EFFECTS OF FLYING ON PATIENTS WITH CARDIOVASCULAR DISEASE*

BY

GEOFFREY BOURNE, M.D., F.R.C.P.

Physician, St. Bartholomew's Hospital, London

The enormous increase in air travel during recent years has, among other results, led to the necessity of considering its effect upon passengers suffering from organic disease. The physical standards insisted upon by Government services and by private air lines in the selection of pilots and air crews of all sorts are naturally very high. This attitude has perhaps led to the parallel conclusion that none but physically fit individuals can safely be subjected, as passengers, to the strains and stresses of this form of transport.

Whittingham, Barbour, and Macgown (1949) surveyed, from the point of view of air-fitness, most of the common medical diseases. They referred to cases of heart disease as follows: "Those suffering from angina pectoris must have the condition adequately controlled with trinitrate, and an electrocardiogram should be done to exclude infarction: such cases can be accepted if the angina is provoked only by a brisk walk of half a mile. Cases with congenital heart lesion can be accepted for low-altitude flights if there is no veno-arterial shunt as evidenced by cyanosis, or if there is no heart-block or severe hypertension resulting from coarctation of the aorta. Cases of high blood pressure are acceptable if the systolic pressure is not over 200 mm. Hg and the diastolic is less than 120, provided they have flown before and there is no pulsus alternans, cardiac asthma, gross albuminuria, or cellular casts in the urine: those who have not flown before may be upset by nervous tension."

Whittingham (1953) states: "*Cardiovascular disease of marked degree is present in about three-quarters of those who are taken ill during flight.*" The low oxygen tension, even at altitudes between 5,000 and 8,000 ft. (1,500 and 2,400 metres), throws a serious strain on the heart. These patients should travel in a pressurized aircraft and limit their movements to the minimum; oxygen and any special drugs prescribed by their doctors should be available; and the medical department of the air line should be made aware of their condition. Patients with *angina* or *coronary occlusion* should not fly unless they have been free from symptoms for at least three, preferably six, months. Even then the altitude should be limited to 5,000 ft. (1,500 metres). A test of fitness for anginal patients is whether they can walk briskly for about half a mile (0.8 km.) without symptoms. Patients with *valvular disease* should not fly while the condition is acute, nor when it is chronic if there are signs of congestive failure or pronounced anaemia. Those with *congenital heart disease* can be accepted for flights up to 8,000 ft. (2,400 metres) altitude, in the absence of veno-arterial shunt, as evidenced by cyanosis, heart-block, or severe hypertension resulting from coarctation of the aorta. Those suffering from *myocardial lesions* are unacceptable if there is marked bradycardia or if they have had diphtheria within six months. Cases of *high blood pressure* can be accepted if there is no pulsus alternans, cardiac or renal asthma, frequent

headache, much loss of weight, gross albuminuria, cellular casts in the urine, or optic fundus change. They should be given a sedative before flight to prevent nervous tension worsening their condition, particularly if they have not flown before."

Whittingham's paper is naturally written from the point of view of the Director of Medical Services, British Overseas Airways Corporation, and quite rightly is conservative in its approach to the subject. An air line is responsible for the delivery, safe and sound, of its passengers; and from the point of view of its liability it must take stringent measures concerning the safe transportation of individuals known to be suffering from cardiovascular disease.

My own experience has for some time been that this view is ultra-conservative, especially regarding cases whose journey is really necessary. I was therefore led to collect a series of patients suffering from the more serious forms of cardiovascular disease who to my knowledge had safely flown considerable distances.

General Considerations

The chief stresses to which human beings are liable through flying are (1) oxygen lack, (2) excitement, and (3) air-sickness. The oxygen lack is compensated for in modern aeroplanes by pressurization of the aircraft. This is usually so adjusted that the pressure at the altitude flown, whatever this may be, does not surpass 8,000 ft. (2,400 metres). At 8,000 ft. the oxygen saturation of the blood passing through the lungs is about 86%. It is not until an arterial saturation of 83% or less has occurred in the arterial blood that any measurable increase in cardiac output occurs in normal resting individuals. The standard pressurization figure, therefore, is such that there should in ordinary circumstances be no added call upon the heart at the altitude flown normally by passenger aeroplanes properly pressurized. An obvious point is that the pressurization must be known to be adequate before the start of the journey. When Case 3 of the present series (myocardial infarction) was about to fly from New Delhi to London the start of the flight was delayed. Inquiry revealed that the pressurization system was out of order. The journey was put off, being made at a later date when an efficient aeroplane was available.

Certain other general facts are worth remembering. (1) Patients with organic heart disease which is properly compensated are able to increase their cardiac output for considerable periods during the day, remaining free from symptoms. (2) Women with organic heart disease who become pregnant, and who thereby develop a cardiac output of 20% or more above the average, still can remain in a reasonably comfortable physical state. (3) Patients with coronary disease have been safely investigated by reducing the oxygen content of their inspired air. Electrocardiographic changes will only result if the oxygen reduction is in the neighbourhood of 13%. These facts supply additional evidence suggesting that well-compensated cardiac patients flying in properly pressurized aircraft should not be materially influenced for the worse.

Influence of Anaemia

There is one important factor which may intrude upon the problem without being detected unless proper steps are taken in advance, and that is anaemia. It is generally accepted that anaemic patients show an increase in cardiac output. The extent of such an increase is at the moment uncertain, since the experimental methods used are all subject to criticism. The modern view would seem to be that a reduction in the oxygen saturation of an extent resulting from a measurable reduction in the haemoglobin is likely to produce some increase in cardiac output. A proper blood count, therefore, should certainly constitute an essential

*A paper read at the Second World Congress of Cardiology in Washington, U.S.A., on September 16, 1954.

preliminary to a prolonged aeroplane flight planned by a patient suffering from organic cardiovascular disease. Anaemia, if present, should be treated. The other factors of air-sickness and nervousness are readily preventable by proper remedies.

The present series consisted of 30 cases—6 with hypertension, 4 with angina of effort, 14 with myocardial infarction, and 6 with other forms of severe organic heart disease. No case in any of these four series was in the slightest extent incommenced by flying.

Hypertension

Details of these cases are given in Table I. The first case provides a good example of the fact that an individual with hypertension can fly without deterioration.

TABLE I.—*Hypertension*

No.	Age and Sex	Duration and Average B.P.	Heart Enlargement	E.C.G.	Remarks	Miles Flown
1	58 M	230/130 9 years	Slight	T flat I, II, QRS 0.1	Lumbar sympathectomy, 1946	More than 100,000
2	58 M	280/146 248/120 6 years	Moderate	T ↓ I, II, VL, V5, QRS 0.11	Left hemiparesis. Lumbar sympathectomy, 1950	17,000
3	75 M	230/130 190/110 7 years	Slight	Lt. B. Br. QRS 0.13, T ↓ I, V5	Hypertension non-progressive	More than 100,000
4	57 M	194/110 6 years	Moderate	Rt. B. Br. QRS 0.12, S + I, V5, M shaped V1	Heart size slowly increasing during 6 years	119,000
5	56 F	220/140 5 years	Slight	Left vent. strain. E.C.G. for 10 years	"Benign" hypertension	1,600 one year ago
6	63 M	240/114 4 years	Moderate	T flat in I, V5. R tall in I, V5		7,000

Case 1.—A man of 58 concerned with aeroplane insurance has in the course of his business flown many thousands of miles every year for the last nine years. During the whole of this period his blood pressure has varied between 230/130 and 220/120. In 1946 a lumbar sympathectomy was performed. Whether or not this has influenced the good result is open to doubt. His heart has remained well compensated, but after nine years, during which time electrocardiograms showed flattening of the T waves and a QRS of not more than 0.1 second, changes of a definite left bundle-branch lesion have recently occurred.

Case 2.—A man of 58 had had a blood pressure of 280/146. Six years later it was still 248/120 when taken in the lying position. Lumbar sympathectomy was performed in 1950, and since then he has had a measurable postural hypotension. His electrocardiogram from the first showed the typical changes of left ventricular hypertrophy and left ventricular strain. He suffered a left hemiparesis nine years ago, from which he has made a good recovery. The distance flown is given as 17,000 miles, but it is considerably more than this. Exact figures are not available.

Case 3.—A man of 75 had had hypertension for seven years, the figures varying between 230/130 and 190/110. He has lost count of the number of times he has flown the Atlantic during the past ten years. He has no symptoms and his hypertension has been non-progressive.

Angina of Effort

The history of pain and tightness was typical in all four cases. It involved the upper part of the chest. It was exactly proportional to the amount of exercise taken, causing the individual to stand still. It was in all cases worse in cold weather and was accentuated by hurrying. The details are shown in Table II.

TABLE II.—*Angina of Effort*

No.	Age and Sex	Duration of Angina of Effort	Heart Size	B.P.	E.C.G.	Miles Flown
7	59 M	10 months	Normal	172/104	Q + I, VL, V5, R + VL, V5	50,000
8	68 M	4 years	Slight increase	132/78	S + and prolonged I, VL, V5	6,230
9	73 M	7 "	Normal	146/80	Normal	12,000
10	53 M	4 "	"	156/90	QRS abnormal and notched II, III, V3, V4	125,000

Myocardial Infarction

In the series of 14 patients with myocardial infarction 12 had suffered one infarct before flying, one had suffered two, and in one patient angina of effort had preceded the aeroplane journey by a year, the infarct occurring three months after the flight. The details are shown in Table III.

TABLE III.—*Myocardial Infarct*

No.	Age and Sex	Site of Myocardial Infarct	Interval between Infarct and Flight	Remarks	Distance of Flight (Miles)
11	64 M	Posterior T2, T3, TVF ↓	9 years	Now has angina of effort, hypertension, and left ventricular strain, E.C.G. Left bundle-branch lesion also	7,000
12	72 M	Anterior	4 days		5,000
13	56 M	Antero-lateral	2 years 9 months	No hypertension, good recovery	10,000 5,000
14	51 M	Postero-lateral	2 years 4 "	Severe angina of effort 4 years	47,000 2,500
15	50 M	Antero-lateral	2 "	B.P. 160/100	and 2,500 1,000
16	53 M	"	3 "		5,000
			5 "	Previous angina with paroxysmal tachycardia. B.P. 160/100	1,200
17	59 M	Posterior	2 months	B.P. 190/110	470
18	64 M	Antero-septal	2 years 7 months	B.P. 188/108	300
				Complete heart-block. Left bundle-branch block. Heart size 16 cm.	6,000
19	38 M	Antero-lateral	3 years	Angina of effort since infarction	total, several journeys 1,300
20	69 M	? Left bundle-branch lesion. E.C.G. equivocal	2 months	Angina of effort before and since attack	5,000
21	53 M	Antero-lateral	2 years 18 months	Attack slight. Second severe attack four months later	11,300 3,000
22	58 M	Posterior	—	Infarct three months after flight. Angina of effort	2,000
23	68 M	"	1 year	Flights in war conditions. Angina of effort	100,000
24	66 M	1. Posterior 2. Postero-septal	4 months	Partial heart-block after second infarct	5,100

Hypertension was present in three of these cases. Hypertension had also probably been present previously to some extent in four further cases, since the diastolic blood pressure was 100 or more in these individuals. No hypertension was present in seven of the cases.

The time interval between the occurrence of the infarct and the flight in seven cases was one year or less. In one case the interval was as short as four days; in two cases it was two months, and in one case four months. Two of the patients had flights of considerable stress, one of them (Case 13) flew 5,000 miles nine months after his attack, and 47,000 miles during the next two years, including transit of the Andes between Rio and Lima four separate times. He never suffered any inconvenience from this.

Case 23.—This patient, a man of 68, produced an even more severe test. He did nearly all of his flying during the war years from 1942 onwards. He was an expert with the Australian stock-whip, and flew from England to North

Africa, West Africa, Sudan, Iceland, and other areas under wartime conditions and in whatever aeroplane transport might be available. He entertained the troops by his skill. He always took glyceryl trinitrate tablets before his performances to prevent angina of effort. He flew considerably more than 100,000 miles before the end of the war. In 1945 his electrocardiogram (Fig. 1) showed that auricular

FIG. 1.—Case 23. Electrocardiogram taken after the onset of auricular fibrillation. It shows the typical Q-T changes of a posterior myocardial infarction in Leads II and III.

fibrillation had supervened. He subsequently died at the age of 72.

Case 18.—A man aged 64 had suffered from intermittent claudication for three years. Seven months before his flight he had had a severe myocardial infarct which left him with complete heart-block (Fig. 2). For personal and business

FIG. 2.—Case 18. Electrocardiogram showing changes characteristic of complete heart-block with a left bundle-branch block.

reasons he desired to make a journey to Australia, to which continent he travelled by sea. When there he flew 6,000 miles or more on personal and business errands. Radiologically his heart was much enlarged.

Only one patient (Case 24) in this series had had two infarcts. The first, a posterior lesion, occurred two years before his flight, and the second, a postero-septal lesion, four months before. The second electrocardiogram showed a transitory partial heart-block.

Case 22 illustrates a further point. This patient had suffered from angina of effort of a severe degree a year before his coronary attack. In spite of this he made two aeroplane flights of 1,000 miles, and it was not until three months later that he developed his myocardial infarct. It is reasonable to assume that at the time of his flight he was in a condition when if flying was going to induce myocardial infarction it would have done so.

Miscellaneous

The miscellaneous group (Table IV) includes the following examples: a case of auricular fibrillation, without evidence of coronary disease or of thyrotoxicosis, but asso-

TABLE IV.—Miscellaneous

No.	Age and Sex	Diagnosis	E.C.G.	B.P.	Remarks	Flew (Miles)
25	65 M	Myocardial degeneration	Auricular fibrillation	150/110	Decompensated till digitalized	7,000
26	68 M	Aortic stenosis	T↓ I, T↓ VL, T↓ V5	168/90	Faintness on exertion	5,140
27	35 M	Aortic regurgitation (rheumatic)	QRS—0.12 T↓ I, T↓ VL, T↓ V5	154/62	Large heart	3,540
28	59 M	Aortic regurgitation hypertension, W.R.—ve	QRS—0.12 T↓ I, T↓ 2, T↓ V5	230/102	Class II (N.Y.) failure	9,850
29	19 F	Rheumatic myocardial and mitral disease	Auricular fibrillation QRS+	122/64	Enormous heart	13,000
30	41 F	Mitral stenosis	Normal rhythm	156/94	Paroxysmal dyspnoea attacks	8,500 before valvotomy

ciated with a slightly raised diastolic blood pressure and a history of severe chronic bronchitis and bronchospasm; a case of aortic stenosis with the typical physical signs and electrocardiogram, and with the history of faintness induced by exertion; and a case of well-marked aortic regurgitation, rheumatic in origin, with a blood pressure of 164/62. This patient had been under observation from 1940 to 1953, during which time his heart had shown a progressive increase in size. In 1940 the transverse diameter was 13 cm., in 1949 13 cm., in 1950 16 cm., and in 1953 16.5 cm. He flew 3,540 miles in 1952. Case 28 is of particular interest, and Case 29 is perhaps the most interesting of all.

Case 28.—An Indian business man with hypertension and some aortic incompetence arrived in England, having travelled by sea, complaining of increasing dyspnoea and of attacks of nocturnal paroxysmal dyspnoea. The history also suggested that he had had several attacks of slight pulmonary oedema. The heart was enlarged. The electrocardiogram showed evidence of left ventricular hypertrophy, and while in England he developed congestive heart failure, for which he was taken to hospital. Although far from well, he wished at all costs to make the journey back to India, where his family lived, and to which country his friends had returned. It was decided that this could safely

FIG. 3.—Case 29. Antero-lateral x-ray picture of chest. The heart shadow is typical of advanced rheumatic carditis with enormous dilatation of the heart as a whole.

be done by air, and he made a transit of 9,850 miles by this means. A year later, except for a little weakness, he was keeping reasonably well.

Case 29.—A girl of 19 was first seen in 1949, when she had an extensive rheumatic heart disease. The history suggested the possibility of pericarditis 18 months previously, and physical examination showed very great enlargement of the heart, auricular fibrillation, and systolic and diastolic murmurs at the apex. Broadbent's sign was positive in the interspaces behind on the left. The x-ray film (Fig. 3) showed that the heart was enormous; the transverse diameter of the chest was 23.5 cm. and that of the heart, by orthodiagraph, was 19.5 cm. In spite of the extent of organic change she has remained symptomatically remarkably well, and flew with her father from San Francisco to Australia via the Philippines without symptoms. In recent years she has flown more than 13,000 miles.

Case 30.—A woman aged 41 with mitral stenosis, normal rhythm, and pulmonary hypertension had had increasing shortness of breath with several attacks of severe paroxysmal dyspnoea before her journey from Singapore to London. She was found to have a severe degree of narrowing, the mitral orifice measuring 1.5 by 0.5 cm. at the time of operation. She has now returned to her home in the Far East.

Comment

These examples from many different varieties of cases of organic heart disease would seem to show that flying is perfectly safe when the heart is well compensated, and that it is a reasonable risk in patients whose state of compensation is not perfect, provided that the journey is necessary, or provided it is of such personal importance to the patient that he is prepared to take what can accurately be described as a very moderate risk. Generalizations as to suitability or unsuitability for flying cannot be made. Every case must be considered on its merits.

This opinion is confirmed by figures obtained from a recent survey carried out by the Medical Committee of the International Air Transport Association, which includes figures from 13 different air lines. It seems that on a five-year average one cardiac death has occurred per 1,113,000 passengers carried, and that one cardiac death has occurred per 800,000,000 passenger miles.

Conclusions

Thirty individuals, all with organic cardiovascular disease, are shown to have been able to undertake journeys by air successfully. They comprised most of the common varieties of severe organic heart diseases. In all cases the state of cardiac compensation was good at the time of flying, and in no patient did such air travel deleteriously affect the heart or the hypertension, either at the time or subsequently.

Adequate pressurization of the aeroplane must be assured in such cases. This point must be confirmed with the airport officials as an essential preliminary.

The benefit of the short air journey must be set against the disadvantage of the longer sea transit in such patients as may require to be in close contact with specialized medical care for therapeutic or other purposes, and who yet need, perhaps for personal reasons, to make a long journey.

REFERENCES

- Whittingham, Sir H. (1953). *British Medical Journal*, 1, 610.
— Barbour, A. B., and Macgown, J. C. (1949). *Ibid.*, 1, 603.

The establishment of the "American College of Angiology" is announced. This new organization has been formed by physicians and surgeons interested in diseases of the blood vessels. The College, whose official journal will be *Angiology*, is "dedicated to the teaching, research, and dissemination of knowledge concerned with the science and practice of angiology."

GASES ADMINISTERED IN ARTIFICIAL RESPIRATION

WITH PARTICULAR REFERENCE TO THE USE OF CARBON DIOXIDE

A Report to the Medical Research Council by its Committee* for Research on Breathing Apparatus for Protection against Dangerous Fumes and Gases

WRITTEN BY

Dr. K. W. DONALD

AND

Professor W. D. M. PATON

John Hunter suggested, in 1776, that inflation of the lungs with oxygen would be a valuable procedure in resuscitation. In 1780 Chaussier (see Hahn, 1899) administered oxygen in asphyxia of the newborn and later devised a laryngeal tube for this purpose. Early in the present century oxygen was being used increasingly in attempted resuscitation. However, in 1920, Henderson and Haggard reported that 90% oxygen and 10% carbon dioxide caused more rapid elimination of carbon monoxide in experiments on dogs. In later papers they recommended a mixture of 95% oxygen and 5% carbon dioxide for carbon monoxide poisoning, ether or alcohol intoxication, or for respiratory failure due to any cause. These workers also made a great contribution by persuading the authorities concerned that there was no efficient apparatus generally available for the administration of oxygen or other gases and that there was an urgent need for portable apparatus with properly fitting masks. Nicloux *et al.* (1925), Walton *et al.* (1926), and other workers could not confirm the great increase of carbon monoxide elimination with added carbon dioxide reported by Henderson and Haggard, and continued to support the use of pure oxygen only. Nevertheless, mixtures containing carbon dioxide were adopted almost universally for use in resuscitation.

Since this time evidence has accumulated against the use of carbon dioxide for this purpose, and recently the Medical Research Council Committee for Research on Breathing Apparatus for Protection against Dangerous Fumes and Gases recommended (unpublished memorandum) that, in first-aid practice, pure oxygen and not oxygen and carbon dioxide (carbogen) be administered to persons suffering from respiratory failure or respiratory depression and requiring manual artificial respiration. This recommendation was stated in simple terms, and it is now considered desirable that the reasons for abandoning "carbogen" should be given in greater detail. It is to be emphasized that the recommendation applies only to the resuscitation of subjects suffering from respiratory depression or failure and requiring immediate manual artificial respiration.

The urgent decision on whether artificial respiration is required may be very difficult. It is often hard to assess the degree of respiratory failure by looking at the movements of the chest or the colour of the patient.

*Members of the Committee: Professor Sir Bryan Matthews (chairman), Mr. S. H. Clarke, Mr. F. Dann, Professor E. A. Pask, Professor W. D. M. Paton, Dr. J. M. Rogan, Dr. J. S. Weinert, Mr. A. H. A. Wynn, and Dr. K. W. Donald (secretary).