassette sont, en règle générale, plus légers.

g) Contrôle du signal enregistré

Il est indispensable, lors de la mise en place de l'enregistreur, de contrôler le signal enregistré sur un appareil E.C.G.-standard.

Ceci permet, en changeant les électrodes de place, d'obtenir un signal d'un voltage tel (supérieur à un minivolt) que le lecteur pourra le dépister.

Ceci permet également de repérer et supprimer au départ certains parasites.

2° Lecteur

Le lecteur est un appareil capable d'identifier les complexes Q.R.S. normaux, et d'en séparer les complexes anormaux.

Il le fait après que soit défini un complexe Q.R.S. normal.

a) Définition du complexe Q.R.S. et de S.T.

La valeur d'un lecteur tient essentiellement à la définition du programme (Q.R.S. normal).

Selon le type d'appareil seront pris en compte :

- la durée de Q.R.S.,
- l'amplitude,
- plusieurs points (5) sur Q.R.S.,
- la surface de Q.R.S.,
- la précocité de Q.R.S. par rapport au complexe précédent (prématurité).

C'est en fonction des performances du lecteur et de l'affinement du programme que la lecture sera plus ou moins exacte et précise.

Ainsi, au mieux, le lecteur pourra-t-il différencier :

- les complexes normaux,
- les extra-systoles (complexes prématurés),
- leur nature supra-ventriculaire ou ventriculaire (complexes fins ou larges).

Selon le degré d'affinement ou non du programme, certaines extra-systoles ne seront pas reconnues, ou, au contraire, certains parasites peuvent être comptés comme complexes anormaux.

Définition du segment S.T.

De même, certains appareils permettent de définir le segment S.T. normal, grâce par exemple à un système de surbrillance réglable.

b) Vitesse de lecture et base de temps

La vitesse de lecture est de 60 à 120 fois la vitesse d'enregistrement. Le lecteur dépouille donc une bande de 24 heures en 24 à 17 minutes.

Ceci ne signifie pas qu'une bande soit exploitée dans le même temps. Ce temps est plus long et varie avec la fréquence des anomalies, les exigences de l'opérateur, les possibilités techniques de l'appareil.

Comme pour l'enregistreur, certains lecteurs sont munis d'une horloge à quartz qui règle la vitesse de déroulement, et éventuellement asservit le déroulement à la base de temps de l'enregistreur.

Le lecteur peut également afficher le temps et l'on peut même, sur certains appareils, lui faire rechercher et déchiffrer une fraction bien définie du tracé en affichant un horaire précis.

c) Lecture sur scope

Tous les lecteurs affichent sur scope tout ou partie du tracé enregistré, selon les modalités mariables.

Lecture continue :

La représentation sur le scope de l'E.C.G. se fait sous forme d'un (ou deux, ou trois) cycle cardiaque par superposition des images, tant que les complexes cardiaques restent identiques.

Le travail et le talent de l'observateur consistent à repérer une modification parfois fugitive de l'image.

Lecture discontinue :

Le scope affiche une suite de complexes d'une durée de quelques dizaines de secondes (20 à 40 sec.) qui reste fixe tant que le tracé est stable.

Si une modification apparaît, une nouvelle bande apparaît. Si le lecteur ne déchiffre pas une nouvelle anomalie, la bande reste fixe.

Certains appareils combinent les deux systèmes. Ceci permet à un observateur attentif de dépister des anomalies sur le déroulement en continu que le lecteur aurait laissé passer.

d) Signal sonore et arrêt automatique

Certains dispositifs permettent de pallier un défaut de vigilance de l'observateur :

- signal sonore,
- arrêt automatique du déroulement pendant un temps court qui peut ou non être prolongé.

e) Validation de la lecture

Certains actéfacts peuvent être reconnus comme anomalies par le lecteur, et être transmis comme tels au système d'analyse automatique (cf. infra) (par exemple, bouffées de parasites reconnues comme accès de tachycardie).

Il est possible, à notre connaissance, sur un seul appareil de valider ou au contraire d'effacer le passage de l'enregistrement reconnu comme anormal par le lecteur.

De même, il est possible, avec ce système de validation, d'affiner le programme Q.R.S. au début de la lecture.

f) Fonction "Jog"

Lorsque l'appareil s'arrête sur une modification du tracé, il est souvent intéressant de pouvoir examiner les instants précédant et suivant cette modification. C'est la fonction "Jog".

Elle se fait habituellement par fractions successives selon un temps plus ou moins long (de 40 s. à quelques minutes). Il est, en règle, possible de vérifier toutes les parties désirées de l'enregistrement mais avec une manipulation plus ou moins complexe, et donc plus ou moins longue.

g) Enregistrement sur papier

Il est nécessaire de pouvoir enregistrer sur papier certaines anomalies du tracé.

Les possibilités d'enregistrement varient selon les appareils :

- possibilité d'enregistrement total et continu,
- possibilité d'enregistrement total, mais en discontinu (par fraction de quelques dizaines de secondes à quelques dizaines de minutes),
- là encore, il est de règle possible d'enregistrer sur papier tout le tracé, mais avec une manipulation plus ou moins longue.

3° Analyse automatique (Système informatique)

A partir de la reconnaissance de l'enregistrement faite par le lecteur, différents paramètres peuvent être analysés automatiquement par un système informatique et exprimés sur une imprimante :

- soit sous forme de courbes et diagrammes à interpréter,
- et parfois, en plus, sous forme d'un compte-rendu diagnostique.

Les possibilités sont variables selon les appareils.

a) Données numériques

- fréquence cardiaque. Maxima. Minima. Moyenne,
- nombre de complexes totaux,
- nombre d'extra-systoles ventriculaires, supra-ventriculaires,
- nombre de doublets, triplets,
- complexes R/T,
- prématurée,
- intervalle RR inférieur ou supérieur à un temps donné,

etc ...

b) Courbes et diagrammes

Nombre de paramètres sont figurés sous forme de courbes ou diagrammes.

La durée de l'intervalle RR, en particulier, est souvent représentée sous forme d'histogramme en barre. Ces histogrammes sont faits de petites barres représentant chacune la durée moyenne de RR pendant 5 ou 10 minutes.

Ces diagrammes, qui demandent l'apprentissage d'une technique de lecture particulière, permettent de repérer très vite les anomalies du rythme.

Effet-loupe :

Il est intéressant de s'arrêter sur les barres signalant une anomalie et de les reprendre en les étalant sur le lecteur. C'est ce que permet l'effet-loupe qui s'intrique parfois avec la fonction "Jog". La possibilité de faire rechercher automatiquement par le lecteur une barre déterminée en affichant son heure d'enregistrement est particulièrement intéressante dans cette optique (Cf. II-2).

Segment ST :

Les variations du segment ST sont également représentées par une ligne continue, faite d'une suite de segments représentant sa variation moyennée dans un temps de 5 minutes, autour d'une ligne de référence.

c) Aide au diagnostic

Les systèmes les plus perfectionnés donnent même un compte-rendu synthétique et une orientation diagnostique.

Il faut supposer que l'établissement du programme soit à la fois assez strict pour qu'il n'y ait pas d'erreur de lecture, et assez complexe pour que toutes les anomalies soient retenues. Ce système demande une confiance totale à la machine. Il n'est pas certain que cela soit possible actuellement.

EN CONCLUSION :

Il est possible d'exiger des différents appareils proposés par les constructeurs des critères précis. Mais il est beaucoup plus difficile, voire impossible, d'établir une hiérarchie absolue de ces appareils.

Le choix doit être fonction de l'usage que l'on veut en faire : recherche, clinique (orientation vers les troubles du rythme, l'insuffisance coronarienne). Il est fonction également de la disponibilité des médecins qui l'utilisent et de leur expérience, le danger nous paraissant être l'utilisation à grand débit de systèmes entièrement automatisés où le médecin n'intervient pas.

II. INTERET ET EXPERIENCE ACQUISE EN CARDIOLOGIE

L'enregistrement continu de l'E.C.G. en ambulatoire selon la méthode de HOLTER est venu combler un espoir formulé depuis longtemps par les cliniciens : pouvoir affirmer la concordance d'un trouble fonctionnel paroxystique (perte de connaissance, douleur, etc ...) à une altération de l'E.C.G.

La méthode est actuellement très largement utilisée et a fait la preuve de son grand intérêt. De nombreux travaux lui ont été consacrés, et lui sont encore consacrés car elle reste d'une grande actualité. On ne saurait tous les évoquer.

Nous donnerons les principales indications de la méthode telles que nous les avons mentionnées dans un précédent article (29).

1° Chez les sujets asymptomatiques

L'étude n'est pas sans intérêt ; elle a en particulier pour but de fixer les limites de la normalité.

Des études ont été pratiquées de façon intensive dans toutes les tranches d'âge (2-6). Elles ont permis de souligner la grande fréquence des troubles de la fonction sinusale chez le sujet jeune pendant le sommeil et le pourcentage élevé d'arythmies ventriculaires au cours du troisième âge. Certaines anomalies rencontrées permettent de confirmer l'importance des troubles rythmiques dans l'étiologie des morts subites.

2° Symptômes évocateurs d'une arythmie paroxystique

La sémiologie peut avoir une résonnance cardiaque : palpitations, irrégularité du rythme- ou neurologique : lipothymies, vertiges, syncopes, voire pertes de connaissance vraies.

Il est bien certain que cette technique d'enregistrement pendant une durée de 24 heures a une plus grande efficacité diagnostique qu'un électrocardiogramme standard, même un peu prolongé (5).

La méthode, ici, pourrait paraître décevante, d'abord parce que de nombreux "malaises" n'ont en fait aucun rapport rythmique cardiaque, ensuite, parce que, pour avoir quelque valeur, l'enregistrement doit avoir pu se dérouler au moment où la symptomatologie se produisait (3-7).

Néanmoins, certains auteurs font état de 25 % de cas où elle a été effectivement contemporaine d'un enregistrement continu (18).

D'autres statistiques ont mis en évidence jusqu'à 34 % d'arythmies considérées comme sérieuses et qui ont pu nécessiter la mise en place d'un stimulateur (14-25).

3° Symptômes en faveur d'une insuffisance coronarienne transitoire

L'intérêt de cette méthode est évident dans des cas particuliers : angor de Printzmetal, crise se déclenchant dans certaines circonstances de stress, patients âgés ou hypertendus.

Cette technique n'entre pas en concurrence avec l'E.C.G. d'effort, mais apporte un complément d'information appréciable.

L'équipe de l'Hôpital BROUSSAIS (24) a rapporté son expérience de corrélations avec la coronarographie. Elle indique 63 % de bonnes corrélations, c'est-à-dire HOLTER positif associé à des lésions coronaires et HOLTER négatif chez des patients sans lésion coronaire.

Les études comparant les troubles du rythme enregistrés au cours d'une épreuve d'effort et pendant un E.C.G. continu de 24 heures sont un peu contradictoires quant à la fidélité comparée des deux techniques (22-11).

Il semble néanmoins que les types d'anomalies enregistrées soient différentes dans les deux cas.

4° Patients présentant des extra-systoles ventriculaires

C'est un domaine particulièrement intéressant pour tous ceux qui tentent d'apprécier le risque de mort subite d'un patient porteur d'un trouble de l'excitabilité ventriculaire.

C'est ainsi qu'ont pu être mis en évidence des épisodes de tachycardie ventriculaire totalement asymptomatique (1-27).

Des corrélations ont pu être établies entre la survenue de ces épisodes et la fréquence des extra-systoles, leur mode de couplage, leur caractère uni ou multi-focal et l'existence de phénomènes R sur T.

L'incidence de ces arythmies ventriculaires sur le risque de mort subite est très différente selon qu'elles surviennent sur un coeur supposé sain ou dans les suites d'un infarctus du myocarde.

5° Patients dans les suites d'infarctus

Les études ont été nombreuses pour préciser la fréquence des troubles du rythme, leur période de survenue élective, leur incidence pronostique (1-5-10-16-19).

Tous les travaux s'accordent pour confirmer la fréquence des anomalies du rythme, aussi bien pendant la phase précoce que dans celle du premier mois après la nécrose. Il est établi que l'existence de troubles importants de l'excitabilité ventriculaire n'est pas sans incidence sur le pronostic vital des patients chez lesquels ils auront été détectés.

L'E.C.G. ambulatoire est également un bon instrument de surveillance du coronarien au cours de sa période de réadaptation et il permet d'apprécier de façon assez fidèle l'adaptation de son système cardiovasculaire aux efforts qui lui seront imposés (8).

6° Atteintes cardiaques diverses

Dans les myocardiopathies obstructives et non obstructives, une évaluation du risque de mort subite a été tentée (23).

On a pu mettre en évidence la fréquence des troubles du rythme dans la forme obstructive et l'incidence des épisodes de tachycardie ventriculaire sur le risque de mort subite.

Dans le prolapsus mitral (26), une étude détaillée des manifestations rythmiques a été réalisée. Elle montre la haute fréquence de ces troubles chez certains patients et leur corrélation avec les anomalies de la repolarisation remarquées depuis longtemps dans le syndrome de BARLOW.

7° Evaluation de la thérapeutique

Il s'agit certainement d'une indication privilégiée de cette méthode, et ceci dans quatre types de problèmes :

- l'efficacité des anti-arythmiques ne peut plus actuellement se concevoir en dehors d'un contrôle suffisamment prolongé de l'E.C.G. L'utilisation des méthodes statistiques a permis de préciser les critères nécessaires pour affirmer la réalité de l'action anti-arythmique (20-21-28). De plus, en indiquant de façon précise l'heure de la prise thérapeutique, on pourra mesurer le délai d'action de la drogue et sa durée d'action, éléments qui conditionnent les modalités de prescription (12-13),
- la surveillance des stimulateurs cardiaques : des dysfonctionnements intermittents sont souvent difficiles à mettre en évidence et nécessitent une étude prolongée en modifiant en particulier la position du patient. Un E.C.G. continu, surtout s'il est contemporain d'un éventuel malaise, peut contribuer très utilement à la détection de la panne. Il pourra également mettre en évidence certaines arythmies provoquées par le stimulateur et non perçues par le patient (1),
- le traitement des coronariens mérite également un contrôle de son efficacité, aussi bien sur d'éventuels troubles de la repolarisation que sur des manifestations rythmiques et ceci dans des conditions plus physiologiques que l'E.C.G. d'effort,
- la cardio-toxicité des médicaments pourra être, dans une certaine mesure, appréciée par son incidence sur le rythme cardiaque et sur la repolarisation.

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III. INTERETS EN MEDECINE AERONAUTIQUE DE LA METHODE DE HOLTER

La rareté des publications consacrées à l'enregistrement continu de l'E.C.G. en médecine aéronautique contraste singulièrement avec l'abondante littérature qui lui est consacrée en cardiologie.

Elles n'intéressent, le plus souvent, que des pilotes de transport.

Parfois, seule la fréquence est évaluée. Il s'agit, dans ce cas, d'une étude essentiellement ergonomique, pour évaluer la charge de travail par la fréquence cardiaque (3).

Certaines études portent sur un nombre très limité de cas (4 - 5 cas) ou des temps relativement courts (1 - 8 heures).

D'autres ont un caractère purement technique expérimental, ne concernant que le matériel (5-6-8).

L'absence de critères de normalité définis chez le personnel navigant est reconnu comme une des difficultés à l'emploi immédiat de la méthode (1).

L'intérêt de la méthode en médecine aéronautique se situe à différents niveaux.

1° Etude du comportement cardiaque du pilote en vol

Comme nous venons de le voir, cette étude n'a encore jamais été réellement faite.

Elle devrait intéresser :

- d'une part, le pilote de chasse soumis au fortes accélérations,
- d'autre part, le pilote de transport soumis aux ruptures de rythme circadien.

Le problème de la tolérance aux accélérations nous paraît d'une très grande actualité. En effet, de nombreux travaux sont actuellement consacrés à la tolérance aux hautes accélérations qu'auront à subir les pilotes des nouvelles générations de combat, et que nous avons déjà développés par ailleurs (9-10-11).

Avec la technique de HOLTER, il est possible d'enregistrer l'activité électrique du coeur du pilote dans toutes les phases des différentes missions (décollage, atterrissage, voltige, accélérations, basse ou haute altitude, etc ...).

2° Définition de critères de normalité

A partir de données recueillies sur un nombre suffisant, il serait possible de définir les critères de normalité. Apparition et fréquence d'extra-systoles ventriculaires à un certain niveau d'accélération, par exemple ; tachycardie à l'atterrissage, au décollage, etc ...

3° Adaptation du pilote à ses fonctions

De même, par exemple, le degré d'entraînement d'un sportif peut être suivi grâce à l'E.C.G., de même, certaines particularités de l'E.C.G. pourraient renseigner sur le degré d'adaptation du navigant à ses fonctions.

On sait, en particulier, qu'il existe une modification du tonus vagal avec l'expérience aéronautique (12) qui peut renseigner sur le degré d'adaptation. L'E.C.G. est un bon reflet du tonus vagal.

A propos des trois pôles d'intérêts que nous venons d'envisager, il faut rappeler la richesse des renseignements qu'à apporté l'étude de l'enregistrement continu de l'E.C.G. au cours des vols spatiaux (13-14).

Ainsi, ont été définies :

- des modifications E.C.G. spécifiques à l'espace,
- reconnues la fréquence et la bonne tolérance habituelle de certains troubles (extra-systoles ventriculaires).

L'analyse de l'E.C.G. et ses modifications a conduit à modifier la programmation des phases de travail et de repos.

D'une façon un peu paradoxale, ce qui a été fait chez le cosmonaute reste à faire chez l'aviateur.

4° Aide au diagnostic et à la décision d'aptitude. Sécurité aérienne.

Trois chapitres de la cardiologie posent de difficiles problèmes d'aptitude :

- les extra-systoles,
- les troubles mineurs de la conduction,
- les troubles primaires de la repolarisation.

En général, ces troubles sont bénins. Encore faut-il les départager des rares cas qui ne le sont pas. L'E.C.G. en vol peut y contribuer.

Une telle méthode ne pénalisera pas le pilote expertisé. En effet, le devenir en vol des troubles cités étant encore inconnu, l'expert a souvent tendance à se montrer sévère, mettant en avant, à juste titre, la SECURITE AERIENNE.

La vérification de la bonne tolérance du coeur en vol est un élément qui renforce la SECURITE AERIENNE et aide à l'octroi de l'aptitude.

L'emploi de la méthode de HOLTER en vol permettrait aussi de valider ou d'invalider des techniques d'expertise actuellement utilisées, comme la centrifugeuse de BRETIGNY.

La méthode apporterait beaucoup également à la connaissance du vaste chapitre des MALAISES EN VOL. Là encore, elle serait un appoint à la SECURITE AERIENNE.

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EPIDEMIOLOGICAL BASIS FOR THE PREVENTION OF CORONARY HEART DISEASE

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Coronary heart disease (CHD) is an important cause of premature death and of disability in the economically active population of most industrialized countries. Therefore there is a great need for measures to control this mass disease. This presentation deals with some of the controversies concerning links between life styles, behavioral factors and the risk of CHD and provides preliminary results of an ongoing controlled preventive trial.

1. IS PREVENTION OF CHD POSSIBLE ?

If CHD was an inevitable consequence of aging it would not be easily preventable. However, there are numerous data showing that the rate of occurrence of CHD is largely determined by the environment. Three different types of evidence are given as examples :

a. Geographical variation

There are important international differences in the occurrence of CHD. This can be illustrated by comparison of national mortality statistics. Differences were also documented in international prospective surveys. In the Seven Countries Study (1) the average annual incidence rate for CHD, in men aged 40-59 year at entry, varied from 15/10.000 in Japan to 198/10.000 in Finland. Differences in incidence of myocardial infarction were clearly documented by the Myocardial Infarction Community Registers (2).

b. The experience of migrants

It has been shown that men of Japanese ancestry living in the U.S. experience a higher rate of CHD than the Japanese in Japan (3). Along the same line data have been collected among Scandinavians living in their homelands and in the U.S.A., Irish people from Ireland and the U.S.A., Yemenits from Yemen and Israel (4-6).

c. Variation with time

A third set of evidence favoring the influence of the environment on the occurrence of CHD is the variation with time. The CHD rate observed in a particular country is changing. In most industrialized countries there is evidence of a marked increase in the 20th century, especially among the male population group. Changes in frequency are also occurring over short periods :-during the second world war there was a decline in CHD mortality in some European countries and this has been attributed to changes in diet (7); - since 1968 there is a decline in CHD mortality of more than 20% in the U.S.A. (8). Similar trends are more recently observed in other countries. Such comparatively rapid changes make an environmental explanation likely.

2. RISK FACTORS FOR CORONARY HEART DISEASE

Epidemiological studies have been important in identifying factors that are correlated with the subsequent development of clinical CHD. These have been called risk factors. Faced with a clear and significant association between disease and

some feature of the evironment some particular characteristics of this association should specifically be considered before drawing any conclusions about the nature of the relations.

a. Strength

How strong is the association between the factor and the disease. How important is the relative risk attributed to this risk factor ?

b. Consistency

How consistent is the observed association ? Has it been repeatedly observed by different persons in different places, different populations and times ?

c. Specificity

If a particular feature of the environment is specifically associated with one particular disease this is a strong argument in favour of causation. However it should be kept in mind that disease may have more than one cause and that environmental factors can promote different kinds of disease.

d. Temporality

A fourth characteristic to be considered is the temporal relationship of the observed association. Does for instance a particular diet lead to disease or do the early stages of the disease lead to particular dietary habits ?

e. Congruence

Finally the association should not seriously conflict with the known facts concerning the disease from experimental and clinical pathological studies. On the contrary it should be coherent with these findings. Out of a long list of possible risk factors and taking into account these considerations of the associations a selection of a few factors can be made. Some of these and especially some of the controversies that have appeared recently in the medical literature concerning these factors will now be considered.

3. THE RELATION BETWEEN FOOD HABITS, SERUMLIPIDS AND CHD

An article in an eminent journal (9) recently concluded that there were sufficient defects in the diet-heart theory to disregard any preventive action in that field. On the contrary many national expert committees had previously concluded that the evidence linking a high fat diet to the risk of CHD was sufficiently strong to recommend immediate steps to lower the fat content of the national diet of many industrialized countries. In several studies in different populations a clear relationship between the level of serumcholesterol and the incidence of CHD has been shown and the risk of CHD increases throughout the range of plasma cholesterol levels (10-13). What is the evidence to link dietary fat-intake to serumcholesterol ? Sound epidemiological studies among large heterogeneous populations using systematic methods of observation reveal strong correlations between CHD and habitual diet of the population (10,11,13)

Similarly most of the differences in average serumcholesterol levels between populations can be explained by differences in habitual diet. However, these correlations do not by themselves prove a causal relationship between dietary fat and CHD. In international comparisons there are also strong correlations between CHD mortality and sucrose intake, protein intake and other factors. These correlations must therefore be evaluated in the light of other data not only from epidemiological but also from clinical-pathological and experimental research. After having evaluated these data properly in the light of all other data sets, using the guidelines to weigh causative importance as defined above, strong evidence emerge supporting a primary role of fat, especially of saturated fatty acids on the severity of atherosclerosis and the incidence of CHD.

In studies of individuals within a single population a relationship between an individual's intake of saturated fat and his level of serumcholesterol or his risk of CHD was generally not found. This can be surprising also because it is easily possible to induce a change in an individual's serumcholesterol level by changing the fat content of the diet experimentally. Several explanations can be given to account for this lack of relationship between diet, cholesterol and CHD risk within a single population. Among these :-individuals vary markedly from day to day in their fat intake. Therefore it is difficult to characterize precisely a person's diet. It has been calculated that one needs to collect data over more than a full week period to characterize a single individual's diet with some precision. So the variability of the dietary methods is certainly one of the reasons why an association between diet and cholesterol is less apparent within a single population survey.
- The range of fat intake is much narrower within a single population than between populations. Therefore a lower-order correlation between dietary fat and serumcholesterol is expected within a single population.

4. THE RELATION BETWEEN SMOKING AND CHD

A second major factor that has been identified as a causal factor in CHD is smoking of cigarettes. Several prospective studies in different populations have shown that smokers have an increased risk for CHD than non-smokers. However, it should be noted that in countries where other risk factors - and especially the diet - lipid factor - are lacking and where the overall level of CHD is low - as for example in Japan - smoking appear not to be a risk factor for CHD.

Further evidence that the association between smoking and CHD is causal, is provided by the experience of ex-smokers. Studies in Sweden, the United Kingdom and the U.S.A. have all shown that ex-smokers have a lower risk of CHD. The longer the interval since stopping smoking the closer the CHD risk becomes to that of people who never smoked.

The case for including smoking cessation in a program for CHD prevention is strengthened by the knowledge of the possible benefits in reducing the frequency of other diseases.

5. THE RELATION BETWEEN THE ARTERIAL BLOOD PRESSURE AND CHD

As with serumcholesterol there is a strong relation between the level of the blood pressure and the risk of developing CHD and there is no clearly defined cut of point below which a blood pressure could be defined as "normal" as "bearing no risk". The lower the blood pressure, the lower is the risk. This is true for men and women and for all ages.

In preventive programs hypertension is defined from an operational point of view. If the action to be taken is treatment with drugs one must consider the possible side effects of the drugs and one must weigh up the possible benefits of therapy against the social, medical and personal costs of drug treatment.

On the benefit side the findings of the Veterans Administration trial (14) carried out in the U.S.A. have long been advocated. More recently data have become available from one of the greatest undertakings concerning the effect of anti-hypertensive therapy namely the Hypertension detection and follow-up program (15). This trial is a community based randomized, controlled trial involving 10.940 persons with high blood pressure. A systematic anti-hypertensive treatment program was compared with referral to community medical therapy.

In the special care group more than two thirds continued to receive medication over a five year period of the trial and more than 50% achieved BP levels within the previously defined normotensive range. Control of BP was consistently better for the special care group than for the referred care group. Five year mortality from all

causes was 17% lower for the special care group compared to the referred care group and 20% lower for the special care subgroup with entry DBP of 90 to 104 mm Hg compared to the corresponding referred care subgroup. These findings indicate that the systematic effective management of hypertension has a great potential for reducing mortality for the large number of people with high BP in the population including those with so called "mild" hypertension. These favorable results stimulates further preventive action and emphasize the importance of the real primary prevention of the development of hypertension. Research is urgently needed to the question of lowering blood pressure by hygienic means and even more to the question of how to prevent the development of hypertension.

6. MULTIFACTORIAL CONCEPT

Another very important point is that each of the three major risk factors - cholesterol, smoking, arterial blood pressure - contribute independently to the risk of CHD. The more risk factors an individual has, the greater is his level of risk. This concept is not only from academic importance; it also explains the excess risk of a majority of the population due to slight elevation of different risk factors.

7. OTHER RISK FACTORS

The three risk factors that have been discussed only account for part of the known variation in the occurrence of CHD. This is true for both the variation in CHD frequency between populations and within populations.

Other factors as physical activity, psychosocial factors, hardness of drinking water, diabetes and hyperglycemia, oral contraceptives are of great interest in explaining a part of the unexplained variation in CHD risk. Further research should take place into these factors and into their possible mechanisms. At the same time however, preventive efforts are needed to deal with the known major risk factors.

8. PREVENTIVE TRIALS

As a result of the evidence from epidemiologic, clinical-pathological and experimental research, several national bodies have made recommendations as to preventive strategies and at the same time, trials have been instituted to assess the efficacy of different modes of interventions.

a. The Belgian Heart Disease Prevention Project (BHDPP)

The BHDPP is a part of the WHO European multifactorial prevention trial (16). The questions under study are practical ones :

- to what extent can people be motivated to change behavior ?
- what is the best strategy ?
- will a reduction in CHD incidence follow ?

The study population was recruited in industry and the program operated at the participant's place of work. Thirty factories were recruited into the trial after they had first agreed to accept allocation to either the intervention or the control program. All male subjects, aged 40-59 years (n=19.390), were regarded as participants and were considered to be at risk for incidence measurements; the purpose of the trial was to assess the effect of the program on these communities taken as a whole and not simply on volunteers or on those who adhere to treatment.

Factories were arranged in pairs and within each pair one was allocated randomly to intervention and the other served as control; 84% of all invited subjects (n=16.222) took part in the screening examination. In the intervention group all the participants underwent a screening for cardiovascular risk factors. In the control group, 10% of the subjects was randomly selected to undergo a similar

screening examination; the remaining 90% of the control group was subjected to a resting electrocardiogram.

For all the subjects in the intervention group and for the 10% of the control group that underwent the same screening examination risk profiles were calculated on the basis of the initial results according to a risk score. The subjects of the top 20% of the risk score distribution were arbitrarily selected as the "high risk group". A six-year follow-up period is still ongoing. Changes in risk factor levels have been evaluated after two and four years (17-18).

The program is directed towards five risk factors :

- serumcholesterol;
- cigarette smoking;
- hypertension;
- obesity;
- sedentarity.

The lower risk group received booklets on particular risk factors and benefited from the mass counselling program including posters, anti-smoking conferences and dietary surveys of the canteens. Each individual's general practitioner was informed of the results of the screening as well as the occupational physician. The subjects from the high risk group were given individual advice, twice a year, by two physicians from the project. Annually and from the second anniversary on, every six months, a random sample of 5% of the total intervention group was invited for risk factor level measurement and individual counselling. By the end of the trial the subjects from the high risk group will have received advice at ten occasions while 8 times a 5% random sample of the total intervention group will have received individual instructions.

The mean systolic blood pressure (SBP) in the high risk subjects of the control group decreased after two years from 153.0 mm Hg to 147.9 mm Hg (-3.4%) as compared to a drop from 152.2 to 140.4 mm Hg (-7.8%) in the intervention group, the difference being highly significant. The mean SBP in the random sample of the control group did not change (141.0 versus 140.4 mm Hg) while the mean SBP in the random sample of the intervention group decreased from 139.1 to 132.5 mm Hg (-4.7%). The differences in SBP changes at four years were of the same magnitude.

In the high risk subjects of the control group the serumcholesterol level was respectively 262.2 and 263.1 mg% at baseline and after two year while in the comparable group of the intervention group a decrease from 264.8 to 254.5 mg% was observed. In the random sample of the control group there was an increase in serum cholesterol from 232.2 to 242.2 mg% as compared to a slight increase from 231.5 to 233.9 mg% in the intervention group. Changes in cholesterol correlate well with changes in dietary habits assessed through 24 hour food intake recalls in subsamples (17).

As far as smoking is concerned, 12% of the high risk subjects of the control group said they had stopped all cigarette smoking at two years; the corresponding precentage was significantly higher, namely 19%, in the intervention group. For the random samples there was an identical smoking cessation rate of 12% in both intervention and control groups.

Although the changes in individual risk factors have been small the potential effect on CHD incidence is not negligible. If it is assumed that the risk of CHD is fully reversible, one can estimate the potential effect of the degree of risk factor reduction using the multiple logistic function (MLF). At the second anniversary the risk of developing a fatal cardiac event or a non-fatal myocardial infarct over the next period of five years, increased with 12.5% for the high risk subjects of the control group, while it decreased by 25% in the intervention group. For the random samples a difference in MLF prediction of 27% was observed after 2 years.

b. Other preventive trials

In the last decade, different preventive projects have been instituted in the U.S. and in Europe. The efficacy in terms of risk factor modification of some of these trials has been assessed and presented. The Oslo study has published encouraging CHD incidence data (19). Most of the trials are still at an interim stage.

While waiting for results suggestions can be made to increase the potential benefit of prevention : to start intervention earlier in life, to prevent the formation of bad habits before pathological changes commence; to prevent that people start smoking, to prevent that hypertension develops and that the cholesterol raises. At the same time efforts have to be intensified to identify other etiological factors in the epidemiology of CHD in order to improve the ability to predict and to prevent the disease.

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PREVENTION OF CARDIOVASCULAR DISEASES

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Cardiovascular diseases, especially those caused by coronary heart disease, belong to today's major killers. They account for 55% of the total death rate in our country and are three times more important than cancer. Modern epidemiological research underlined the multifactorial origin of cardiovascular diseases and identified several risk factors.

The purpose of this brief review is to give a survey of the most important risk factors influencing cardiovascular mortality. At the same time we will provide the reader with various recommendations in order to decrease the adverse effects of these risk factors with regard to health and life expectancy.

THE SERUM CHOLESTEROL LEVEL

The higher your serum cholesterol level, the higher the risk you'll die from coronary insufficiency. Coronary insufficiency is due to partial or total blockage of the coronary arteries by atheroma or thrombosis. This results in the occurrence of angina pectoris or myocardial infarction.

Myocardial infarction (MI) is accompanied by a very high death rate. Approximately 25% of MI patients die during the (first) 48 hours after the infarction. Life expectancy for those who survive is much shorter.

Comparative studies of several population groups show that in populations with a low serum cholesterol level (<200mg%) coronary insufficiency is virtually absent. Recent studies have reported the following findings with regard to serum cholesterol levels. Serum cholesterol is bound to lipoproteins of different kinds; the most important are :

VLDL (very low density lipoproteins), LDL (low density lipoproteins), HDL (high density lipoproteins) and VHDL (very high density lipoproteins).

This classification is made on the basis of lipid density, molecular weight, diameter, form and composition. Several recent studies have demonstrated that HDL protect against arteriosclerosis and as a consequence we can state that the higher your HDL-cholesterol level is, the lower the risk for coronary heart disease.

LDL-cholesterol, however, easily permeates the cell membrane via specific receptors and is responsible for a chain of events which leads to the genesis of atherosclerosis. Thus, the higher your LDL level the higher your risk for coronary heart disease.

The total serum cholesterol level mainly reflects the LDL-cholesterol rate which is significantly correlated with total cholesterol. Recent studies have shown that the HDL level is similar in populations with a very different lifestyle and dietary habits ; this has as a consequence that it probably will be very difficult to modify HDL at the population level.

Diet is the most important factor to influence serum cholesterol level. The more saturated fat you consume, the higher your serum cholesterol will be. This has been demonstrated by many studies of populations in different coutries. Lowering LDL by means of a low saturated fat, high poly-unsaturated fat diet, will result in a higher HDL/LDL ratio. This ratio is probably the best indication of the risk for ischaemic heart disease. Studies carried out in our country have demonstrated a very significant correlation between butter consumption, serum cholesterol level and death rate in the population. Moreover, on the basis of mortality differentiation between types of blood groups and between the language communities (Dutch-speaking and French-speaking) in Belgium, it could be demonstrated that a decrease in serum cholesterol level of 1mg% would already result in a decrease of approximately 1,000 MI annually in Belgium.

Saturated fats are recognizable in that they are solid at room temperature such as butter and margarines. It is most important to reduce the consumption of saturated fats and to replace them by poly-unsaturated fats such as corn,oil, soya-been oil or sun-flower oil. Olive oil and peanut oil are less unsaturated but still much better than saturated fat. Researchers found that risk factors for chronic disease can be identified among young children and that the serum cholesterol level in adults is mainly influenced by nutrition during early years of life. Ideally primary prevention of atherosclerosis (in reducing fat intake) has to start from birth onwards already. In annex you will find a list of fat products to be avoided and those which can be used freely.

BLOOD PRESSURE

Hypertension (elevated blood pressure levels), that is a mean systolic blood pressure (SBP) of more than 110 mmHg and a diastolic blood pressure (DBP) of more than 90 mmHg, also increases the risk for coronary insufficiency and for cerebrovascular disease. Epidemiological research between populations led to the finding that blood presure is modifiable by habitual salt intake. Low salt populations show a low blood pressure and it does not rise with age. Even within population studies, in the Far East as well as in Western countries, revealed a positive correlation between blood pressure level and sodium intake.

The mean daily dietary sodium intake is astimated at 10 to 12g, whereas an intake of 3g of sodium is already sufficient. Virtually all processed foods are heavily salted. One of the most important sources of salt intake in the Western world is bread. It must be strongly recommended to lower the salt quantity in bread from approximately 12g per kg to approximately 3g/kg. To add salt in cooking and to use it at table in order to make food tasteful, is a dangerous misconception. Salt appetite is acquired and to palates accustomed since infancy to saltiness, the absence of salt is at first distressing but it only requires determination to substitute salt by herbs and seasonings other than salt. Individuals accustomed to a salt free diet may have no desire but, on the contrary, a distinct dislike of salt. Mothers usually add too much salt to the food of their children because they rely on their own taste. Well, the more one eats salt, the less one tastes it.

Salt contained naturally in foods sufficiently covers the actual metabolic requirements for sodium and a high salt intake is contrary to physiological needs. As a matter of fact, sodium can be considered a dangerous additive to the diet. Evidence is accumulating pointing to a blood pressure lowering effect of potassium, but still needs further investigation.

SMOKING

Cigarette smoking is considered the number one health hazard? It very much increases coronary heart disease mortality. Particularly in Western populations, cigarette smoking is the more dangerous because it accelerates the pathological processes already generated by an increased cholesterol level in the vascular tissues. Smoking 10 cigarettes a day from the age of twenty onwards has been shown to shorten life expectancy with five years on average. This reduced life expectancy is due to an increase of lung cancer mortality and especially to an increase of heart disease mortality. Somone smoking more than forty cigarettes a day from the age of twenty onwards, shortens his life expectancy with about 8.5 years.

It is clear that someone already suffering from a coronary heart disorder is even more susceptible to the adverse effect of cigarette smoking. Subjects with a MI continuing cigarette smoking have a lower life expectancy than those who quit. To quit smoking at once is the only thing to do for smokers to protect their health and prolong their lives. Attempts to gradually decrease smoking usually fail. Smokers cough and cough sputum very easily disappear after one stopped smoking.

Cigarette smoking also accelerates the ageing process of the skin, particularly of the face. After quitting, an inclination exists to gain weight. This can be prevented by simple dietary measures. Pipe or cigar smoking is far less dangerous to health as long as one does not inhale. In general, it should be kept in mind that every minute one smokes a cigarette one also shortnes his life with one minute and smoking a cigarette takes at least five minutes...

OBESITY

High body weight is invariably coupled with enhanced risk for coronary heart disease and hypertension. The ideal weight for a man is lower than we used to think. It amounts to 0.96kg for each cm above the one meter line. This optimal weight score is even lower for women. The only harmless remedy to lose weight is to eat less. Most people who are overweight think they do not eat much but after close examination things turn out differently. If you say that you could still eat more this does not necessarily mean that you did not eat enough already.

One of the main causes of obesity is chronic alcoholism which often gives rise to heavy social difficulties. Daily consumption of more than 3 beers or 3 glasses of wine or 3 doses of spirits, is considered too high. Chronic alcoholism also results in psychological distress and causes an enhanced risk of severe liver disease. One has to fight chronic alcoholism with all possible means, this is a social task for all of us. A limited alcohol intake -within the above mentioned limits- is not linked to harmful side effects.

LIFESTYLE

Modern life is often very hectic. Economic stress, tensions, noise, pace of life, social competition, extra responsibility make life very strenuous. Very often we we get frustrated not to be able to realize our objectives because of too much competition. Most of us lack leisure time and physical activity. Relief from everyday strains restores the joy of living. Get away from your routine work and do somethink you enjoy. A weekly walk of 5 to 10 km or a bicycle ride of 40 to 50 km is highly recommendable. Take time to relax and exercise regularly. Be careful, however, not to put too much stress on physical exercising exclusively, especially if you did not exercise regularly before. Population groups achieving regularly laborous work show ischaemic heart diseases if their diet contains much saturated fat.

GENETIC FACTORS

Heredith plays an important role in the genesis of both hypertension and ischaemic heart disease. We should be careful, however, not to overemphasize the susceptibility to degenerative diseases under genetic influences. Not everyone who smokes will get lung cancer. What is e.g. the significance of genetic predisposition to develop lung cancer by cigarette smoking if one does not smoke ? The same holds true for someone who does not use salt and very little saturated fat, here again, genetic predisposition is of minor importance.

Thus, the alert individual can do very much (more than the doctor) to protect himself from getting these heart disorders. Knowing this gives us the incentive to be less fatalistic and to take better care of ourselves. The key to a long and happy life is to use as little saturated fat as possible, as little salt and refined sugar as possible and not to smoke. Exercise regularly in order to stay (or become) fit and enjoy your leisure time.

Epidemiological research demonstrated that in many people one or more of the higher mentioned risk factors are present, yet, these people are not aware of their presence. The above recommendations are the more important for people with a higher risk of getting cardiovascular diseases due to the presence of one or more risk factors. We should realize that a longer life is chiefly up to us.

TO BE AVOIDED :

Fat : mutton fat, cooking fat, saturated margarines.

Eggs : all kinds of eggs.

Milkproducts : all kinds of cheese, cream, ice cream, whipped cream, yoghourt, whole milk.

Meat : beef, pork, mutton, veal, bacon, sausages, minced meat.
Lean meat still contains 20% fat. It is therefore strongly recommended only to eat 100 g of meat per day, 4 times a week.
Oxo-cubes, canned soup (virtually all foods processed for the general market, except fruit and juices, are heavily salted).

Specialties : chinese food (bami-goreng, nasi-goreng) in cans or deep frozen.

Pastry : cakes and buns, tarts.

Bread : wholemeal bread.

Chocolate : all kinds, chocolates, chocospread.

Delicacies : crisps, peanuts, marzipan, coconuts and coconut oil.

RECOMMENDED FOODS

All kinds of vegetables and fruit, all kinds of fish (unsalted), skimmed mi[illegible] (eventually with corn oil for the preparation of rice, custard etc.), low fat yoghourt, corn-oil, sunflower oil, soya-bean oil, unsaturated margarines, cocoa-powder for preparation with skimmed milk, nuts (except cocnuts and peanuts), bread, potatoes, rice ; all herbs and seasonings (without added salt) are allowed as well as vinegar, lemon, saltless mustard, honey and jam.

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CARDIOVASCULAR PROBLEMS DURING THE PILOTS CAREER

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Introduction

In a population which is highly selected at entry and which is generally composed of the younger age groups in our Air Forces the pattern of cardiovascular problems tends to depart from that of the general population. In particular congenital heart disease, valvular disease, and hypertensive heart disease consequent upon chronic renal disease are comparatively rare. The effects of repeated regular physical and ECG examinations of aircrew also tend to produce special problems of the elucidation of presymptomatic cardiovascular disease rather than the management of symptomatic patients and it is this special experience of Air Force medical officers which comprises much of the substance of this advanced operational aviation medicine course.

Out of the very large field of possible subjects in cardiology I have chosen to discuss in this context the following subjects:-

Essential Hypertension
Ischaemic Heart Disease
Arrhythmias
Myocarditis including Sarcoidosis

Essential Hypertension

The initial problem is one of definition. Pickering[1] has stated that no clear cut levels of blood pressure separate health from disease and that even within any given "normal" range of blood pressures those in the lower range will tend to have a better life expectancy than those in the higher range. For practical purposes however we need a sensible compromise and in recent years there have been two reports (2, 3) on the cardiovascular health of airline pilots which agreed on the following table of blood pressure ranges related to age which have been accepted with slight modification by the Royal Air Force as guidelines for the assessment of blood pressure.

Table

Age	Unadjusted	Adjusted
20-29	140/90	-
30-39	145/90	155/95
40-59	155/95	165/100

These levels should be compared to the average of repeated 'casual' measurements of blood pressure in an individual pilot without any attempt to obtain a 'basal' blood pressure level by prolonged rest or sedation. In cases of doubt we advise repeated examination by more than one examiner and we find the use of a "random zero" sphygmomanometer or an automatic cuff blood pressure recorder extremely useful. We now use the 5th phase of the Korotkoff sounds as routine for the diastolic level, recording the 4th phase when there is no clear cut off point for the 5th phase.

The reference in the Table to "adjusted" levels refers to the levels which may be accepted after a completely negative investigation of the pilot. Our practice is to investigate each case where blood pressure exceeds the unadjusted levels with particular reference to other risk factors for ischaemic heart disease (IHD) and for evidence of target organ damage. This will include full blood and urine biochemistry, retinal examination, chest X-ray and ECG examination. IV urography is now not routine unless other factors indicate the need for it. Our experience has shown that less than 2% of symptomless hypertensives show any abnormality on this exam and in most cases the abnormality is not likely to be causal.

Management of Hypertension

Where, as rarely happens, a causal condition is found at investigation loss of flying category is automatic except in the even rarer cases where the cause and the blood pressure can be permanently corrected. In the vast majority of pilots the problem of management remains the dilemma of whether or not treatment should be instituted. This dilemma is illustrated by the consideration of the prognostic danger to the individual by withholding treatment as opposed to the potential loss of career and loss of money to the nation if he is put on treatment (4). In contrast to practice in the case of civil professional pilots the decision is further made difficult by the lack of aircrew roles available to those with any restriction of flying category. Our present policy can be summarised as follows:

(1) We grant a reasonable period of time for mild cases to be reviewed while they correct risk factors by losing weight or stopping smoking, and generally improving physical fitness.

(2) If their levels fall they continue without treatment but under increased surveillance.

(3) Where the BP readings continue consistently above the 'adjusted' levels the overall risk is assessed to decide whether treatment is indicated.

(4) Diuretic therapy is still used as an initial treatment. Where complete evaluation while on treatment shows an excellent uncomplicated response a few pilots may continue flying without restriction depending on their age and role. The majority will be restricted. Career decisions are discussed between the medical and air operations staff.

(5) The use of betablockade as an alternative or additional treatment is under urgent review and research. Other hypotensive agents are not expected to be considered for military pilots.

Betablockade has in recent years been increasingly used as a first line hypotensive drug in civilian practice. As with other possible agents its use in aircrew would depend upon satisfactory elimination of the likelihood of its producing either or both orthostatic effects under accelerations or central effects on human performance. Work on these aspects is proceeding in a number of countries. So far Glaister (5) has reported no significant orthostatic effect in the human centrifuge. Nicholson (6) has shown that the newer betablocking drugs such as acebutolol and atenolol appear to have minimal central effects in animals whereas Propanolol is liable to effect reaction, time and accuracy. Work on human subjects is continuing.

Ischaemic Heart Disease

Only a short review of this vast subject is possible in this paper. Comparison of the incidence of IHD between civil professional pilots and the Framingham population suggests that selection and regular physical examination produce reduced rates in aircrew and there are hopeful reports that the overall incidence and mortality in high risk populations is declining as the education of the public on the avoidance of the established risk factors takes effect. As regards aircrew the main problem is that of presymptomatic diagnosis. Symptomatic cases in military aircrew will surely continue to be made unfit despite the apparent continuing liberalisation of attitudes by civilian licensing authorities.

The main source of case material remains the abnormal ECG which is the subject of other papers in this course. At the present time all pilots in the RAF have an annual resting ECG and exercise stress testing is not routine, but reserved for the further evaluation of doubtful cases. We use treadmill exercise in preference to a bicycle egometer and the Masters test is only used as a preliminary screen in some cases. We tend to interpret ST changes as abnormal fairly strictly by the criteria of the Bruce protocol but we have of course always got the borderline problems. We have been very interested recently in the effects of catecholamines released by anxiety on the ST segment which have been reported by Taggart. He feels that these false positives produced in resting and exercise ECGs can be shown to be normal by repeating the tests after a small dose of a betablockading agent. We hope this will result in a reduction of our cases with abnormal ECGs subsequently shown to have normal angiography.

Our present policy for the investigation of cases with abnormal resting ECG is as follows:-

(1) Treadmill exercise with Bruce protocol.
If negative - surveillance.
If positive proceed to (2).

(2) Temporary grounding. Assessment of risk factors. Repeat exercise tracing with betablockade followed by Echocardiography. If negative - close surveillance. If positive proceed to (3).

(3) Coronary Angiography and Ventriculography and Isotope Cardioperfusion studies.

In general terms any significant degree of coronary stenosis proven by these data will make the pilot unfit for military flying. The definition of significance is variable according to the vessel involved but we find it difficult to accept the whole Bethesda (3) recommendations as applicable for military pilots. The incidence of positive angiograms is in fact very low and does not accord with the observed incidence of significant coronary narrowing in all aircrew autopsies described by Mason (7). We have had no certain fatal accident caused by a cardiac incapacitation in flight in the RAF but the velocity of military aircraft accident impact often produces destruction of the heart and the data cannot be complete. Meantime we have seen a number of cases where the cause of the accident has been known to be unrelated to medical causes but where autopsy has shown gross coronary artery disease so that the difficulty of certain proof of cardiac incapacity in an unexplained fatal aircraft accident remains.

Arrhythmias

The arguement as to the prognostic significance of ectopic beats in symptomless individuals continues. The situation has almost been made worse by the data produced by 24 hour monitoring of large numbers of asymptomatic individuals. Minor arrhythmias are now known to be very common, particularly during sleep. Once again we take the pragmatic view that an occasional finding of ectopic beats is likely to be of no significance. This particularly applies to supraventricular ectopic beats. Frequent ventricular ectopic beats (VEBs) are further investigated. We tend to use both 24 hour monitoring and the effect of a maximal exercise stress test. If these do not show any further dysrhythmic tendency we do not disqualify the pilot. Ventricular tachycardia, even in short bursts, we regard as virtually disqualifying even if full investigation proves no certain aetiology.

Supraventricular tachycardia (SVT) and atrial fibrillation (AF), the latter usually paroxysmal, seem to be on the increase in the general population and there have been suggestions that AF may often be related to excessive alcohol consumption. We investigate to eliminate that possibility as well as the more usual causes such as hyperthyroidism. Occasional senior pilots with no loss of effort tolerance have been given very restricted flying categories with established AF but the tendency is to disqualify the younger man with AF or SVT unless there is prolonged remission after full investigation and treatment. Occasionally we find a case of Wolff Parkinson White syndrome in this group whose ECG pattern was intermittently normal and so missed at initial examination.

Myocarditis

We have been interested in this aspect of cardiology since Stevens and Underwood Ground (8) described the finding as incidental in a number of hearts of pilots at autopsy. More recently Rainford and Lewes reported the association of ECG changes with myalgia occurring in patients suffering from viral and mycoplasma infections. They noted that the ECG changes could closely mimic IHD or septal cardiac infarction and advised that such ECG changes in a symptomless individual should be the cause of inquiry into their previous history for a recent pyrexial illness marked by muscle pains. In all their cases where such changes were found a history of severe myalgia was invariable. We now include such inquiries in our investigation of abnormal ECG patterns. The persistence of ECG changes for up to 12 months after such an infection can be very worrying to both the pilot and his medical advisers.

The association of Boeck's Sarcoidosis as a cause of potential aeromedical risk of incapacitation has been the subject of increasing risk in recent years. Fleming reported an apparent high incidence of myocardial involvement in Sarcoidosis of perhaps 15% of all cases. Evidences of involvement may present as conduction disturbances or arrhythmias, or the ECG may again mimic patterns of myocardial infarction. The presentation may be as sudden death. The disturbing aspects are the fact that a mild asymptomatic form of the disease detectable only by chest X-ray abnormalities does not preclude the possibility of cardiac involvement and that the elapse of time even of years after the original diagnosis does not eliminate the possibility of sudden death from this cause. Pettyjohn et al (10) commented upon the threat to air safety comprised by a history of this disease. Arguement still continues as to whether the risk can be excluded by rigorous cardiac testing or whether a history of sarcoidosis should be totally disqualifying. The situation is being reviewed by several Air Forces.

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DISPOSITION OF ELECTROCARDIOGRAPHIC ABNORMALITIES IN AVIATORS

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INTRODUCTION

The diagnostic criteria for specific findings in electrocardiography have traditionally been based on a symptomatic or hospitalized population. The present criteria for disposition of electrocardiographic abnormalities in United States Air Force aviators are based upon findings within the flying population and observation of the natural history of specific electrocardiographic findings. It must be remembered that electrocardiography is not an exact science. The electrocardiogram is a laboratory test requiring a history, physical examination, and other laboratory tests for interpretation.

This paper will be devoted to a discussion of serial ST and T wave changes, ectopic atrial and ventricular beats, ventricular tachycardia, supraventricular tachycardia, conduction abnormalities such as right and left bundle branch block, Wolff-Parkinson-White electrocardiographic finding, sinus bradycardia, and sinus pauses. The current aeromedical dispositions for these abnormalities will be discussed. The disposition of certain aeromedical abnormalities will remain flexible and continue to evolve as more experience is gained in dealing with healthy aviators.

PREVALENCE OF ELECTROCARDIOGRAPHIC ABNORMALITIES

All aviators receive an initial electrocardiogram (ECG) upon entry into flying duties and annually thereafter beginning at age 35. An analysis of all initial ECGs performed in the U.S. flying population reveals that 82.6% of the ECGs are normal. Ten percent of these normals are labeled as normal variants. Of all initial ECGs, 17.4% are abnormal. A normal variant is a finding which is sufficiently common in normal individuals that it is usually not associated with underlying organic heart disease, incapacitating events, or a shortened life span. No waivers are required for normal variants, but extensive workups may occasionally be required to clarify their significance. For example, ventricular premature beats are common examples of a normal variant which may also represent heart disease. One may define a normal variant in one of two ways. The first definition may be based upon prevalence, or one may choose to use a second criterion which is the state of health of the individual. A normal ECG, when defined in terms of prevalence, means that it agrees with the commonly established types of ECGs. The prevalence definition of abnormal simply means that it is contrary to the usually observed type of ECG. A normal ECG, when defined in terms of the state of health of the individual, means that the individual is "healthy". Conversely, an abnormal ECG means that the individual is "not healthy". Obviously, to judge an ECG from the state of health requires more information than one usually has accompanying the electrocardiographic tracing. A normal variant, when defined from the state of health, usually means that an atypical electrocardiographic feature is present, or that the electrocardiographic findings exceed criteria for abnormality in a person known not to have the disease suggested by the criteria. A normal variant, defined from the standpoint of prevalence, usually means that the ECG falls outside the established limits of normal, but does not reveal a significantly greater prevalence of disease than in otherwise healthy individuals. Diagnostic criteria based upon prevalence are preferable in an asymptomatic population. In an asymptomatic population, especially a population of healthy aviators, an abnormal tracing must be considered the tracing of an individual at increased risk. A waiver is required for all abnormal ECGs, and in the United States Air Force (USAF) only the Surgeon General of the Air Force can grant this waiver. Continuation of this waiver is contingent upon periodic reevaluation at the United States Air Force School of Aerospace Medicine (USAFSAM).

THE SIGNIFICANCE OF AN ABNORMAL TRACING

An abnormal tracing in a population of healthy aviators usually means that a potentially serious condition would have been overlooked had it not been for the annual ECG. Further, the majority of the abnormalities potentially represent a threat to flying safety. Many of the abnormal findings when viewed alone would have been considered nonspecific, but when compared to the previous ECGs on file represent a significant serial change. The USAF Central ECG Library at USAFSAM is serial change oriented, and herein lies the strength of the centralized library approach. The scalar ECG remains as the basic tool in the early detection of coronary artery disease, cardiomyopathy and arrhythmias.

SPECIFIC ELECTROCARDIOGRAPHIC FINDINGS BY AGE

Approximately 30% of aviators aged 50 years or over in the USAF have an abnormal ECG. The most common abnormality seen is that of repolarization changes, largely ST and T wave changes. The prevalence on the initial ECG is lowest in the 30 to 34 year age group. This is the age before which coronary artery disease, hypertension, cardiomegaly, and cardiomyopathy begin to appear. It is also the age after which most conduction disturbances, congenital heart disease, and other abnormalities have been screened out. After an initial normal ECG, low amplitude T waves remain rather static over time, while nonspecific T wave changes continue to increase to a maximum of 320 cases per 1,000 at age 50 to 54. Repolarization abnormalities, consisting of ST segment changes, have a strong correlation with age, and are present in 280 out of every 1,000 aviators by age 40. Serial repolarization changes

on a resting ECG increase the predictive value of the treadmill two-fold. ST changes are most meaningful when they occur in a serial manner.

EVALUATION OF REPOLARIZATION CHANGES

Serial repolarization changes require a repeat fasting 12-lead ECG and a maximal treadmill exercise test. Each aviator with serial repolarization changes should also receive a thorough risk factor analysis. Positive treadmill exercise tests should receive thallium scans, but thallium has not yet replaced cardiac catheterization in the USAF aeromedical evaluation service.

PREMATURE BEATS

A study of premature beats on the initial ECG reveals that ventricular premature beats are much more common in the older age group. While the great majority of premature ventricular and premature atrial beats occur in those without heart disease, the steady rise in ectopic beats with age parallels the increased prevalence of hypertension, coronary disease, and cardiomyopathy. After an initial normal ECG, the prevalence of supraventricular premature beats remains rather constant, while ventricular premature beats continue to rise, reaching a maximum of 260 per 1,000 at age 40. Premature atrial contractions are important because they represent the substrate upon which atrial tachycardia, atrial flutter, and atrial fibrillation occur. Just as it is often difficult to know the true significance of atrial premature beats, ventricular premature beats may occur with great frequency in both healthy persons and in those with heart disease. While ventricular premature beats are frequently seen in healthy individuals, they may also occur as harbingers of organic heart disease, including cardiomyopathy, hypertension, metabolic disturbances, and coronary artery disease. The presence of new atrial or ventricular premature beats as a serial change on an ECG requires a Holter monitor. A tracing of at least 12 hours in length will net over 75% of the serious arrhythmias.

We are well aware that arrhythmias which may not be present in the resting state may be produced by increasing sympathetic tone, by increasing myocardial oxygen demand, or a combination of both factors. However, whether an exercise-induced arrhythmia represents an independent predictor of coronary artery disease is unclear. In particular, we have been concerned at USAFSAM as to whether or not the presence of ventricular premature beats during exercise testing represents a significant marker for coronary artery disease.

We studied 51 asymptomatic men (Group I) with abnormal exercise tests and at least a single vessel diseased at the 50% level on coronary angiography.(1)

TABLE 1

GROUP I

1. 51 asymptomatic subjects
2. Mean age 45 ±5.8 years
3. No resting ventricular arrhythmia
4. "Positive" exercise tests
5. At least one vessel with $\geq$ 50% lesion

We then constructed an age-matched control group of asymptomatic subjects (Group II) who also had positive exercise tests, but no angiographic coronary artery disease.

TABLE 2

GROUP II

1. 51 age-matched asymptomatic subjects
2. "Positive" exercise tests
3. No asymptomatic CAD

We then constructed a third control group of age-matched asymptomatic subjects with normal exercise tests, normal noninvasive cardiovascular evaluations, and low risk cardiovascular profiles (Group III).

TABLE 3

GROUP III

I. 51 age-matched asymptomatic subjects
2. Normal exercise test
3. Low risk cardiovascular profiles
4. Normal noninvasive studies

The exercise test of each subject within these groups was thoroughly analyzed for a number of characteristics as well as the presence or absence of ventricular premature beats (VPBs).

TABLE 4

ARRHYTHMIA CHARACTERISTICS EVALUATED

1. Presence of any ventricular arrhythmia
2. Complex arrhythmia
   - A. >5 VPBs per minute
   - B. Bigeminy, trigeminy
   - C. Paired VPBs
   - D. Multiformed VPBs
3. Pattern of onset
4. Ventricle of origin
5. Peak heart rate
6. Duration of exercise

Forty-three percent of Group I demonstrated a ventricular arrhythmia. The frequency of ventricular arrhythmias in Groups I and II was 35% and 49% respectively. The figures did not reveal a statistically significant difference among the groups for prevalence of ventricular arrhythmias.

TABLE 5

FREQUENCY OF VENTRICULAR ARRHYTHMIAS

GROUP	PREVALENCE	COMPLEX	RBBB* CONFIGURATION	PEAK EXERCISE
I (n=51)	22	6	9	15
II (n=51)	18	4	7	13
III (n=51)	25	8	3	22
P Value	NS	NS	<.025	NS

*RBBB - Right Bundle Branch Block

These data compare closely with those of exercise-induced arrhythmias in healthy populations. These figures underscore the observation that exercise-induced ventricular arrhythmias are very common at or near maximal exercise in patients without clinical evidence of heart disease. When complexity of the arrhythmia was analyzed as a possible discriminant, no difference was noted. A complex arrhythmia was noted in 27, 22, and 32% respectively, differences which are not significant. The only finding of statistical significance was that of configuration of the ventricular premature beats.

TABLE 6

CONFIGURATION OF INDIVIDUAL VPBs

SUBJECTS WITH VPBs	RBBB CONFIGURATION	LBBB* CONFIGURATION	MULTIFORMED	INDETERMINANT
I (n=22)	9	9	1	5
II (n=18)	7	6	2	3
III (n=25)	3	17	2	3

*LBBB - Left Bundle Branch Block

Although an analysis of the configuration of ventricular premature beats did not separate those with angiographic disease from those without, both groups with positive exercise tests demonstrated a predilection for a RBBB pattern, implying origin in the left ventricle. An apparent left ventricular origin was seen in 41% and 39% of the group with positive exercise tests. However, a left ventricular origin was noted in only 12% of those with negative exercise tests.

TABLE 7

FREQUENCY OF RBBB CONFIGURATION

SUBJECTS WITH VPBs	RBBB CONFIGURATION
I (n=22)	9 (41%)
II (n=18)	7 (39%)
III (n=25)	3 (12%)

A widespread belief has existed that ventricular premature beats of a right ventricular origin have more benign implications than those originating from the left ventricle. This is consistent with the observation that the majority of ventricular premature complexes in persons with normal hearts originate in the right ventricle. Studies from the coronary drug project revealed a significant relationship between left-sided ventricular premature beats and decreased survival rates. In this USAFSAM study, left ventricular premature beats, which are generally regarded as most likely to occur in the presence of a diseased left ventricle, were equally frequent in those with positive exercise tests, with or without coronary artery disease. If the left ventricular origin of ventricular premature beats is to be viewed as a marker for disease, perhaps the term "false positive exercise test" must be reassessed. We are all well aware that a positive exercise test, in and of itself, is a potent risk factor. However, in our USAFSAM population, the prevalence, complexity and time of occurrence of ventricular premature beats are not strong indicators of coronary disease in an asymptomatic population. Further, a RBBB pattern (implying left ventricular origin) does not discriminate between the two angiographic categories. The RBBB pattern was statistically more frequent in the positive treadmill group, and the presence of a right bundle pattern of ventricular premature beats correlates with an abnormal treadmill irrespective of angiographic findings.

Ventricular premature beats are the substrate from which more serious arrhythmias frequently arise. Exercise-induced ventricular tachycardia occasionally arises during exercise testing of apparently healthy males. Exercise-induced ventricular tachycardia has been seen at USAFSAM in 0.5% of all treadmills performed. We compiled a list of 45 males (age range 25 to 60 years) with a mean age of 43 years.(2) All of these individuals had asymptomatic exercise-induced ventricular tachycardia. The mean followup period was six years in the 43 individuals for whom followup data was available. Of these 43 individuals, 9 or 21% had cardiac events.

TABLE 8

EXERCISE-INDUCED VENTRICULAR TACHYCARDIA

FOLLOWUP

43 patients

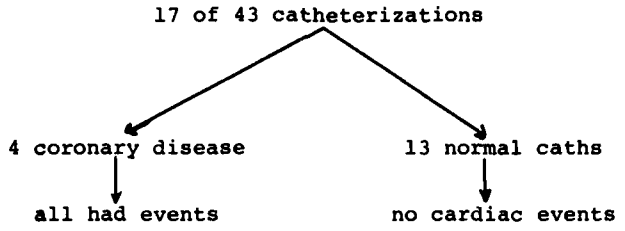
9 cardiac events (21%)

3 deaths	6 nonfatal events
Amyloid, 9 mos.	4 Angina
Sudden death, myocardial infarction, 3 yrs.	2 infarctions
Sudden death, mitral valve prolapse, 6 yrs.	

There were three deaths, one with amyloid at nine months, one sudden death due to myocardial infarction at 3 years, and one sudden death in a patient with mitral valve prolapse at 6 years. Six nonfatal events occurred, four experiencing angina and two myocardial infarction. Since ventricular tachycardia is a disqualifying and nonwaiverable arrhythmia in the USAF, these individuals could not be returned to flying status, even with a normal cardiac catheterization. However, 17 of the 43 underwent cardiac catheterization for delineation of their clinical status.

TABLE 9

EXERCISE-INDUCED VENTRICULAR TACHYCARDIA



Four of these subjects who were catheterized had coronary artery disease and 13 were normal. None of the patients with normal cardiac catheterizations had cardiac events during the followup, and all of the patients with coronary artery disease had subsequent events. Multiple characteristics of the ventricular tachycardia as well as the Holter monitor and echocardiogram were analyzed in an attempt to find a discriminator for those predisposed to future events.

TABLE 10

EVENT VS. NON-EVENT GROUP

NONDISCRIMINATORS

1. Length of ventricular tachycardia
2. Number of episodes
3. Rate of ventricular tachycardia
4. Configuration of ventricular tachycardia
5. Heart rate of onset
6. ST segment response
7. Holter monitor
8. Echocardiogram

Neither the length of the tachycardia, the number of episodes, the rate of the ventricular tachycardia, configuration of the ventricular tachycardia, heart rate at onset, ST segment response, Holter monitor data, or the echocardiogram revealed any discrimination between those with and without subsequent events.

Table 11 enumerates the reasons for referral to USAFSAM. It is noteworthy that 13 of the 45 individuals with exercise-induced ventricular tachycardia were referred to USAFSAM for noncardiac reasons.

TABLE 11

REASONS FOR REFERRAL TO USAFSAM

(n=45)

Noncardiac reasons	13
Serial nonspecific ST-T wave abnormalities	9
Hypertension	7
Acquired RBBB	6
Frequent VPBs	6
Remote episodes of atrial fibrillation	3
First-degree atrioventricular block	1

We further attempted to describe the nature of the exercise-induced ventricular tachycardia (EIVT).

TABLE 12

DESCRIPTION OF EIVT

(n=45)

Single episode of 3 VPBs in a row	26
Single episode of 4 VPBs in a row	7
Multiple episodes of 3 to 7 VPBs in a row	12
Sustained ventricular tachycardia	0
Symptoms with VPBs	0

Technical ventricular tachycardia is three VPBs in a row. Of the 45 subjects, 26 had only technical ventricular tachycardia, and an additional 7 had only 4 VPBs consecutively. Of the 45, 12 had multiple episodes of ventricular tachycardia, but all episodes were less than 7 VPBs in a row. All subjects were asymptomatic during the exercise-induced ventricular tachycardia. We further attempted to look at the pattern of ventricular ectopy in reference to the ventricle of origin. The differences were not significant.

TABLE 13

PATTERN OF VENTRICULAR ECTOPY*

(n=45)

RBBB	24
LBBB	18
Mixed	3

*Defined as greater than 10 VPBs per minute, pairing, multiformity, or bigeminy.

Arrythmias which might have been considered as "warning arrhythmias" were analyzed. Greater than 10 ventricular premature beats per minute, pairing of VPBs, multiformity, or a bigeminal pattern were all considered to represent warning arrhythmias. Of the 29 subjects with warning arrhythmias, 6 had subsequent cardiac events while 23 did not.

TABLE 14

WARNING ARRHYTHMIAS*

(n=45)

Patients without cardiac events	23
Patients with cardiac events	6

*Defined as greater than 10 VPBs per minute, pairing, multiformity, or bigeminy.

Table 15 compares this group of individuals with exercise-induced ventricular tachycardia to USAFSAM evaluation subjects with normal cardiovascular systems, and to the USAF flying personnel at large. A comparison of event rates reveals that cardiac events were significant in the exercise-induced ventricular tachycardia group at a significance of $p<.001$.

TABLE 15

COMPARISONS OF THIS STUDY GROUP AND OTHER USAF GROUPS

Population	N	Cardiac Events	CAD
USAF flying personnel	47,896*	222**	unknown
USAFSAM Group V***	710	unknown	7
EIVT Group	43	12	7+ ($p<0.001$)

*Mean population 1970-1976 inclusive

**Total number of events 1970-1976 inclusive

***Normal men referred to USAFSAM for noncardiac minor health problems which could affect flying suitability

+$p<0.001$ for comparisons with both groups

Thus, there are some valid conclusions regarding exercise-induced ventricular tachycardia in healthy men. Men with exercise-induced ventricular tachycardia are definitely at an increased risk for sudden events. Exercise-induced ventricular tachycardia is unsustained, usually occurs in late exercise or recovery, usually occurs at heart rates less than 150 beats per minute, and is usually an isolated event. Antecedent complex arrhythmias are usually absent. Holter monitoring is invariably unrevealing in these subjects. Particularly noteworthy is the fact that all of the patients at risk for sudden events with exercise-induced ventricular tachycardia could have been identified by catheterization or a thorough noninvasive evaluation. In terms of aeromedical disposition, ventricular tachycardia remains a nonwaiverable arrhythmia in the USAF. With further long-term followup, it is conceivable that those with completely normal cardiac evaluations, including cardiac catheterization, may be considered for limited flying duties.

AEROMEDICAL DISPOSITION OF SUPRAVENTRICULAR TACHYCARDIA

Supraventricular tachycardia is a problem with serious implications for sudden incapacitation due to compromised myocardial function. Even in the healthy individual, rapid sustained tachycardias, with very short diastolic filling periods, may lead to inadequate cardiac output and near syncope or frank syncope. Further, individuals with subclinical coronary artery disease may develop symptoms of angina, heart failure, or cardiovascular collapse as the sustained tachycardia causes the coronary artery disease to become clinically manifest. Prior to 1974, all episodes of supraventricular tachycardia were disqualifying and nonwaiverable in the USAF. Since that time, individuals with isolated asymptomatic episodes of supraventricular tachycardia have been returned to flying status after stringent evaluations. The most favorable cases of supraventricular tachycardia for return to flying status are those associated with classical precipitating factors for supraventricular tachycardia in younger persons. Not infrequently, the episode of supraventricular tachycardia is related to a combination of fatigue, stimulants such as caffeine, hunger, alcohol, and anxiety. The episodes of supraventricular tachycardia occurring following alcohol, tobacco, and stimulants are frequently referred to as "holiday heart", since these episodes often occur as a result of indiscretions during a vacation. These are usually self-limited episodes which do not tend to recur if the precipitating factors are avoided. "Holiday heart" accounts for the majority of cases of supraventricular tachycardia referred to USAFSAM.

The proper disposition of supraventricular tachycardia is heavily dependent upon the correct diagnosis. Is it atrial flutter? Is it atrial fibrillation? Is it a reentrant atrial tachycardia? Is it a supraventricular arrhythmia with aberrancy, or does this represent a ventricular tachycardia? A thorough analysis of the electrocardiographic tracings is necessary, because atrial flutter and ventricular tachycardia are nonwaiverable arrhythmias, while atrial fibrillation, atrial tachycardia, or supraventricular tachycardia with aberrancy are all potentially waiverable arrhythmias. Prior to evaluation at USAFSAM, certain requirements for potential waiverability must be met.

TABLE 16

DISPOSITION OF SUPRAVENTRICULAR TACHYCARDIA

1. No syncope or vascular collapse
2. No recurrence of arrhythmia
3. 6-month waiting interval before catheterization
   A. Rule out mitral disease
   B. Rule out thyroid disease
4. No medication required

During the episode of supraventricular tachycardia, there must have been no symptoms of syncope or vascular collapse. Further, the arrhythmia must not be a recurrent one, and no maintenance medication is allowed. Following the episode of supraventricular tachycardia, a full six-month waiting period is required for referral to USAFSAM. During this six months, the arrhythmia may be noted to be a recurrent one, and further aeromedical evaluation is not indicated. Further, metabolic processes such as hyperthyroidism may declare themselves during this period of time. During this period of observation, occult mitral valve disease or other cardiovascular problems may become manifest. Thus, at the end of the six-month waiting period, if no secondary causes of supraventricular tachycardia are found, then the aviator is evaluated at USAFSAM. At USAFSAM, individuals must undergo a left and right heart catheterization if they are over 35 years of age.

TABLE 17

DISPOSITION OF SUPRAVENTRICULAR TACHYCARDIA

Cardiac catheterization

A. Left and right heart >35 years

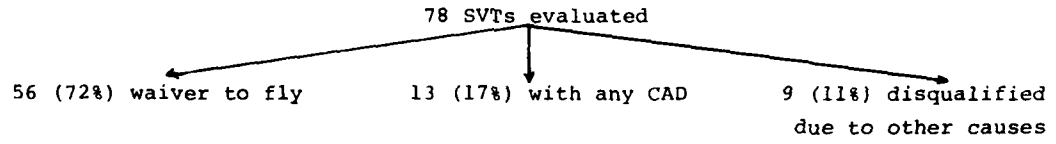
B. Right heart only ≤35 years

1. Electrophysiological studies
2. Sinus node recovery times
3. Atrial, atrioventricular nodal refractoriness
4. Stable hemodynamics during induced arrhythmia
5. No bypass tracts

Left heart catheterizations are performed in those over the age of 35 because of the necessity to rule out coronary artery disease. Even insignificant coronary artery disease may become manifest during a rapid supraventricular tachycardia, especially with the superimposed stresses of high $+G_z$ acceleration. If the individual has any degree of coronary artery disease, no further studies are performed. If the coronary arteriograms are completely normal, and the left ventriculogram reveals no evidence of mitral valve prolapse, then an electrophysiologic study must be a complete study in order to rule out bypass tracts, abnormal refractory periods, or unstable hemodynamics if one is successful in inducing the arrhythmia in the cardiac catheterization laboratory. Individuals 35 years of age or under receive right heart catheterizations only, if the maximal treadmill exercise is normal, and the thallium scintigram reveals no perfusion defect. Seventy-eight cases of supraventricular tachycardia (SVT) have met the criteria for referral to USAFSAM.

TABLE 18

SUPRAVENTRICULAR TACHYCARDIA



Of these cases, 72% were waivered to fly, 17% were found to have some degree of coronary artery disease, and 11% were disqualified due to other causes. Supraventricular tachycardia is not a marker for coronary artery disease, as evidenced by the fact that the majority of those with supraventricular tachycardia have no coronary disease whatsoever. However, left heart catheterizations are performed because of the absolute necessity to rule out subclinical coronary artery disease in those who may have rapid tachycardias.

RIGHT AND LEFT BUNDLE BRANCH BLOCK

Both right and left bundle branch block are rare conduction disturbances in our aviation population. LBBB occurs in less than 2 per 1,000 aviators under the age of 50. RBBB occurs in less than 6 per 1,000. All conduction defects, including nonspecific intraventricular conduction defects as well as the bundle branch blocks, remain basically static at about 8 per 1,000 until the age of 45. A consideration of conduction defects requires some consideration of the location of the delay. Possible sites are the bundle of His, the right bundle, the left bundle, the anterior division of the left bundle, or the posterior division of the left bundle. We must be especially sensitive to wide QRS patterns. Bifascicular and trifascicular blocks account for 90% of cases of complete heart block, while monofascicular block accounts for only 10% of cases. Left anterior hemiblock is especially troublesome, since left anterior hemiblock can mask an anterior infarction if the chest electrodes are placed below the heart's electrical center.

Cardiac catheterization, including left heart catheterization, with coronary arteriograms and a right heart catheterization with full electrophysiologic study have been required in the past for waiver of an acquired RBBB. Using this data from cardiac catheterization, we sought to define the nature of the delay in the right bundle in asymptomatic patients with isolated acquired RBBB as their only cardiac abnormality.(3) Each of these individuals had undergone an electrophysiologic study which included endocardial mapping of the right ventricle. Table 19 lists a series of normal electrophysiologic intervals as well as the mean intervals, for the following distances: His to right bundle (H-RB); His to surface Q wave (H-Q interval); His to right ventricular inflow tract (H-RVIT); His to right ventricular apex (H-RVA); and His to right ventricular outflow tract (H-RVOT).

TABLE 19

CONTROL RIGHT VENTRICULAR CONDUCTION TIMES (MILLISECONDS)

AGE	H-RB	H-Q	H-RVIT	H-RVA	H-RVOT
29	11	49	63	81	77
30	10	52	71	60	96
34	10	47	66	59	91
48	10	58	79	82	95
48	9	46	58	66	92
25	11	55	68	63	86
36 ±10	10 ±1	51 ±5	68 ±7	69 ±10	90 ±7

These values were likewise measured in men with acquired RBBB, whose electrophysiologic intervals are recorded in Table 20.

TABLE 20

RIGHT VENTRICULAR CONDUCTION TIMES IN ASYMPTOMATIC RBBB (MILLISECONDS)

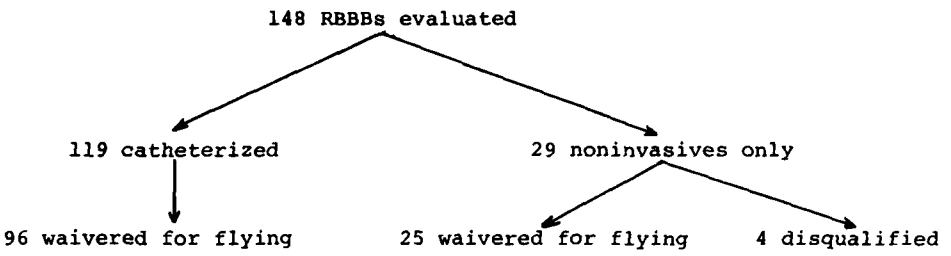
AGE	H-RB	H-Q	H-RVIT	H-RVA	H-RVOT
34	8	46	58	63	124
44	10	55	73	80	139
44	11	48	64	83	142
20	12	53	88	64	124
21	11	46	63	86	105
33 ±12	10 ±2	50 ±4	69 ±11	75 ±11	127 ±15

The differences between the intervals for the controls and the individuals with RBBB were not significant, except for the His to right ventricular outflow time, which was longer in the RBBB group, significant at a level of .005. Therefore, the normal right ventricular apex activation time with a prolonged outflow tract activation time in acquired RBBB suggests that the main right bundle is intact. Further, we have concluded that conduction in our asymptomatic patients with RBBB block is most likely to be impaired distally at the level of the Purkinje fibers beyond the moderator band. Although the etiology is unknown, the location of the electrical abnormality suggests that progressive conduction delay is unlikely. As previously reported from USAFSAM,(4) only one of 372 patients with RBBB in the flying population developed complete heart block over a followup period averaging greater than ten years. Because of this electrophysiologic and epidemiological information, RBBB block may now be waivered with a full noninvasive evaluation, and catheterization may only be required under special circumstances. Cardiac catheterizations are still required for right bundle with left axis or right bundle with marked right axis deviation.

Our experience with RBBB at USAFSAM is based upon 148 right bundles evaluated.

TABLE 21

RIGHT BUNDLE BRANCH BLOCK



Waivered to fly	82%
Any coronary disease	16%
Abnormal His bundle	1%
Other abnormalities	1%

Of these 148, 119 were seen during the period when catheterization was required. Ninety-six of these 119 receiving catheterizations were waivered for flying. Subsequently, 29 RBBB have undergone noninvasive evaluation only, with 25 being waivered for flying, and 4 disqualified because of noninvasive abnormalities. Thus, in acquired RBBB, 82% have been waivered for flying. Coronary artery disease was found in 16%, an abnormal His bundle ECG in 1% and other abnormalities in 1%.

LEFT BUNDLE BRANCH BLOCK

Full invasive evaluations, including coronary arteriography and electrophysiologic studies are still required for all aviators (irrespective of age) with acquired LBBB. The LBBB individuals have tended to be slightly older, and the prevalence of coronary artery disease and hypertension have been slightly greater, consistent with the older age. LBBB is slightly more difficult to evaluate, since the exercise ECG is totally unreadable in LBBB. However, the exercise ECG is still interpretable to some extent with RBBB, using R wave amplitude.(5) Further, electrocardiographic evaluation of the left bundle is impractical, whereas RBBB block can be evaluated in greater detail on the venous side of the circulation.

Our USAFSAM experience with LBBB is based upon 63 evaluations. All 63 of these individuals underwent left heart catheterizations and electrophysiologic studies. Forty-six or 73% were waivered to fly, while 14 or 22% were found to have some degree of coronary artery disease. Five percent were disqualified due to other causes, including one individual with a prolonged H-Q interval.

TABLE 22

LEFT BUNDLE BRANCH BLOCK

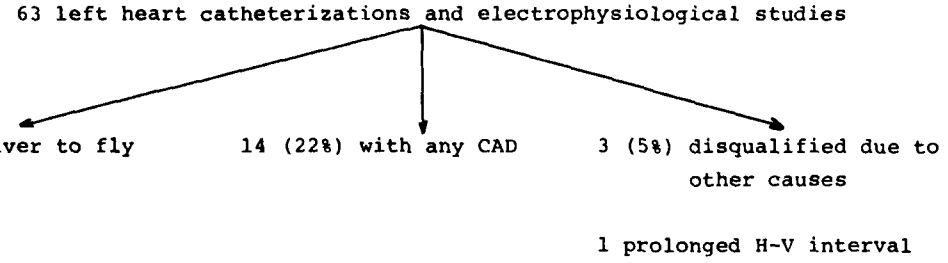


Table 23 lists a comparison of right and left bundle branch blocks. While the prevalence of coronary artery disease (CAD) is slightly higher in LBBB than RBBB, bundle branch blocks do not seem to be markers for coronary disease in the asymptomatic population.

TABLE 23

BUNDLE BRANCH BLOCKS

	RBBB	LBBB
Waiver to fly	82%	73%
Any coronary disease	16%	22%
Abnormal His bundle	1%	1%
Other abnormalities	1%	4%

WOLFF-PARKINSON-WHITE ELECTROCARDIOGRAPHIC FINDINGS

For clarity of discussion, the Wolff-Parkinson-White (WPW) electrocardiographic finding is the classical short PR interval, delta wave, and wide QRS complex. By definition, all individuals with the WPW electrocardiographic finding who have tachyarrhythmias have the WPW syndrome. The electrocardiographic finding of WPW implies the presence of a bypass tract. The WPW electrocardiographic finding becomes the WPW syndrome when the patient has a history of tachycardia. By definition, all individuals with the WPW syndrome have had tachyarrhythmias.

The WPW electrocardiographic finding is disqualifying for entry into flying training in the USAF. The WPW electrocardiographic finding is waiverable if discovered in already trained aviators. Since the electrocardiographic finding may be inconstant on the scalar ECG, some cases of WPW are not discovered until the aviator has had a series of ECGs over the years. If, however, a new WPW electrocardiographic finding is discovered in a fully trained aviator, waiver is allowable if there are no tachyarrhythmias. We do not perform any electrophysiologic studies in individuals with the WPW electrocardiographic finding or in the tachycardia syndrome. The finding of the WPW electrocardiographic finding is cause for rejection for pilot training. Conceivably, one could perform electrophysiologic studies on these applicants to determine retrograde conduction and bypass refractoriness, thus defining some WPWs who would be acceptable trainees. However, in the USAF we do not perform invasive procedures in order to qualify individuals for training. Invasive procedures are reserved for those who are already rated and represent a significant flying experience base. While electrophysiologic studies are indicated in a number of conduction and arrhythmic disturbances in trained aviators, there is also no reason to perform invasive studies in trained aviators with newly discovered WPW. In those who are already trained aviators, WPW is occasionally discovered on the first ECG performed since pilot training which occurrs at age 35. By this time, we generally have a number of years of experience with this individual, and the mere presence of a bypass tract is not disqualifying. Thus, an electrophysiologic study would not change the aeromedical disposition. Further, if the individual has the tachycardiac syndrome, an electrophysiologic study will not alter the disposition since this syndrome is disqualifying and nonwaiverable.

Table 24 lists some of the considerations in WPW electrocardiographic finding.

TABLE 24

CONSIDERATIONS IN WPW

1. WPW is not a marker for coronary disease
2. Sustained tachycardia
   a. Short diastolic filling period
   b. Syncope, vascular collapse
   c. Unmasking of subclinical coronary disease
3. Exercise test becomes unreadable

We do not feel that WPW is a marker for coronary artery disease. However, coronary artery disease is of special concern, since this is the subclinical condition which individuals with rapid tachycardias are least able to tolerate. While a 25-year-old pilot with tachycardia may remain asymptomatic, during a reentrant tachycardia, his clinical state at age 35 or 40 may become quite tenuous due to asymptomatic coronary artery disease. Thus, the entry into pilot training of individuals with known WPW places them at subsequent risk because of the possibility of acquired coronary artery disease, the most common cardiovascular condition in our aviation population. Further, the ST segment of the exercise test becomes unreadable in the great majority of those with WPW. The loss of the exercise test as a repetitive noninvasive cardiovascular test is most unfortunate. The flight surgeon is then deprived of a tool to screen serially for the one condition which those with WPW can least tolerate in the face of tachyarrhythmias-coronary artery disease. Further, the numbers of individuals applying for pilot training with WPW are not insignificant. In less than a decade, the USAF could easily have well over 100 individuals with WPW electrocardiographic finding in the flying ranks. The presence of 100 men with abnormal exercise

ECGs presents a very formidable medical followup problem, and would seriously hamper continued surveillance for coronary disease. The continuing risk of sustained tachycardia, as well as the logistical difficulties of disease surveillance in WPW will continue to make this disorder a disqualifying one for flying training.

SINUS BRADYCARDIA

The overall prevalence of sinus bradycardia in U.S. aviators is 9.4%. The prevalence of sinus bradycardia in those less than 30 years of age is 11.4%. For purposes of definition, sinus bradycardia in our USAFSAM population is defined as 50 beats per minute rather than 60 beats per minute. Sinus bradycardia, of course, is commonly seen in healthy trained athletes. However, sinus bradycardia cannot always be taken as presumptive evidence of good physical conditioning. Particularly, sinus bradycardia as a serial change in an unconditioned individual may be a pathologic finding. In one 10-month study conducted at USAFSAM, 64 subjects greater than 30 years of age were noted to have heart rates equal to or less than 50 beats per minute as a serial change. Twenty-four subjects less than 30 years of age had heart rates of less than 43 beats beats per minute as a serial change. Surprisingly, 20% of these new sinus bradycardia subjects rarely engaged in exercise, and 40% failed to respond to 0.02 mg/kg of IV atropine. In the case of a serial sinus bradycardia in unconditioned individuals, one must be sensitive to the possibility of sinus node disease. Sinus node dysfunction must be suspected in cases of asymptomatic sinus arrest, sinus node exit block, heart rates less than 40 beats per minute as a serial change, unexplained syncope, or in episodes of supraventricular tachycardia, which may have a brady-tachy syndrome as the underlying disorder. The evaluation of suspected sinus node dysfunction is outlined in Table 25.

TABLE 25

EVALUATION OF SUSPECTED SINUS NODE DYSFUNCTION

24-hour Holter monitor

Maximal treadmill

Tilt table test

Centrifuge test

Carotid sinus pressures

Atropine 0.02 mg/kg maximum

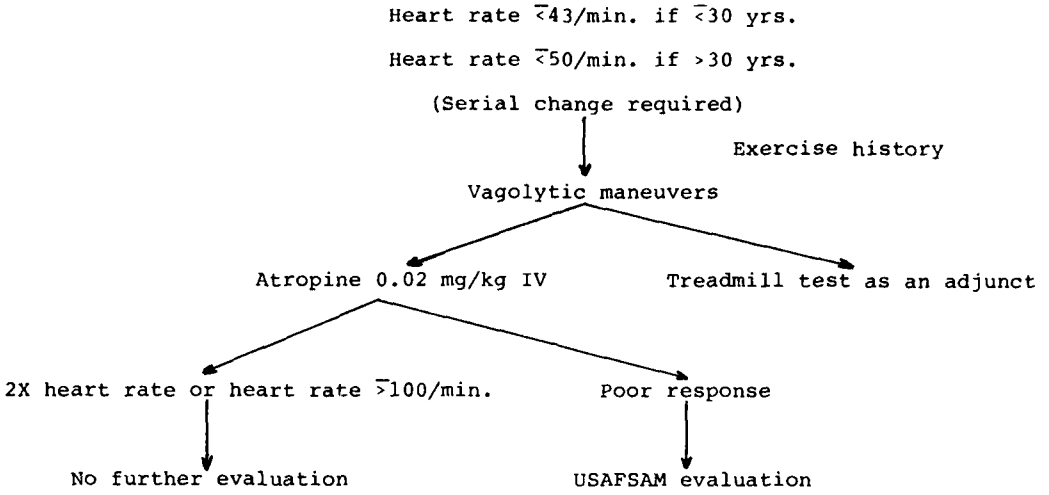
Full electrophysiologic studies

A 24-hour Holter monitor should be performed on all individuals with new bradycardia in order to detect more serious bradyarrhythmias. Individuals may be tested with a variety of stress tests to induce vagal withdrawal. Heart rates should accelerate appropriately with maximal treadmill exercise, 70° of headup tilt, centrifuge testing, or upright bicycle exercise. Carotid sinus massage may produce slowing, with prompt return of rhythm when the stimulus is terminated. For those failing to respond to vagal withdrawal, atropine 0.02 mg/kg may be administered intravenously. Higher doses of atropine should be used cautiously. Individuals with glaucoma, pre-glaucoma, or symptoms of prostatism should not receive atropine. Failure to respond to atropine may be an indication for full electrophysiologic studies.

Sinus arrest as an etiology for syncope or presyncopal episodes must always be considered. Asymptomatic individuals who have pauses greater than two seconds must be considered abnormal, until sinus node function is demonstrated to be normal. The most common causes of sinus node arrest are increased vagal tone (well-trained athletes), digitalis, and sinus node disease. Table 26 outlines the aeromedical evaluation of sinus bradycardia.

TABLE 26

SINUS BRADYCARDIA EVALUATION



The sinus bradycardia must occur as a serial change. The exercise history is, of course, quite important. Serial sinus bradycardia is a more potent finding in those who are non-exercisers. The next level of the workup involves vagolytic maneuvers such as stress tests or intravenous atropine. For those individuals with a poor response to stress testing, intravenous atropine should be given. A heart rate of 100 beats per minute, or doubling of the resting heart rate should be achieved. For those with a poor response to both treadmill testing and intravenous atropine, a USAFSAM evaluation is required.

AXIS DEVIATION

Right axis deviation is defined as a mean QRS axis of equal to or greater than +120° in the frontal plane axis. Left axis deviation is defined as equal to or more negative than -30° in the frontal plane axis. Left axis deviation increases with age in the Air Force population, occurring in 5 per 1,000 in the early twenties and 50 per 1,000 in the late fifties. Left axis deviation is often related to conduction disturbances, myocardial disease, and obesity. In our population, right axis deviation is extremely rare after the age of 50. When present in those aviators age 50 or above, pulmonary disease is the most common cause. Right axis deviation in our younger pilots is usually a persistent juvenile pattern, missed congenital heart disease, or right ventricular hypertrophy.

In the absence of other findings suggestive of organic heart disease, acquired right and left axis deviation may be worked up noninvasively.

SUMMARY

Electrocardiography is not an exact science, and involves the use of the ECG as a laboratory tool in conjunction with all other information available regarding the aviator. Only through detailed natural history followup studies will we be able to determine the significance of certain electrocardiographic findings in a healthy population. Surveillance of aviators through annual ECGs should begin at age 35, with a previous tracing upon entry into aviation training. The ECGs in asymptomatic men are most useful when viewed in a serial fashion. The strength of the centralized electrocardiographic review lies in the strong orientation toward serial change. USAFSAM is now pursuing a long-term effort to develop a computerized vectorcardiographic interpretation system, which will store the actual electrocardiographic signal for serial comparison.

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5. Uhl GS and Hopkirk JAC: Analysis of exercise-[illegible] detection of coronary artery disease in asymptomatic [illegible] block. American Journal of Cardiology 44 [illegible]

AD-A101 444 ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT--ETC F/G 6/5
ADVANCED OPERATIONAL AVIATION MEDICINE COURSE (6TH), HELD AT CE--ETC(U)
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CONCLUSIONS

Summary of the roundtable discussions between the lecturers and the participants of the Sixth Advanced Operational Aviation Medicine Course on Friday 28 Mar 80

1. Fitness-criteria for applicants

a. ECG-abnormalities

There is a general consensus about the following points : (1) to (5)

(1) Wolff-Parkinson-White		unfit
(2) Left Bundle Branch Block (of any degree)		unfit
(3) Complete Right Bundle Branch Block		unfit
(4) Left and Right Axis Deviation		unfit
(5) AV Block		
PR distance	less than 0.22	fit
	0.22 - 0.24	fit if PR decreases on exercise test
	more than 0.24	cardiologic evaluation required

(6) Arythmia

Lt Col HICKMANN MD (USAFSAM) states

(a) that the disappearance of premature beats on exercise is not reassuring; however an applicant should be considered fit for flight service if :

- there are no complex ventricular ectopic beats
- the clinical examination is normal
- echocardiography, treadmill and Holter-monitoring (24 h ECG) are within normal range

(b) that a candidate is to be rejected in the presence of :

- pared ectopy
- multiformed complexes
- more than ten (10) premature beats per minute

Air Vice Marshall COOKE (RAF) considers a candidate unfit when there are frequent premature beats (no number specified) or three (3) consecutive premature beats.

b. Hypertension

Dr. HICKMANN states that a candidate is rejected if the bloodpressure exceeds 140/90 mm Hg, calculated as a mean value of six bloodpressure measurements, during three days, before and after noon, on an applicant in sitting position, with hanging arm at the side.

In Norway the limit is fixed at 135/85 mm Hg.

c. HDL-Cholesterol

There is a general consensus about the advisability of a systematic HDL determination on all candidates. These HDL-values would be integrated into a risk function. If this function exceeds a limit which is to be calculated, a candidate would be rejected.

d. Echocardiography

General consensus : all candidates ought to be subjected to an echocardiography, mainly in order to exclude a mitral valve prolaps, which makes them definitely unfit for "High Sustained GZ".

2. Fitness-criteria for graduated aircrew

a. Treatment of hypertension

(1) Belgium

Flight missions are allowed with a treatment consisting in diet and low doses of diuretics, providing the blood-potassium levels are checked.

Flight missions with restriction to transport aircraft or with the presence of a second-pilot are allowed with the use of beta-blocking medication.

(2) The Netherlands

Flight missions are allowed with a treatment based on diet and diuretics. A beta-blocker can be given as an additional drug (maximum 120 mg propanolol a day), after an observation period of one year.

(3) USA

Flight missions are allowed with intake of diuretics in addition to dietary measures.

(4) Great-Britain

Beta-blockers are never allowed in military aviation. Since then is an increasing use of beta-blockers as a first line treatment for hypertension, these drugs are expected to be allowed in civil aviation, with restriction to multipilot aircraft.

b. Repolarisation abnormalities on ECG

(1) Treadmill test :

USA : If the test is negative : the pilot remains fit, without further investigation.

If the test is positive : due to the excessive false positive rate (60%) a risk function established on the basis of the following data : HDL-cholesterol, family history, glucose intolerance, hypertension, abnormal resting ECG, postural ST changes, postural T changes, hyperventilation changes, time on treadmill (minutes) is evaluated.

Afterwards a thallium-scan can be performed, if necessary followed by a heart catheterization.

(2) Coronary arteriography

USA : A degree of obstruction above 30% in one branch as well as a combined obstruction in several branches above 50% is disqualifying for all air service.

c. Atrial flutter

USA : no waiver is granted for atrial flutters

d. Centrifuge testing

(1) There is a general consensus about the necessity of this test for all applicants for High-Performance-Aircraft.

(2) France : The lower-body-negative-pressure test cannot replace the centrifuge testing, since it is not a real indicator of G-tolerance.

FINAL PROGRAM OF THE AGARD AEROSPACE MEDICAL PANEL

SIXTH ADVANCED OPERATIONAL AVIATION MEDICINE COURSE

ON

"CARDIOVASCULAR PROBLEMS IN AVIATION MEDICINE"

held at the conference room of the
Centre de Médecine Aéronautique
Quartier Roi Albert I
70 rue de la Fusée
1130 BRUXELLES

MONDAY MARCH 24

General Introduction

0900 - 1000	Registration
1000 - 1030	Welcome address by :
	- Med Gen Maj e.r. E. EVRARD Belgian National Delegate to AGARD
	- Med Col J. BANDE Deputy Chairman AMP, Course Director
1030 - 1200	1. "Evolution of physical fitness and cardiovascular drug toxicity with special reference to aviation medicine" by Med Col H. KESTELOOT Mil Hosp BRUSSELS
1200 - 1400	Lunch at the Officers Mess
1400 - 1520	2. "Modern and non invasive techniques in cardiology" by Prof JM.R. DETRY, Service de Cardiologie, Universté de Louvain à Woluwé
1520 - 1540	Break
1540 - 1700	Visit of "Centre de Médecine Aéronautique"

TUESDAY MARCH 25

Selection and Screening Problems

0900 - 1020	3. "Cardiological Selection Criteria in the NATO AIR FORCES" by Med Gen Maj e.r. E. EVRARD
1020 - 1040	Break
1040 - 1200	4. "Apport du mécanogramme dans l'expertise du PN" by Prof R. CARRE CPEMPN Paris (France)
1200 - 1400	Lunch at the Officers Mess
1400 - 1520	5. "l'Echocardiographie en médecine d'aviation" by Med Chef G. LEGUAY HIAD Versailles (France)
1520 - 1540	Break
1540 - 1700	6. "Principales anomalies ECG dans l'expertise du PN" by Prof R. CARRE CPEMPN Paris (France)

WEDNESDAY MARCH 26

Selection and Screening Problems (continued)

0900 - 1020	7. "Exercise tolerance testing" by Lt Col James R. HICKMANN Jr. MD USAFAM
1020 - 1040	Break
1040 - 1200	8. "Twenty-four hours ECG" by Med Chef G. LEGUAY HIAD Versailles (France)
1200 - 1400	Lunch at the Officers Mess
1400 - 1520	Round table discussion on selection and screening problems including High Performance Aircraft
1520 - 1540	Break
1540 - 1700	Round table (continued)
1930	Course Banquet

THURSDAY MARCH 27

Epidemiology and prevention

0900 - 1020	9. "Epidemiological basis for the Prevention of coronary heart disease" by Dr. G. DE BACKER, afdeling Cardiologie, Rijksuniversiteit GENT
1020 - 1040	Break
1040 - 1200	10. "Epidemiological cardiovascular survey in the Belgian Military Forces" by Med Col H. KESTELOOT Mil Hosp BRUSSELS
1200 - 1400	Lunch at the Officers Mess
1400 - 1700	Visit of the Cardiological Department of the Universté Catholique de Louvain à Woluwé.

FRIDAY MARCH 28

Aging Problems

0900 - 1020	11. "Cardiovascular problems during the pilots career" by Air Vice Marshall J.N.C. COOKE Royal Air Force
1020 - 1040	Break
1040 - 1200	12. "Aging and ECG disturbances" by Lt Col James R. HICKMANN Jr. MD USAFAM
1200 - 1400	Lunch at the Officers Mess
1400 - 1540	Round table and general discussion on cardiovascular problems throughout the pilots career.
1540 - 1600	Break
1600 - 1700	- Conclusions by Med Col J. CLEMENT
	- Closing remarks by Med Col J. BANDE

LIST OF PARTICIPANTS

SIXTH ADVANCED OPERATIONAL AVIATION MEDICINE COURSE

"CARDIOVASCULAR PROBLEMS IN AVIATION MEDICINE"

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14. Abstract

This report contains most of the lectures delivered to the course participants. It dealt with the cardiological problems of selection and screening, the epidemiology and prevention aspects and the problems of ageing.

Special emphasis was placed on the cardiovascular problems and follow-up of pilots of the new generation, high performance aircraft.

The course was conducted under the auspices of the Aerospace Medical Panel of AGARD.

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