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VALVOTOMY FOR MITRAL STENOSIS

A FURTHER REPORT, ON 100 CASES

BY

CHARLES BAKER, M.D., F.R.C.P. R. C. BROCK, M.S., F.R.C.S., F.A.C.S.(Hon.)

MAURICE CAMPBELL, D.M., F.R.C.P.

AND

PAUL WOOD, M.D., F.R.C.P.

(From Guy's Hospital, the Brompton Hospital, and the Institute of Cardiology)

Our interest in valvotomy for mitral stenosis extends back over several years, although it was not until September, 1948, that our first patient was operated on. In June, 1950, we were able to report our experiences in nine patients, seven with successful operations (Baker, Brock, and Campbell, 1950). We are now able to report the immediate results on 100 patients treated by operation, with a more detailed analysis and follow-up of the first 50, the last of whom was operated upon in May, 1951, so that all have been followed for six months, the majority for more than a year, and some for two to three years. Apart from two patients at the Johns Hopkins Hospital, Baltimore, the operations were done at either Guy's Hospital or the Brompton Hospital, and all by one surgeon. For the purpose of analysis and follow-up the two Baltimore cases have been omitted from the first 50.

In previous papers we have followed common usage in writing of pulmonary or mitral " valvulotomy," but it is a valve and not a valvule that is divided, and we think the term " valvotomy " is more correct, even though it is still a hybrid formation. The operation really does more than splitting the commissures, for if the valve cusps are reasonably supple the operation may enable them to close better and more normally, but we have thought it better to reserve the term " valvoplasty " for more elaborate operations that may be possible in the future.

Present Position of Mitral Valvotomy

Our earlier paper contained a fairly full presentation of the problem of mitral valvotomy up to that time, and there is no need for repetition here. The great improvement observed in seven of the nine patients enabled us to say with some confidence that the operative relief of mitral stenosis was a practical procedure with a reasonably low mortality, and that it could justifiably be recommended in suitable cases and would probably have a wider application. Our subsequent experience reported here with 100 cases and with 32 good or excellent results in the follow-up of the first 50, as well as the experience of several other clinics, amply confirms these views.

The relatively low mortality of the operation deserves immediate emphasis. Thus of our first 20 patients, 7 died ; only one more patient died in the next 30, making 8 deaths in the first 50 cases, and only 5 more in the next 50, making 13 deaths in the first 100 cases. Even severely ill patients with advanced mitral stenosis will stand cardiotomy well, *provided the mechanical obstruction within the heart is relieved by the operation.*

As soon as our first report appeared the great need for operative relief of mitral stenosis was borne vividly upon us by the large number of patients presenting themselves for consideration, the requests coming from cardiologists, from general practitioners, and from the patients themselves. A future that previously seemed bleak for many patients, generally under 40 and often under 30 years of age, has been completely changed. It is only in dealing with a large number of these patients that one realizes the true extent of the tragedies that mitral stenosis can produce.

Successful surgical treatment of mitral stenosis has disclosed a problem of great extent. Congenital heart lesions, for instance, constitute only 2% of all cases of heart disease, and it is fair to say that their operative relief is best undertaken in a few special centres. By contrast, rheumatism causes 25% of cases of heart disease in hospital (Wood, 1950), and in half of them mitral stenosis is the predominant lesion. It is not possible for all the patients for whom operation is required to be dealt with in a few special centres. Mitral valvotomy is now a standard procedure that should be practised in all thoracic surgical clinics in large centres.

Although a new field of surgery has been opened up, the problem is even larger than the purely surgical conception. In some respects it is comparable with that of pulmonary tuberculosis, in which surgery has come to play a large and increasing part, but is still only one factor in the general management. Many patients with mitral stenosis, as many with pulmonary tuberculosis, will never need operation, but must have medical treatment. Close co-operation between surgeon and physician is essential, and when operation is needed the selection of the best time for surgery comes from

discussion between the surgeon and the physician who has guided the patient up to operation and will continue to advise him afterwards.

In no case in this series has the decision to operate been made solely by the surgeon. Even when the patients have been referred direct to the surgeon (as now happens not infrequently and somewhat significantly) they have always been transferred to the care of one or other of the cardiologists for a full and independent assessment.

Grading

In assessing the severity of the disease we have graded the patients into five groups, based largely on the capacity for exertion without dyspnoea, but partly also on the general disablement.

When there is no disability the patient is classed in grade 0. Grade 1 means undue breathlessness on hurrying, walking uphill or upstairs, running for a bus, or on other relatively strenuous activity. Patients in this grade lead a virtually normal life, but cannot keep up with their fellows during physical pursuits.

Grade 2 means breathlessness even on moderate exertion. Patients in this grade cannot hurry, although they may be able to walk some miles on the flat at their own speed. Hills and stairs are only managed slowly, and running provokes acute discomfort.

Grade 3 means serious incapacity that interferes with the daily round. The men are unable to do more than light or sedentary work, and the women do their shopping and housework only with difficulty; hills are out of the question, and stairs are avoided or taken in spells. Patients in this grade are usually orthopnoeic, and may have bouts of paroxysmal cardiac dyspnoea or even pulmonary oedema.

Grade 4 is reserved for patients who are completely incapacitated. Housework and shopping are abandoned, the least physical exertion causing great fatigue and breathlessness. Patients in this grade are usually in congestive heart failure or on the verge of pulmonary oedema.

The chief difficulty in grading a patient is caused by the changes that take place from time to time. For example, a woman in grade 0 may develop paroxysmal cardiac dyspnoea during pregnancy and for some months may be in grade 3. Transient upper respiratory tract infection or paroxysmal auricular fibrillation may quickly induce total incapacity (grade 4) in a person previously in grade 1 or 2. Again, grade 4 may be quickly changed to grade 3 as a result of adequate medical treatment. We have tried to grade patients according to their usual condition when they are living at home; not when under transient adverse circumstances, nor after a beneficial period of prolonged medical treatment in hospital.

By using these grades we have come individually to a reasonable agreement in classifying the patients. The assessment at the time of operation in the first 50 patients was made by at least two of us after full investigations, including cardiac catheterization, and was as follows: grade 1, 0; grade 2, 1; grade 3, 19; grade 4, 30.

It will be seen, therefore, that the patients selected for operation up to the present have reached an advanced stage of mitral stenosis.

Results

Deaths

The results in the first 50 cases are summarized in Table I. There were eight deaths. Cerebral embolism occurred in three fatal cases, all with auricular fibrillation (of five years', six years', and three months' duration). The first (G2)* might have survived but for intrathoracic bleeding from heparin therapy. The second (G11), who still had signs from a left hemiplegia three years before, died of an embolism in the right middle cerebral artery. The third (G17) died the day after operation from an embolism of the basilar artery.

TABLE I.—*Results of 100 Mitral Valvotomy Operations*

No. of patients operated on	100
Deaths	13
Follow-up of First 50 Cases	
Deaths	8
Valvotomy not possible	1
Poor result	5
Fair result	4
Good result	15
Excellent result	17

The other five patients, three of them with auricular fibrillation, died within a few hours to three days after operation from circulatory failure. In one (G12) the lateral papillary muscle controlling the anterior cusp of the mitral valve was torn and severe regurgitation resulted. One (G3), a severe risk, lived 36 hours with a gradually falling blood pressure. The other three (G7, G14, G15) did not regain consciousness after the operation and died after a profound fall of blood pressure which failed to return to a normal level: the importance of maintaining the blood pressure must therefore be emphasized. All the eight deaths occurred in the first 22 cases.

In one patient (B2) valvotomy was not carried out because the auricular appendage was solid with firm clot which also extended over a wide area on the adjacent wall of the atrium. It was thought that disturbance of this would probably lead to a fatal massive embolism, as had happened in an earlier case with widespread mural thrombosis (G2).

Poor and Fair Results

In 5 of the 41 patients on whom valvotomy was done there was no improvement or the patient was worse. Two (B12 and G18) developed fibrillation and congestive failure after operation: the first improved with digitalis and returned to light work, but has since relapsed; the second did not respond to digitalis and committed suicide a few months later. These two were men aged 35 and 33 with uncomplicated stenosis, a cardiothoracic ratio (C.T.R.) of 50, and pulmonary congestion; both were expected to do well; both had adequate openings made at operation and no regurgitation was noted. The first had had cardiac pain, which suggests a possible factor; the second was thought to have developed active carditis, though this was not proved. A third patient (G16), with severe pulmonary hypertension, has shown little if any clinical improvement, and catheterization six months after operation showed no fall in pressure (see Table IV) or rise in cardiac output: it is possible that the operation was not successful, for there was much calcification, or that his pulmonary hypertension had become irreversible.

The fourth (B15), a man aged 37, with a history of embolic cerebral disturbance six months before, fibrillating for two months, and with a small heart (C.T.R. 48), had mitral regurgitation, confirmed at operation; this appeared to be successful, but he remained drowsy and developed jargon speech for some time after the operation. He is not improved, and too prolonged fall of blood pressure or cerebral embolism may be partly responsible. The fifth (G33), a woman aged 32, was completely disabled by dyspnoea, repeated haemoptyses, and acute pulmonary attacks. As well as stenosis, she had signs of mitral incompetence, which was confirmed at operation, where the valve orifice was found to be contracted to 1 cm. by 0.5 cm. and surrounded by a hard mass of calcium. The medial commissure alone could be divided, and the opening was increased only to 2 cm.; the regurgitant stream seemed less. Her condition was unaltered by the operation, and the signs of mitral incompetence are more obvious.

Of the remaining 36 patients, we have judged four (B4, G25, G26, G33) as only moderately improved, though they

*Where a patient is referred to in the text the letter refers to Guy's or Brompton, and the figure to the serial number at one or other hospital—for example, G2 means the second operation at Guy's Hospital.

themselves are pleased with the result and have been relieved of orthopnoea and pulmonary episodes. All were incapacitated before operation; now two lead a quiet life at home and two are fit to do clerical work. In two mitral calcification was found: in one it was so extensive and the valve so fibrous that a good result was not expected; in the other it was associated with mitral regurgitation, which was not apparently changed by operation.

Successes

Of the remaining 32 patients we have judged the result as good in 15, where disablement has decreased by two grades, and excellent in 17, where it has decreased by three grades. Some of the results classed as good may later prove to be excellent, for there has not yet been time to test the full improvement. Only twice have we had to revise an early estimate in the opposite direction.

Some concrete examples of results classed as good may make this clearer. A hospital matron, able to hold her post only because her executive work enabled her to sit down, returned to a full day's work, much of it on her feet, without symptoms. A labouring man who had been unable to work because of periods of congestive failure for over a year has since returned to five months of manual work without a day off. A married woman has made a very strenuous tour of France and Italy, doing all she wanted without symptoms, but her result is classed as good only because her disability was graded as 2 before operation; she had, however, been dyspnoeic for nine years with attacks of cardiac asthma and haemoptysis for 10 months.

The 17 patients in whom the results have been adjudged excellent have all improved three grades of disability. This means that those with complete disablement have returned to a full life, either in employment or at housework. Some have protested that they have no symptoms whatever, and need reminding that they must not consider themselves as perfectly normal people. They have passed through a severe winter without being upset by respiratory infections; they have walked up to five miles (8 km.); and a rapid gain in weight of two stone (12.7 kg.) is not an isolated instance. Some previously prohibited by their symptoms from sexual activity have resumed a normal married life. The physical improvement often alters the whole outlook—from resignation or despair to hope and a full savour of life. The women are delighted to return to dancing, and the men to cultivate their gardens. Improvement is immediate and they lose their orthopnoea and "tight breathing" from the second day; one patient who could not walk the length of the ward before operation, when convalescing ran 30 yards (27 metres) for his last bus, missed it and walked the necessary four miles (6.4 km.) without symptoms. The functional improvement in some of these patients has been checked by a second catheterization after operation, and this has shown a large fall in the pulmonary artery pressure (see Table IV).

The demonstration that mitral valvotomy can be performed successfully on very ill patients with a low mortality and with a good prospect of success is most important. Once this was established it was possible, with increasing confidence, to advise the operation more widely and in a greater variety of cases. An operation for mitral stenosis has for a quarter of a century been looked on as a desperate and dangerous venture. It is remarkable that now the pass has been carried the operation is seen to be one of relative safety. No longer is it necessary to reserve operation for those advanced cases that are soon going to prove fatal without it: such cases clearly deserve help, and in our series have not been denied it. To-day there is no need to delay operation on earlier cases through undue fear of the operative risk, and as our experience has extended we have been encouraged to perform valvotomy earlier in the disease. Our recent low mortality is not, however, due to early cases being operated upon, for the number of severe and even desperate cases has so largely occupied our operating resources that it has not been possible so far to include more than a few of the earlier less severe cases.

Analysis of Results in Relation to Selection of Patients

It would be more logical to discuss the results and the selection of patients separately, but to avoid much repetition they are taken together. Greater and more varied experience will be needed before precise statements can be made about the correct selection of patients, but much can be gained by a review of conclusions from time to time. Longer experience alone can tell how lasting the good results will be and how great is the danger of further scarring and narrowing of the valve.

Contraindications or Unfavourable Features.—Hypothetical speculation may well confuse these two, and it is important to distinguish between them. Moreover, what now seem to be true contraindications may later be shown to be only unfavourable features. At present the contraindications are few: among these we would include rheumatic activity that can be recognized clinically, severe disease of the aortic valve, severe mitral incompetence, severe tricuspid stenosis, a patient who is too old, perhaps over 55 years of age. We would add irreversible pulmonary hypertension or a heart muscle that is irretrievably damaged, but at present there are no means of being sure of either. Unfavourable features, which are certainly not contraindications, include a large heart, moderate aortic valve disease, some degree of mitral incompetence, extensive calcification of the mitral valve, functional tricuspid incompetence, auricular fibrillation, congestive heart failure, a history of embolism, and considerable pulmonary hypertension. Each of these is discussed below.

Age and Sex of Patients Operated On

Of the 100 patients 30 were men and 70 women. The ages ranged from 19 to 53; 12 were under 24 and 10 over 45 years of age. Table II shows the age incidence, separately for each sex and for those with and without normal rhythm: 78 of the patients were between 25 and 45, 47 of these being between 30 and 40.

TABLE II.—*Age and Sex Incidence of 100 Patients Submitted to Mitral Valvotomy*

	Age in Years							
	−19	20–24	25–29	30–34	35–39	40–44	45–49	50–54
Men (30) ..	1	0	5	4	10	8	2	0
Women (70) ..	2	9	11	16	17	7	4	4
Total (100) ..	3	9	16	20	27	15	6	4
With auricular fibrillation (44)	—	3	2	5	14	12	4	4
With normal rhythm (56) ..	3	6	14	15	13	3	2	—

We suggested in our first paper that it was doubtful if operation should be done below the age of 17, and that great caution must be used up to the age of 20. This is because of the greater danger that active, even if latent, rheumatic carditis may interfere with the outcome; but, if the mitral stenosis is so severe that it is threatening life, the age should not stand in the way. Experience shows that operation may become imperative in the late teens or very early twenties. The first of two patients aged 19 had attacks of pulmonary oedema which threatened her life and recurred as soon as she left the shelter of hospital (B19); several features suggested recent active rheumatism, but it was thought that valvotomy must be done even if it should need repeating in later years.

A patient may, however, sustain severe valve damage from rheumatic fever early in life and develop grave symptoms in late adolescence without any evidence of recurrent or smouldering disease. Thus a girl aged 19 who had acute pulmonary oedema gave no history of rheumatic fever since her first attack when 7 years old (G40). Yet at operation the valve orifice was very small and fibrous, with a craggy mass of dense calcification on the medial commissure; once the commissures had been divided the flaps were quite thin

and pliable. The whole appearance was like that commonly seen in patients 20 years older, and strongly suggested that this severe mechanical derangement had followed the attack at 7 years and that there was no special risk of recurrent rheumatism.

We have operated on four patients who were 50 years of age or over. Three have done well—two after a precarious convalescence; it is too early to assess the result in the fourth. In general we are reluctant to operate on patients as old as this, especially with limited operating resources and the long waiting-list of much younger patients in whom greater and more lasting improvement can be expected with a lower risk. On the other hand, each case demands a decision on its own merits. Some older patients may exhibit other unfavourable features such as tricuspid regurgitation, hypertension, or coronary insufficiency, all of which have been found in one or more of our patients. A case may be made out for operation as late as the middle fifties in special circumstances, but probably not beyond this.

Pulmonary Congestion

It is doubtful if we, as doctors, have appreciated how much his disability means to the patient. To be unable to hurry or climb stairs without paying a penalty, to forgo healthy physical pursuits, to have to sleep propped up in order to avoid suffocating at night, and to live in constant fear of a stroke, of haemorrhage from the lungs, of drowning in his own expectoration, or of becoming waterlogged, are just a few of his troubles. What a load is here for anyone to carry, and what a nightmare for the apprehensive. No wonder that patients seize the chance that surgery now offers.

Of course, many patients with mitral stenosis remain symptom-free for an unpredictable time, occasionally throughout a long and active life; in our experience the development of symptoms means that the disease is advanced and that stenosis is already tight. The average time from onset of serious symptoms to complete incapacity is seven years. For these reasons progressive disability in a patient under 40 with mitral stenosis provides a strong argument for valvotomy, as in such circumstances a rapid downhill course ending with acute pulmonary oedema or right-sided failure is likely. Thus operation at an early stage may be expected to save the patient much distress; it is likely to be safer, and for a variety of reasons may well prove more successful.

The various manifestations of pulmonary congestion provide the commonest and most clear-cut indications for operation, and it is here that the best results may be achieved. The most favourable type is the young patient (25–35 years of age) with a small heart and a high-grade pure mitral stenosis in whom the effects of the obstruction have fallen entirely on the left atrium and the lungs. This type was discussed in some detail in our earlier paper: the signs and symptoms cover the whole range from attacks of "bronchitis" to cardiac asthma and pulmonary oedema. In 22 of our first 50 cases severe pulmonary congestive features were the chief reason for operation; in 19 they were present but overshadowed by some other symptoms; and in 9 they were not present.

It is in pulmonary oedema that operation is particularly urgent, and this was so in 6 of our 50 cases. Attacks seem to be more frequent during the winter, presumably because of the greater incidence of respiratory infections. The problems of pulmonary oedema are so important that this condition is dealt with in a special section later.

Size of the Heart

Generally in rheumatic heart disease the size of the heart varies with the stage and the severity of the condition: the larger the heart the worse the prognosis is current and justified teaching. Gross enlargement in mitral stenosis may therefore indicate a condition too advanced for operation or unlikely to benefit as much as patients with smaller hearts. Table III shows, however, that this one factor should not be given too much weight if other features are favourable. It is true that four of the five patients with a cardiothoracic ratio of under 50 have reached the highest grade of improvement, the fifth having mitral incompetence. Yet among the patients with the larger hearts there have also been excellent results; two with ratios of 64 and 61, both with congestive failure and totally incapacitated, have been at full work for over two years since their operation; two others with tricuspid incompetence and ratios of 62 and 63 are notable successes, and two with ratios of 68 and 70 (one operated on since the first 50) both did very well.

TABLE III.—*Results of Mitral Valvotomy According to Heart Size*

Cardiothoracic Ratio	No.	Good	Fair	Poor	Died
-50	5	4	0	1	0
50–54	19	11	2	4	2
55–59	13	8	2	0	3
60–64	11	8	0	1	2
65+	2	1	0	0	1
Up to 54 ..	24	15	2	5	2
55 and above ..	26	17	2	1	6

If the cases are divided into those with cardiothoracic ratios above or below 55% they fall by chance into two almost equal groups. It is true that the death rate is three times as high in those with the larger hearts; there are, however, as many good results in these, as is clearly shown in the last two lines of Table III. The great improvement may not prove as lasting in those with the larger hearts, and ideally they should be given the chance of operation at an earlier stage. It may be that we have applied more rigorous criteria of selection to those with the larger hearts, but this is not certain. It is clear from these figures that considerable enlargement is not a contraindication to operation, though it is generally a sign of more advanced disease that should be carefully analysed and weighed.

Nor does absence of enlargement always indicate a good prognosis. The patient with extreme mitral stenosis and a relatively good myocardium may have no enlargement and yet may have intense pulmonary congestion. In such patients the significance of bronchitis or haemoptysis may be missed and, even though the diagnosis of mitral stenosis has been made, paroxysmal dyspnoea may be mistaken for bronchial asthma or even for neurosis, especially when the pulmonary congestion has been increased by emotional causes. Such a mistake may prove disastrous, and it is therefore important to emphasize that a patient can die from mitral stenosis with a heart that is little if at all enlarged. In this type operation is very successful.

The dilated chamber or chambers chiefly responsible for the cardiac enlargement can usually be recognized by physical examination with radioscopy and with electrocardiography. Most of our cases showed right-sided enlargement which varied in degree from slight to severe; gross right-sided enlargement was generally associated with tricuspid disease (see below).

Patients with conspicuous left ventricular enlargement were not treated surgically, on the ground that aortic disease, mitral regurgitation, or systemic hypertension was mainly responsible for the disability. In the patients with such complications who were submitted to valvotomy the left ventricle was little if at all enlarged; this was so in five patients with aortic disease, in seven in whom a significant degree of mitral regurgitation was suspected, and in two with hypertension.

The left atrium was slightly or moderately enlarged in all 50 cases—often only slightly in those with the most severe symptoms. No patient with gross or aneurysmal dilatation was selected for operation, on the ground that such dilatation usually means predominant mitral regurgitation rather than stenosis. If it is reasonably sure that the dilatation is associated with severe mitral stenosis, operation is not contraindicated, though perhaps the surgeon may have to contend with a large amount of laminated clot.

Aortic Stenosis and Incompetence

When a patient has aortic and mitral valve disease it is generally possible to assess which is the more important. The character of the pulse and the pulse pressure are a guide to the degree of aortic involvement, and if there is left ventricular preponderance in the electrocardiogram and left ventricular enlargement on radioscopy these will indicate that aortic disease is of major importance. If this is not so, and the patient is otherwise suitable for mitral valvotomy, the mere presence of aortic stenosis or incompetence, or both, should not prevent operation. That the aortic valves are not normal seems no reason why the left ventricle should be starved of blood. If, however, these signs indicate that aortic disease is the more important, even successful relief of mitral stenosis is unlikely to give enough improvement to justify operation. Later, when the surgery of the aortic valve has advanced further, it may be possible to carry out a double operation on both valves.

Five of the 50 patients certainly had disease of the aortic as well as of the mitral valve. In a few others a soft basal diastolic murmur was heard but might have been due to pulmonary regurgitation. In one woman with clear signs of aortic stenosis and regurgitation the extreme disability seemed mainly due to mitral stenosis; she died, as the result of operation, from damage to the papillary muscle controlling the aortic cusp of the mitral valve (G12) (Brock, 1950): necropsy showed that the aortic lesion was not gross, and the result would probably have been successful had she survived, though there was a tendency to left ventricular preponderance in the electrocardiogram. Four other patients had clear but lesser signs of aortic stenosis or incompetence. The result in one is excellent, and operation has enabled her to return to a full life; in two the result is good, but in one it is only fair. In two of these patients the murmur of aortic stenosis increased greatly and a thrill was felt for the first time—striking evidence of the increased flow of blood through the left ventricle following the relief of the mitral stenosis. In none of these five cases with aortic disease did we regret the decision to operate, but in all there was evidence that the mitral stenosis was the main cause of the patient's disability.

Mitral Incompetence

A small rigid orifice, especially if calcified, is bound to remain partly open in ventricular systole and allow some reflux of blood. Often in such cases valvotomy can restore almost normal valve function; in quite a number we have found the cusps, outside the rigid orifice, thin and supple. The valvotomy, in addition to relieving the stenosis, can thus restore some degree of normal movement and suppleness to the valve-flaps, allowing more efficient closure. The unfavourable type is the one found at operation to have an orifice much larger than usual in "pure" mitral stenosis and with rigid resistant cusps. It is doubtful if any attempt at valvotomy should be made if this type is found at operation, but perhaps a method of relieving the incompetence will be devised later.

Mitral incompetence may be only an unfavourable feature, or it may be an actual contraindication to valvotomy. Its recognition is therefore of great importance, but is often far from easy. We have relied chiefly on three major criteria: clinical, electrocardiographic, or radiological evidence of enlargement or increased pulsation of the left ventricle in the absence of aortic incompetence; a loud mitral systolic murmur, with or without thrill; and considerable systolic expansion of the left atrium as seen fluoroscopically in the antero-posterior or first oblique position. It is also agreed that aneurysmal dilatation of the left atrium is usually associated with mitral incompetence rather than stenosis. These signs are not completely reliable, as our experience shows.

When these signs have been marked we have not advised operation, but it is important not to deprive a patient of the benefits of mitral valvotomy by overestimating the significance of any regurgitant element. When these signs have been moderate they have certainly not prevented successful and even dramatic results: they have not, however, always been confirmed by the surgeon's assessment at operation.

In 11 patients mitral incompetence was suspected clinically and confirmed at operation: in seven of these the results were good, in two fair only, and in two poor. In eight of these calcification was present, including the four in whom the results were not good.

In two patients with clinical evidence of mitral incompetence the valve was no different at operation from many others in whom "pure" stenosis had been diagnosed and did not show calcification.

A marked regurgitant stream was found in five cases in which mitral incompetence had not been diagnosed before operation. The results were good in three, fair in one (B4), and poor in one (G33), though in two there was a good deal of calcification.

Until more exact methods of assessment are available it seems inevitable that at times a case of predominant mitral incompetence will be explored in error: in one case (G36), not included in this analysis as it was not among the first 50, it was clearly impossible to improve the function of the badly damaged valve by valvotomy, and the patient died.

Calcification of the Mitral Valve

Although it has been suggested that a calcified valve is not amenable to division, this is not borne out by practical experience. Calcification of the valve was present in 40 of the 100 and in 19 of the first 50 cases: all the more severe examples had been noted before operation. It varies considerably in degree, significance, and type, and it is not entirely satisfactory to group all cases together as if the condition were an entity. Thus it may be a fine surface deposit, or a hard craggy exuberant mass may completely replace a part of the valve; in others flat plaques lie within the substance of the valve; yet again the calcification may extend out as far as the wall of the atrium and even encroach upon it; calcification of such an extent must clearly cause very grave interference with the valve function, in contrast with the first type. Light surface calcification was present in four patients, of whom two died and two gave a good result. In the other 15 calcification was heavy; one died, in seven the results were disappointing, and in seven they were good.

In the valve that was most extensively calcified the commissures split rapidly and easily, rather as an egg-shell breaks (G14, Fig. 1). In several others a hard exuberant mass of calcium in one commissure (most commonly the

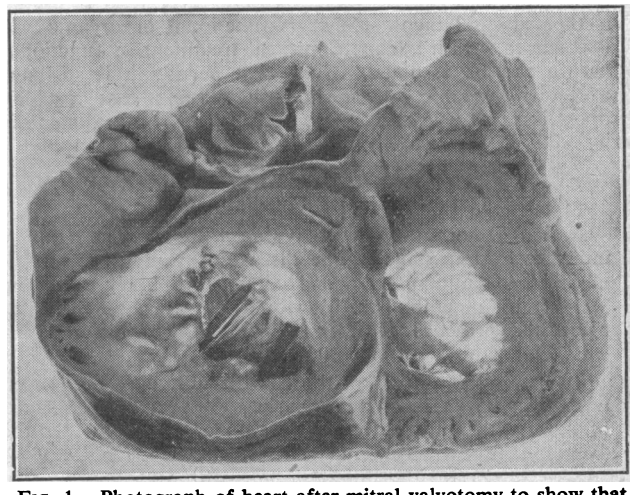

FIG. 1.—Photograph of heart after mitral valvotomy to show that an almost normal-sized orifice has been restored; note that the opening has not been merely dilated. Extensive calcification was present.

medial) either prevented or limited division in that direction, although the opposite commissure was always split or cut. Only once, when dense calcification surrounded the whole of the tiny orifice and extended for over a centimetre along the matted chordae tendineae, was division difficult; forcible digital dilatation was alone possible (G25).

In only one case was embolism, and that of a minor nature, recognized to occur after division of a calcified valve, even though in some the calcified area was felt to be crumbling and friable.

The annulus fibrosus was noted radiologically to be calcified in one case (G16), and this was confirmed at operation. During the manipulations of valvotomy the calcified ring fractured and somewhat free haemorrhage occurred from the auriculo-ventricular junction. This ceased after simple finger pressure for a few minutes; a small pack of gel-sponge was laid over the area before the pericardium was closed. The patient recovered.

A good result was obtained in only 9 of the 19 patients with calcification—a smaller proportion than in those without it. The presence of calcification of the valve seemed to be chiefly responsible for the lack of success in only 3 of the 10 who did not do well.

Tricuspid Stenosis and Incompetence

Two patients presented with the classical features of severe tricuspid incompetence, but after prolonged medical treatment they suddenly lost the characteristic systolic venous pulse; it was then realized that the incompetence was functional.

The first (B9) was a man aged 22, the second (B14) a housewife of 51 who also had essential hypertension; both had been incapacitated for over four years, both had fibrillation, and both had been in congestive failure, the woman with gross ascites; both had a large heart with cardiothoracic ratios of 62 and 63; both had pulmonary congestion and pulmonary hypertension (mean pressures, 47 and 55 mm.). Following operation the man has returned to clerical work and the woman has no difficulty in walking a mile (1.6 km.). (Since this series was completed there have been four other patients with functional tricuspid incompetence of short duration, in whom operation was advised with no hesitation.)

A third patient in the series (G34), when seen six months after operation, showed signs of tricuspid incompetence, despite very great functional improvement. The fourth (G3), reported in our earlier paper, had advanced disease and did not survive operation; necropsy showed a moderate degree of tricuspid stenosis not diagnosed in life.

We are not suggesting that every patient with tricuspid incompetence is suitable for operation, but if it is functional there is at least a case for it. It may be difficult to decide if the tricuspid incompetence is functional or organic. If it disappears with adequate medical treatment its functional nature can be assumed. Even if it persists it is still not necessarily organic, as was shown by a recent case in which operation was withheld but at necropsy tight mitral stenosis was found with a stretched tricuspid orifice.

Auricular Fibrillation

Auricular fibrillation is unfavourable in the sense that it indicates a later stage of the disease. In addition, thrombosis in the auricular appendage is more likely, with the greater risk of embolism. It would, however, be wrong to count the presence of fibrillation against operation, as it was present in 44 of our 100 patients.

In these 100, most of those with auricular fibrillation were over 35 years of age (nearly 90% over 30) and most of those with normal rhythm were under 40 (91%). On the average the former were nearly eight years older (39.1 against 31.6), and the difference was no greater because so many in each group were between 35 and 39 years (see Table II). Fibrillation was always present in those with the larger hearts, but sometimes in those with a small heart, so that the average cardiothoracic ratio was only a little greater in those with fibrillation (57.6 compared with 55.1). Among the 44 with auricular fibrillation there were 8 deaths—4 from embolism—while in the 56 with normal rhythm there were 5 deaths (18% compared with 9%). These figures bear out what might be expected—that fibrillation not only indicates a more advanced stage but adds to the operative risk from embolism.

Auricular fibrillation is in no way a contraindication to operation even if embolism has already occurred; in fact, the onset often indicates the need for a decision. In one of the early patients (G5) with increasing dyspnoea, who was being considered for valvotomy, the onset of fibrillation precipitated right-sided failure and later on attacks of cardiac asthma; it was thought at the time that operation had been delayed too long, but after two years the result remains excellent. Ideally, the patient who is losing ground should be given the chance of operation before fibrillation has become established; even fibrillation for some years does not preclude operation, but it does increase the risk, especially of embolism.

In several cases auricular fibrillation developed while the patient was under observation or while waiting for operation. Auricular fibrillation may develop after operation, and this occurred between the first and fifteenth days in 18 of the 56 in normal rhythm in our first 100 cases; in half this was temporary, normal rhythm recurring spontaneously or with quinidine; one of these later went into permanent fibrillation.

Congestive Heart Failure

Thirteen of our 50 patients had been in right-sided failure; all except one had fibrillation, and in most of them the onset of arrhythmia had precipitated congestive failure, as happens so often. In 5 of the 13 right-sided failure had been noted for at least two years, the extreme being four years; each had a large heart with a cardiothoracic ratio from 57 to 68 (average 63.6); one died, in one valvotomy was not possible, and in three the result was good.

In the other eight, right-sided failure had been present for from 3 to 12 months, and this was often the reason for advising or expediting surgical treatment; the average cardiothoracic ratio was 58.5. One of the eight died; the result was poor in one, fair in one, and good in five of these patients.

Two out of the eight deaths, and three disappointing results out of the nine in the series of 50, is not a high proportion, and shows that right-sided failure is no bar to operation. Certainly the eight patients who benefited showed very gratifying results, and two have continued at work for over two years since the operation. It must be remembered, however, that they were selected from many others with congestive failure, in whom the advanced stage of the disease appeared to be an absolute contraindication, and made it unlikely that they could have stood either anaesthetic or operation. Mitral valvotomy should not be considered the last resort of the dying, but right-sided failure, if not of long duration, and particularly if it responds quickly and can be controlled by medical treatment, is no bar to operation when the patient is otherwise suitable. It would therefore appear that operation may be justified in some apparently hopeless cases, at any rate until greater experience has supplied more certain information.

Embolism

It was thought at first that a history of previous embolism introduced the extra hazard of further embolism occurring as a result of operation. Experience has not supported this view, and we now regard such a history as one of the indications for valvotomy in the hope that less stasis in the atrium will discourage clotting.

Previous embolism had occurred in 17 of our 100 cases, five while in normal rhythm, but at operation in eight of these no thrombus was found in the auricle. A history of embolism

therefore does not necessarily mean a thrombus that may be disturbed. In contrast a thrombus (old or recent) was found in 21 cases with no history of embolism; in 13 of these the removal of a recent soft clot may well have prevented an embolism occurring. In one case (B2) extensive thrombosis extending on to the adjacent atrium made it unsafe to open the heart.

Embolism occurred after operation in seven patients. Of these, four died, one having had a previous hemiplegia. In this patient (G11) the wall of the atrium was found *post mortem* to be covered with a thick irregular layer of clot of varying ages over an area of some 75 cm.^{2}; an embolus was found in the right middle cerebral artery. A second patient (G2), who had a partial hemiplegia, died from massive haemothorax following too early use of heparin. A third (G57), with a history of two previous emboli, had both old and fresh clot in his auricular appendage, did not recover consciousness after operation, and died from cerebral embolism. In the fourth (G17), a man aged 39, the appendage was seen to be small and completely obliterated by firm organized clot. By patient dissection a large polypoid mass of this was freed, but a further fragment of clot was felt momentarily in the atrium before the valve opening was enlarged. Soon after this the anaesthetist reported an unusual rise in blood pressure to 158/110. Before leaving the theatre the patient complained of severe pain in his legs, which he did not move although he was flinging his arms about. Examination disclosed an aortic embolism, with no pulsation below the umbilicus. Anaesthesia was reinduced, and a large saddle-embolus removed from the aortic bifurcation; the circulation in the lower limbs returned at once. He made a good immediate recovery, and the next day seemed none the worse except for pins-and-needles in the soles of his feet. Unfortunately he suddenly became unconscious 36 hours after operation and died after a few hours. At necropsy a small embolus was found in the basilar artery; the site of the aortic incision was quite healthy.

Since that case all the accessible large arteries are carefully palpated before operation and before the patient leaves the operating theatre; the significance of an unusual rise in blood pressure is also appreciated. In addition, if old or new clot is found in the auricle or if suspicious induration is present the auricle is incised and allowed to gush blood for a moment before the clamp is applied, or the clamp is momentarily released to allow a rush of blood to wash out any contained clot. This manœuvre has been successful in clearing clot in seven cases; in one a large clot fragment some 1.5 by 1.5 cm. was projected on to the floor near the operating table. There is therefore no doubt that this is an important practical manœuvre. Post-operative embolism occurred 4 times in the first 24 cases with 3 deaths, and 3 times in the last 76 cases with one death. We do not use heparin as a routine.

Haemoptysis

Haemoptysis is common in mitral stenosis and varies in degree from the blood-flecked sputum that so often accompanies acute pulmonary congestion to massive unexpected haemorrhage. Blood-streaked sputum accompanying congestive attacks is always less important than the distress caused by cough, dyspnoea, and orthopnoea; it occurred in two-thirds of our cases and did not influence the clinical assessment. In other words, an attack of "bronchitis" or of acute pulmonary congestion is neither more nor less serious because of the presence or absence of blood-flecked sputum. The prognosis in these cases is also the same whether slight haemorrhage accompanies the episodes or not. Similar observations apply to acute pulmonary oedema, the attack being neither more nor less dangerous on account of the presence or absence of *pink* frothy sputum. A third form of haemoptysis in cases of mitral stenosis results from pulmonary infarction. This is usually a late event and tends to complicate congestive heart failure, the infarct being due to an embolus liberated from phlebothrombosis in the veins of the legs or from the right atrium. The clinical importance of such haemoptysis depends on the size or number of the infarcts; the prognosis may be adversely influenced by the tendency to thrombo-embolism, but is determined chiefly by the heart failure itself.

These well-known facts have been mentioned in order to avoid confusion, because the haemoptysis we wish to discuss is a fourth type—the sudden frank haemorrhage that may be termed pulmonary apoplexy. This usually occurs unexpectedly when the patient is otherwise well, and may be the first symptom of the disease. Such haemorrhages are often massive—½ to 1 pint (284 to 568 ml.)—but do not last long, rarely more than 24 to 48 hours. In our first 50 cases 20 had haemoptysis of this kind. In 12 of them only one frank bleed occurred, in 4 there were two such haemorrhages, and in the remaining 4 severe recurrent haemoptysis dominated the whole clinical picture.

It is by no means uncommon for a patient to give a history of one or two attacks of pulmonary apoplexy many years before more serious symptoms develop. Precipitating factors include pregnancy and unaccustomed effort, but the trigger is often obscure. Sometimes repeated haemoptysis ceases after a year or so, and does not recur later when the disease is more advanced. There is little evidence that this course is due to diminished pulmonary congestion resulting from active pulmonary hypertension, right ventricular failure, or tricuspid incompetence, although such complications must protect the pulmonary capillaries and venules to some extent; again, haemoptysis may not recur when signs and symptoms of pulmonary congestion are obviously progressive. It is suggested that frank haemoptysis is more likely to occur when the pulmonary venous system is unaccustomed to working at a high pressure, and may cease when the vessels have adapted themselves to the situation. It is known that veins thicken quickly when subjected to a high internal pressure. The point to be emphasized is that pulmonary apoplexy is not necessarily a bad omen, and is rarely an indication for urgent valvotomy. In this respect it is far less serious than orthopnoea and paroxysmal cardiac dyspnoea, and is not to be compared with pulmonary oedema. Moreover, a good bleed relieves pulmonary congestion, and is therefore self-limited. On the other hand, the effect of valvotomy on the tendency to haemorrhage from the lungs is quite remarkable, for there has not been a single haemoptysis of any kind after a successful operation.

Haemosiderosis

Skiagrams revealed unquestionable haemosiderosis in 5 of the first 50 cases. This could not be correlated with any other common factor. There were three men and two women, and their ages ranged between 26 and 40 years. Two had had repeated severe haemoptyses, but two had never coughed blood at any time. Four had normal rhythm, but one had fibrillation. The mean pulmonary artery pressures were relatively low in two (25 and 27 mm. Hg), moderately raised in two (50 and 53 mm. Hg), and very high in one (100 mm. Hg). Four had practically pure mitral stenosis, but the most severe example had moderate incompetence as well. The results were excellent in two cases, good in one, fair in one, and one patient died from cerebral embolism. Subsequent skiagrams showed no change in the characteristic peppering in the four who survived. It is concluded from these and other similar cases that haemosiderosis should not influence the decision to operate one way or the other.

Pulmonary Hypertension

When the left atrial pressure rises, the pulmonary artery pressure must follow suit if the proper gradient between the two is to be maintained. The pulmonary capillary pressure —measured distal to a pulmonary artery branch that has been blocked by the cardiac catheter—usually represents the pulmonary venous pressure and gives a rough estimate of the left atrial pressure. Cases of mitral stenosis with minimal symptoms have usually shown a pulmonary capil-

lary pressure of about 10 mm. Hg and a mean pulmonary artery pressure of about 20 to 25 mm. Hg. Most patients submitted for operation have had a resting capillary pressure of 20 to 30 mm. Hg and a mean pulmonary artery pressure of 30 to 50 mm. Hg, giving a similar gradient of 10 to 20 mm. This may be called passive pulmonary hypertension.

When the pulmonary capillary pressure is around 35 mm. Hg pulmonary oedema may be expected, so that persistently higher left atrial pressures are incompatible with life. In fact, we have not recorded a resting pulmonary capillary pressure much above this.

A group of cases of some interest are those with resting mean pulmonary artery pressures at least 30 mm. Hg above the pulmonary capillary pressure, or of at least 60 mm. Hg if the latter has not been measured; here the gradient between pulmonary artery and approximate pulmonary venous pressure is well beyond the limits of passive pulmonary hypertension, and implies a true increase of pulmonary peripheral resistance on the arterial side of the capillary bed. Twelve of our first 50 cases had this greater degree of pulmonary hypertension, 10 of the 34 at Guy's and 2 of the 16 at Brompton. Selection is likely to have played an important part in determining so high a proportion in the Guy's series, for in a series of 88 cases investigated at Brompton and at the Institute of Cardiology active pulmonary hypertension was encountered in only 11 cases.

These cases can usually be recognized clinically by a variety of signs that cannot be discussed here. The present problem is how they fare after valvotomy. The results did not differ from the series as a whole. Of the 12 cited, five did excellently, three well, two poorly, and two died. Catheterization was repeated 6 to 12 months after operation in six of them, and in the five who were much improved clinically the pulmonary artery pressure had fallen to half or even to a third of its previous level (Table IV). The

TABLE IV.—*Comparison of Results of Catheterization Before and After Mitral Valvotomy*

Case	Mean Pulmonary Arterial Pressure (mm. Hg)*			
	Rest		After Exercise	
	Before Operation	After Operation	Before Operation	After Operation
G1	64	32	—	—
G4	40	27	—	—
G5	46	22	—	42
G6	100	55	116	79
G8	85	24	—	42
G9	52	35	75	44
G10	71	30	115	36
G13	71	22	109	48
G27	57	36	—	52
G31	53	23	104	44
G34	33	15	32	—
Unsuccessful Cases				
G16	100	88	115	141
G25	42	67	—	79

* Measured from a point midway between front and back of chest, at the level of the fourth costal cartilage.

sixth case was not clinically improved by valvotomy, and recatheterization showed no appreciable fall in the pulmonary blood pressure.

Of these 12 patients five had a resting pulmonary systolic blood pressure above 100 mm. Hg. It might be suspected that such pressures would prove irreversible, so the results in these five are exceptionally interesting. Two did excellently, one well, one poorly, and one died. Catheterization in the first two revealed a profound fall in pulmonary blood pressure, from 130/78 to 68/42 in one (G6) and from 130/56 to 40/10 in the other (G8); the third patient who did well (G29) has not yet been recatheterized.† The one who did poorly (G16) had a pulmonary blood pressure of 134/67 before valvotomy and 142/69 some eight months later; the operation in this case was not technically satisfactory. It is concluded that even severe pulmonary hypertension up to 130/80 mm. Hg is not necessarily irreversible. Indeed, we have no example in mitral stenosis of irreversible pulmonary hypertension, a term that can be applied only when the pressure is not materially lowered by a technically successful mitral valvotomy. Nevertheless, we should be surprised if this situation was not encountered sooner or later. In the meantime we have shown that severe pulmonary hypertension must not be regarded as a contraindication to surgical treatment.

†Post-operative catheterization has since shown a mean P.A. pressure of 23, the original pressure being 84 mm. Hg.

Acute Pulmonary Oedema

Acute pulmonary oedema is so important that it demands special consideration; its full significance in mitral stenosis and its correct management are not yet fully appreciated.

The mechanism of the formation of oedema is some final disturbance of the very delicate balance that exists between the hydrostatic and osmotic pressures in the pulmonary capillaries. The obstruction to the emptying of the left atrium causes a rise in pulmonary venous capillary pressure and a secondary passive rise in pulmonary arterial pressure.

The increased pressure gradient across the mitral valve serves to maintain proper left ventricular filling, and therefore an adequate cardiac output. This mechanism has two serious drawbacks: (1) sudden elevation of the pulmonary venous pressure causes reflex dyspnoea (orthopnoea and paroxysmal cardiac dyspnoea); and (2) if the pressure head rises above about 35 mm. Hg the hydrostatic pressure in the pulmonary capillaries may exceed the osmotic pressure, so that pulmonary oedema results. Attempts to raise the cardiac output in accordance with physiological needs are initiated by adjustments such as tachycardia, a rise of systemic venous pressure, and increased strength of right ventricular contraction. The spate of blood poured into the lungs cannot escape through the mitral valve without a sufficient rise of pulmonary venous pressure. This increases the pulmonary peripheral resistance, and the pulmonary blood pressure rises as already stated. A weak right ventricle may fail to deal with the added load, and its output then tails off: this may save the patient from pulmonary oedema at the expense of an inadequate cardiac output for the occasion. Weakness, dizziness, or a feeling of exhaustion then brings the effort to an end; the stimulus ceases, the right ventricular output returns to normal, and the pulmonary spate subsides. When the right ventricle is powerful, however, it may be able to deal with the increased load and may continue to pour blood into the lungs against an ever-increasing resistance. In such circumstances the only physiological event that can save the patient from acute pulmonary oedema is peripheral pulmonary vasoconstriction, so that the pulmonary arterial pressure rises far beyond the level conditioned by the rise in pulmonary venous or capillary pressure. Even the strongest right ventricle may have difficulty in surmounting this obstacle.

It follows that pulmonary oedema is most likely to occur in patients with tight mitral stenosis who are equipped with a powerful right ventricle and with sensitive and energetic reflex adjustments for raising its output, but have little tendency to develop protective pulmonary vasoconstriction.

Isolated attacks of pulmonary oedema or severe cardiac asthma are often found in the history. They are common in pregnancy, and may follow an acute respiratory infection, extra fatigue or effort, or emotion. Several of our patients have told of attacks on the way home or on arrival home after a late dance. Sexual intercourse may also be a cause. The journey to hospital may well precipitate an attack. Several patients have been in early oedema in the out-patient department and have needed immediate admission; one died less than two hours later.

We have observed rapidly occurring mild oedema with the preliminaries of cardiac catheterization, or even when the patient is approached for consultation. The disturbances preparatory to operation may be much more serious; two patients developed severe acute pulmonary oedema in the anaesthetic-room just before induction; clearly the

greatest care must be taken to lessen the risk of this, especially by adequate early sedation and by avoidance of all fussy preparation in the last hour or two of waiting: an orthopnoeic patient should not be laid flat during this period.

Early isolated attacks usually subside spontaneously, but later, when a state of continued and severe pulmonary congestion is present, an attack may prove fatal unless operation can give relief. In such cases pulmonary oedema is an emergency calling for prompt and vigorous first-aid treatment—an emergency just as important in its way as mechanical obstruction of the air passages or of any hollow viscus.

Treatment of an Acute Attack

A mild attack may be short and may respond readily to simple treatment, but the course of an attack is uncertain and may prove rapidly fatal when all seems improving. A vicious circle is apt to be set up by the patient's distress and exhaustion, and death occurs from inability to clear the air passages, the patient drowning in the fluid.

Treatment should be begun promptly and vigorously. The patient should *not be moved until initial treatment at least has been given.* He should be propped upright with the legs dependent, preferably in a simple wooden chair. Venous tourniquets should be applied immediately as high as possible on each thigh, to diminish the venous return; this serves as a rapid and simple venesection. Morphine ¼ gr. (16 mg.), should be injected intramuscularly or even intravenously; in the later stages, however, when the patient is moribund and the respiration is failing, morphine may be dangerous. Aminophylline, 0.24 g. intravenously, is of real value. Oxygen should be given, preferably with a mask. If rapid improvement does not follow these measures, venesection of 500–750 ml. should be done.

The other step of great importance is to clear the air passages by suction, because simple suffocation from drowning is the usual mode of death. A suction catheter should be passed into the trachea, either by the nose or by the mouth, or, if facilities are available, direct bronchoscopic suction should be used. As soon as it is realized that a severe attack has begun the simple instruments for this suction should be prepared; they should be used as soon as there is any suspicion that the patient is failing to cope with increasing fluid in the air passages. It is usual to err on the side of waiting too long. The development of thoracic surgery and anaesthesia during the past 15 years has made us increasingly conscious of the great value of suction in clearing the air passages in many conditions; its importance in the treatment of acute pulmonary oedema should be widely realized, as it may be life-saving.

Treatment of Recurrent and Relapsing Pulmonary Oedema

A patient may have one or more isolated attacks of acute pulmonary oedema over several years, perhaps caused by a special strain or effort. With added care and avoidance of similar stress there may be no recurrence. When, on the other hand, attacks are frequent or when there is a state of chronic pulmonary congestion with frequent exacerbations the time has come to cut short the process by valvotomy if the patient is to survive. The need for operation is urgent, and we have learned to have great respect for this state of affairs.

The congestion should first be lessened by routine medical treatment, but the resulting improvement should not lull the physician into a sense of false security, and operation should not be postponed; indeed, *the patient should not be allowed to leave hospital until it is done.* This is equally the case if routine treatment fails or leads to only slight improvement; only in this way is the patient's life likely to be saved. Valvotomy was undertaken urgently in nine such patients, and the following three illustrate this policy.

Case B13.—A man aged 28 was found to have mitral stenosis on discharge from the Navy in 1947. He was then given a good prognosis by a cardiologist, but two years later began to notice an increasing disability, culminating in large haemoptyses in 1951, and he then had to give up work. When first seen by us he had severe pulmonary congestion clinically and radiologically and moderate pulmonary hypertension (56/32 mm. Hg). Operation was advised, and he was sent home to await admission, but one week later he had to be admitted to another hospital as an emergency. One week later he was transferred to the Brompton Hospital, but arrived almost moribund in severe acute pulmonary oedema. In spite of strict medical treatment his condition remained precarious; intense congestion was present all the time and it was clear that, if he was to survive, operation had to be done in spite of the obvious risk. He made a good recovery from valvotomy and has since returned to full-time work with no symptoms whatever; all pulmonary congestion has been relieved.

Case G32.—A man aged 42 developed severe pulmonary oedema following cardiac catheterization; his condition was grave for 36 hours. In view of this it was thought to be unsafe to send him home to await operation. Although he seemed well controlled he developed another attack on his way to the operating theatre and was gravely ill. He improved after energetic treatment in the anaesthetic room, and it was decided to proceed at once with the operation. This went satisfactorily and he made a good recovery.

Case B22.—A woman aged 30 was admitted to hospital in a state bordering on acute pulmonary oedema and improved on routine treatment. Cardiac catheterization revealed a pulmonary artery pressure of 90/45 mm. Hg. Ten days later, while still awaiting operation, she developed a very severe attack of acute pulmonary oedema; this improved at first with energetic treatment, but over a period of 48 hours frequent severe relapses occurred, and her condition became so desperate that it was clear she would not live unless an operation could help her. In spite of the grave risk, our experience with other severe cases encouraged the attempt. Soon after the heart was exposed ventricular tachycardia developed; she improved following a pause. Valvotomy was followed by cardiac arrest; massage was begun with no response, and adrenaline was injected. The heart began beating, but ventricular fibrillation soon appeared. This was corrected by injection into the left atrium of 10 ml. of 1% procaine solution, once repeated. She left the theatre in fair condition and in normal rhythm, but died 36 hours later with pneumonia and renal failure.

Comment.—Although Case B22 ended fatally it must be considered in conjunction with the other eight operated upon, and with success, in a similar state of severe chronic or recurrent pulmonary oedema. The condition is one of the utmost gravity, and our plea is for recognition that the condition calls for valvotomy as soon as possible.

Although the parallel may not be entirely acceptable it seems reasonable to compare the state of affairs with the more familiar one seen in obstruction of other muscular viscera, such as the bladder, stomach, or intestine. In all of these, once obstructive symptoms occur, the sooner that operative relief is given the better. Without operation the patient struggles on until virtually total obstruction occurs. Conservative measures may achieve temporary abatement, allowing operation to be done in more favourable circumstances. A stage is, however, reached at which no improvement follows non-surgical treatment, and, unless the obstruction is relieved by operation, death is inevitable. At this phase the risk of operation is much greater and the mortality of quite a simple procedure is high.

These cases of mitral obstruction also pass through the earlier phases of "subacute" or "acute obstruction" that respond to conservative measures. Operation must then be done if relapse is to be prevented. Once there is no response to conservative measures death is inevitable unless an emergency operation can relieve the obstruction; the risk is much higher, but it is a risk that must be taken. As in the surgery of obstruction of other muscular viscera, the best way to avoid high mortality is to recognize and treat the obstruction as early as possible so that a serious state of decompensation is prevented.

Pregnancy and Sterilization

It has been, and still is, a common practice in the more severe cases of mitral stenosis to terminate pregnancy and to advise sterilization; or, if the pregnancy goes to term, to advocate sterilization afterwards. This is a policy that demands reassessment in view of the present possibility of successful valvotomy. Apart from the destruction of a life by the termination of pregnancy there is the effect on the marriage itself, which may not stand the double strain of the wife's sterility and incapacity.

Valvotomy can be performed during pregnancy, which can then be allowed to proceed normally. It may be needed as emergency in the middle or later months if severe pulmonary congestion or oedema develops. Both these points should be realized by obstetricians and physicians alike.

Termination and sterilization may still be correct treatment, especially if other complicating lesions or factors are present, but often these are not justified until the exact state of the mitral valve, as revealed at operation, is known. Thus if the valve is found to be densely fibrous, rigid, and calcified, so that an adequate valvotomy is not possible, sterilization may be advisable. If the valve is found to be thin and supple so that restoration of a large valve lumen is possible, then there can be no justification for termination, and still less for sterilization.

Two of us have already reported a case (Brock and Campbell, 1950) of successful pregnancy following pulmonary valvotomy. In another case (R. C. B. and P. W.) pulmonary valvotomy was performed during the fifth month of pregnancy without event; natural delivery occurred safely.

In one case in our series of mitral stenosis valvotomy was performed successfully during the third month and the pregnancy has proceeded to natural delivery; the condition of the valve at operation justifies optimism. In this patient, who was on our waiting-list for valvotomy because of attacks of pulmonary oedema, termination of pregnancy and sterilization had actually been decided on elsewhere. In a second case a successful valvotomy was done at the 28th week in a patient who had severe pulmonary congestion with repeated small haemoptyses from the third month despite treatment in hospital. A third and almost identical case, in which termination and sterilization had been advised but was refused on religious grounds, has since had a successful valvotomy at the 28th week. Both these patients have now had a normal delivery at term.

Operative Experiences

As this paper is chiefly clinical it is not necessary to do more than mention briefly a few technical matters.

An anterior incision through the third intercostal space with division of the third and fourth cartilages was used for the first 45 cases; this gives somewhat cramped access in some, especially if there is much right-sided hypertrophy and the auricle is small. A standard postero-lateral thoracotomy has also been used but is unnecessarily elaborate; it gives an excellent exposure, but there is unnecessary interference with the big scapular muscles. We have abandoned this incision.

Our present incision is almost a straight horizontal one, skirting the lower border of the breast, curving up slightly in front and extending backwards some 3 cm. below the inferior angle for the scapula and about 10 cm. beyond it. The serratus anterior is cut at its origin; the front 10 cm. or so of the latissimus dorsi is divided. The chest is opened through the fifth interspace; if this space is incised from front to back there is no need to divide a cartilage. An excellent exposure is thus given with the minimum of muscular damage. The patient lies on the right side rotated back 45 degrees.

As described in our first paper, the valve is approached by inserting the index finger through the left auricular appendage. It is necessary to emphasize that the valve orifice is not merely stretched or dilated; it is quite wrong to describe the operation as such. The valve is actually split along the line of one or both commissures so that in a favourable case an opening of almost normal size results. It must also be pointed out that it is not necessary, in most cases, to use a valvotome for this purpose. An instrument was used in only 28 of our 100 cases. The impression has been created that without an instrument the operation cannot be done either safely or effectively. This is wrong, and in fact may be a dangerous teaching in that it encourages a surgeon inexperienced in intracardiac manipulations to make things much more difficult. In many cases the finger alone splits the valve with an accuracy and speed that no instrument could rival. It is our practice to introduce the finger and do all that is possible with it alone. If the division is not enough the finger is withdrawn and reinserted carrying a valvotome, which is a simple, thin, strip-like knife that can bend with the finger and slides to and fro through a slot in a finger ring. Quite a small incision may enable the finger to continue and complete the splitting.

The third technical matter is the management of a small contracted thrombosed auricle. The danger of embolism has already been discussed and the importance described of allowing a free gush of blood to wash away any clot. Although it is comforting to find a long patent appendage, the surgeon must not be deterred if he finds it short and solid. By careful dissection the organized or organizing thrombus can be freed and an entry made. In nine such cases in which the opening was very small and the atrial wall very thin, and it was too dangerous to insert the index finger, the little finger found its way in easily, and the valve was split with it alone in six. In the remaining three it was possible to follow with the index finger and complete the division begun by the little finger.

Cardiac Catheterization

This method of investigation has been employed in all but one of our 100 cases. The usual procedure has been to measure the right atrial pressure, pulmonary artery pressure, pulmonary capillary pressure, and cardiac output at rest, and also to measure the pulmonary artery pressure and cardiac output during a standard exercise test. Our aim in this has been not only to assist in the assessment before operation but also to gain information about the cardio-respiratory system in mitral stenosis and the changes occurring before and after valvotomy. To this end we also intend to repeat our observations after the operation. A report on such studies made on the Guy's Hospital cases is being made by Dr. Holling and Dr. Venner, to whom we are indebted for these investigations.

Cardiac catheterization is not without risk in mitral stenosis. We have had several instances of pulmonary infarction which may have been due to the wedging of the catheter into a small pulmonary artery during measurements of pulmonary capillary pressure. Very occasionally an attack of pulmonary oedema (in one case fatal) has followed cardiac catheterization. We prefer to delay operation for at least 7 to 10 days after catheterization, however well tolerated.

Studies after valvotomy in 11 cases have shown a fall in pulmonary artery pressure commensurate with the clinical improvement (Table IV). The maximum improvement may not be seen at once and our present practice is to delay catheterization until 9 to 12 months after the operation. This is shown in patient G5, whose mean pulmonary artery pressure before operation was 51 mm. Hg; six weeks after it was 42 mm. Hg at rest and rose to 62 mm. Hg on exercise. He continued to improve clinically, and when the investigation was repeated 16 months after operation the pulmonary artery pressure had fallen to 22 mm. Hg at rest and was 42 mm. Hg after exercise. This need for waiting has held up our post-operative studies, and the final assessment of the value of catheterization will not be made until they are available. It is, however, possible to give our present

opinion of its value in the investigation of cases of mitral stenosis before operation. For the most part the findings have done little more than support clinical impressions already formed, and have never caused us to alter the decision whether or not to operate. For the time being we are continuing this method of investigation in order to find out as much as possible about the changes associated with mitral stenosis before and after operation. Those who have patients clearly suitable for valvotomy by clinical criteria should not be deterred from operating because they are unable to organize the necessary facilities for catheterization.

Medical Treatment Before and After Operation

To minimize the danger of pulmonary oedema in patients awaiting operation we use sedatives and dehydrating measures, including the mercurial diuretics and a low sodium diet. Those with normal rhythm are given digitalis so that they will already have some measure of protection should they develop fibrillation after operation. At one period we also tried quinidine for some days before and after operation in an attempt to prevent this not infrequent occurrence. It was not, however, successful, and our present practice is to digitalize all patients and to use quinidine only if it is decided to try to restore normal rhythm in those who develop fibrillation after operation. The fall in blood pressure that occurs in many cases during the operation is being investigated, but the subject is too complex to discuss in this paper.

Complications after operation are few and the patient who returns to the ward after a successful valvotomy gives little or no cause for anxiety. We have had abundant experience that when the surgeon is satisfied with what he has achieved at operation the physicians have little need to worry, however ill the patient was before. The improvement to the heart is in fact the reason why patients tolerate this operation so much better than they would any other. The patient is usually ambulant at the end of a week and ready to start convalescence at the end of three weeks.

Symptoms and Signs after Operation

Symptoms are more reliable than signs as evidence of a successful result. An early and striking feature is the obvious improvement of the peripheral circulation as shown by the colour and warmth of the body and limbs and the need for fewer bedclothes. The patient is quickly aware of the improved function of the lungs and notices that "the chest feels more free," and this despite the operative trauma to the chest wall. The loss of orthopnoea is an early indication of success. The degree of functional improvement during convalescence is a fairly reliable guide to the ultimate result, though more time is needed to show whether it is to be classed as good or excellent.

The physical signs give less indication of the change that has occurred. In a few patients the diastolic murmur has entirely disappeared and in many the intensity has diminished, but the absence of any significant alteration does not necessarily mean a poor functional result. In some patients a soft apical systolic murmur has appeared or has slightly increased, but this also is compatible with a good result. More reliable indications of success are a diminution of the signs of pulmonary hypertension. The size of the heart alters little and in some successful cases not at all; we have only a few in which it is easily apparent and two in which it is striking (Figs. 2 and 3). In many, however, the contours alter, showing slight diminution of the prominence of the right border, a less bold pulmonary arc in the anterior and right oblique views, and a very slight increase in the left ventricular contour; in many there is a notable flattening of the left border in the straight view owing to the loss of the shadow of the left auricular

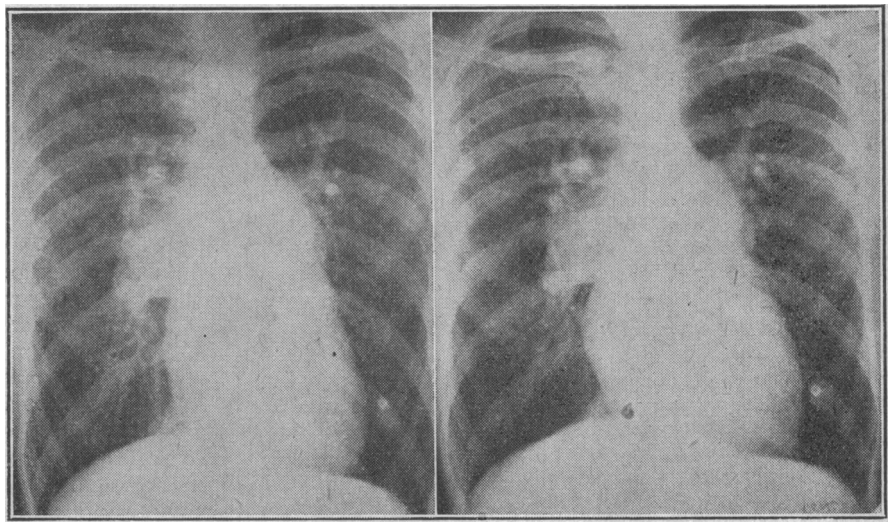

FIG. 2.—Teleradiographs of a man of 26 (G6) six months before and 19 months after operation. Nine years' history of increasing breathlessness and severe pulmonary congestion; he could walk only 20 yards (18 metres) without symptoms; tight mitral stenosis and marked pulmonary hypertension (mean pulmonary artery pressure 100); radiograph shows haemosiderosis. Since operation, on March 2, 1950, has led a full working life; post-operative pulmonary artery pressure, 55.

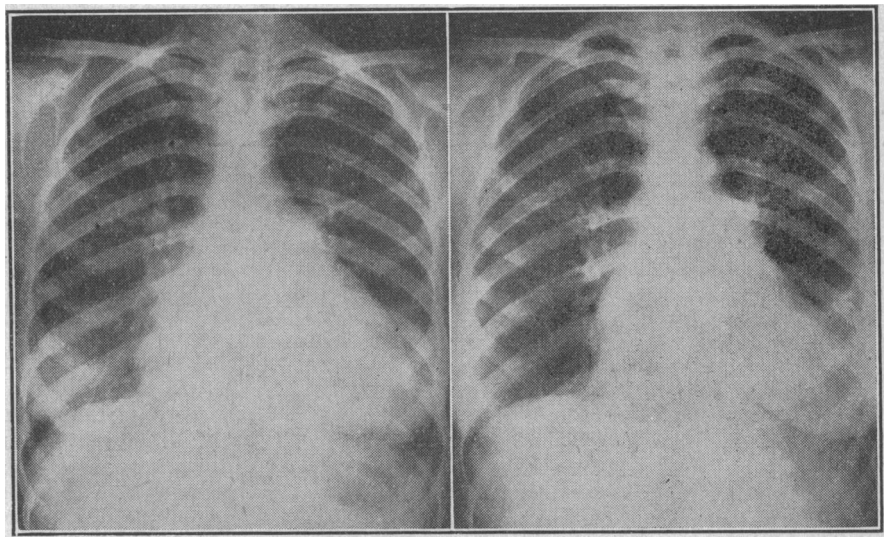

FIG. 3.—Teleradiographs of a woman of 38 (G39), the day before and five months after operation. There was six years' history of increasing dyspnoea and admissions to hospital for acute pulmonary congestion; definite but not significant aortic incompetence, auricular fibrillation for six months, and right-sided failure controlled only by complete rest (capacity D). At operation on July 12, 1951, fresh clot was washed out of the auricle and an opening of 4 cm. in length with two mobile cusps was achieved. Five months later her capacity was A.

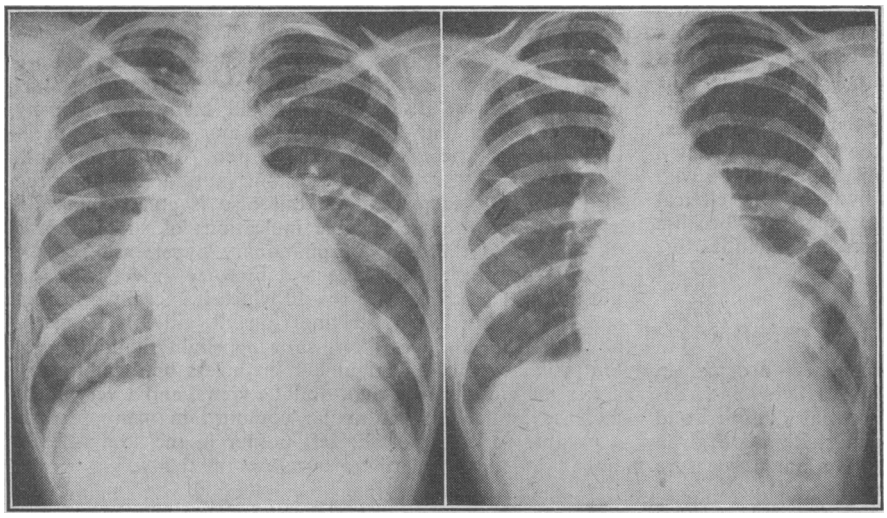

FIG. 4.—Teleradiographs of a woman of 31 (B18) before and after valvotomy, showing relief of pulmonary venous congestion. Five years' history of increasing breathlessness and bronchitis; could walk only 50 yards (46 metres); mean pulmonary artery pressure 44 mm.; successful valvotomy on May 30, 1951.

appendage after operation. Diminution of the hilar shadows denoting pulmonary venous congestion may be quite striking (Fig. 4). Though the main pulmonary vessels appear less dense and prominent in some successful cases, there is no significant alteration in the smaller vascular lung markings.

Follow-up and Future

The longest period of follow-up in the first 50 cases is 40 months, the shortest 8 months. We have deliberately not included the subsequent 50 cases in the assessment of results, though we expect that the proportion of successes in these has increased. In no case have we been far out in our preliminary judgment of success or failure, but we feel more confident of a good result when the patient has successfully withstood the advent of cold and winter weather, so often the stumbling-block or downfall of these patients with mitral stenosis, and often a more exacting test than physical exertion.

In 13 patients we have checked our clinical assessment—one poor, one fair, and 11 good or excellent results—by catheterization at periods varying from 1 to 18 months after operation, and in two patients this was done twice. In all the agreement was close.

A more prolonged follow-up is needed before any degree of permanence can be claimed, but so far the results in this respect are encouraging. The first patient operated on 40 months ago recently returned to hospital as it seemed possible that her improvement was not maintained—she was walking 2 miles (3.2 km.) instead of 4 miles (6.4 km.)—but catheterization showed no alteration from her first test shortly after operation. It is possible in the future that patients may again deteriorate either from further stenosis of the valve or from further rheumatic activity. Time alone will show, but there is as yet no evidence that such deterioration has occurred, nor should such considerations weigh against operation. Even if the disease recurs, successful valvotomy does at the least return the patient to the condition in which he was several years previously, and many of the earlier cases could not have survived till now had operation been withheld.

Summary

It is only 18 months since we reported the results in the first 9 patients submitted to mitral valvotomy. We can now report the immediate results in 100 patients, and a more detailed analysis and a longer follow-up of the first 50 of these.

The results are good or excellent in 32 of the first 50 patients. Before operation nearly all were seriously disabled : after it two-thirds have resumed work and can walk two miles (3.2 km.) or more. Often the improvement is dramatic.

There were 13 deaths in the first 100 cases ; 7 of these were in the first 20, so that for the last 80 the operative mortality has been less than 8% although many of the patients were gravely ill. The presence of auricular fibrillation, which generally indicates a later stage of the disease, adds to the risk (8 deaths in 44 cases, compared with 5 deaths in 56 cases).

Four-fifths of the patients operated on were between 25 and 45 years of age. We were soon satisfied that the young patient with pulmonary congestion, but often with a heart not greatly enlarged, could be vastly improved by operation. Wider experience has shown that increasing years or a larger heart are compatible with success.

Mitral regurgitation is not increased by a successful operation. Neither mitral regurgitation, some degree of which was present in about one-third of the patients, nor calcification of the mitral valve, nor functional tricuspid regurgitation prevents good results, but gross calcification, especially when associated wtih mitral regurgitation, does make success less likely.

No patients were included when mitral regurgitation or aortic valvular disease was thought to be the predominant lesion. Aortic stenosis or regurgitation was, however, an added lesion in 5 of the 50 patients, and this too did not prevent success.

At least 13 of the 50 had suffered from congestive failure. Good results were obtained in many of these, even when the heart was large. When auricular fibrillation and congestive failure have been present for long it seems likely that the ideal time for help by valvotomy has been missed, but their presence even for as long as five years in some patients did not prevent great improvement. Embolism was the cause of death in four of the eight patients with auricular fibrillation.

A history of previous embolism is no argument against valvotomy, and, in fact, no thrombosis was found in the auricle at operation in 8 of 17 such patients. The steps that should be taken at operation to minimize the risk of further embolism have been described.

Some cases with pulmonary hypertension may reach a stage where the pulmonary changes are irreversible, but systolic pressures in the pulmonary artery above 100 mm. Hg did not prevent excellent results. When the pressure in the pulmonary artery at rest is not very high it may rise abnormally on even the slightest exercise, with little or no increase in cardiac output. This state of affairs is often an indication for operation.

The management and treatment of acute and recurrent pulmonary oedema are discussed in detail.

Cardiac catheterization has been carried out in all our cases to obtain as much information as possible. The results have rarely changed our clinical views, and we

think that mitral valvotomy should be undertaken in suitable centres even where cardiac catheterization is not available.

Mitral valvotomy should be considered in all patients with mitral stenosis who are progressively disabled. Orthopnoea and recurrent pulmonary oedema are special indications. The risk of recurrent rheumatic carditis in patients under 20 years of age should make one more hesitant, and the presence of active carditis is one of the few contraindications to operation.

It must also be considered as an alternative to termination of pregnancy and sterilization; it has been carried out successfully in three women during their pregnancies, which have then terminated normally.

Time alone will tell how long the improvement after mitral valvotomy can last and whether fibrosis or recurrent carditis will again lead to severe stenosis of the mitral valve. In the two or three years that have elapsed since the earliest operations there has been no evidence of relapse.

We wish to thank our many colleagues who have been actively interested in the wide problems of mitral stenosis and who have helped in the investigation and treatment of these patients. The Guy's group are particularly indebted to Dr. H. E. Holling, of the Medical Research Council Unit.

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ADRENAL CORTICAL FUNCTION AT DEATH AS MEASURED BY LEVEL OF CIRCULATING EOSINOPHILS

BY

PAUL B. JENNINGS, M.D.

From Atlanta, Georgia

In recent years it has been shown that the chief function of the adrenal cortex is to aid the organism in adapting to stress, either internal or external (Selye, 1949, p. 111). When an organism is subjected to stress an "alarm reaction" is set up, according to the observations of Selye. It is during the countershock phase of this reaction that the adrenal gland is called into play. There is evidence of hyperfunction of the cortex of this organ as demonstrated anatomically and physiologically. There then ensues a stage of resistance during which this hyperactivity subsides and the organism shows signs of recovery. If, however, the stressor persists, the stage of exhaustion ensues and hyperactivity of the cortex again comes into play (Selye, 1946).

The evidence as presented by Selye (1946, 1949) to support these concepts is clear-cut and generally accepted. The picture becomes obscure about exactly what takes place in the adrenal cortex if the stress continues until the organism dies. There seems to be a question whether the stage of hypersecretion of cortical products continues until death ensues or if the opposite occurs and the cortex fails and the organism succumbs in a state of hypoadrenalism.

Grossly, the adrenal is heavier than normal and the cortex appears hypertrophied in animals and humans dying after prolonged stress (Selye, 1937; Armstrong and Heim, 1938; Sarason, 1943; Tepperman *et al.*, 1943). This is not a positive indication, however, of hyperfunction of the gland at the time of death, since changes occurring previously might have persisted in spite of subsequent failure.

Sarason (1943) and Rich (1944) both describe histological changes in the adrenal glands of patients dying from acute illnesses which they interpret as resulting from an increased demand for adrenocortical hormones. Selye (1949, p. 852) describes similar degenerative changes, but also points to the cellular hypertrophy during the exhaustion stage which "may or may not be accompanied by an overproduction of corticoid substances" (Selye, 1946). The haemorrhagic changes in the adrenal following severe burns and in meningococcal infection (Waterhouse–Friderichsen syndrome) are well known (Hartman and Brownell, 1949).

It is obvious from these conflicting reports that morphological studies are inconclusive. Selye (1950, p. 299) summarizes by stating: "During the stage of exhaustion cytolytic phenomena, infarction and necrosis prevail; otherwise the changes resemble those seen in the alarm reaction (corticoid overproduction). A more detailed characterization is not yet possible, since comparatively few data are available concerning adrenal changes in this stage."

Adrenal functional studies during exhaustion are scarce. Selye (1950, p. 223) states: "Unfortunately, up to now no systematic investigations have been published concerning the urinary elimination of corticoids throughout the three stages of the general adaptation syndrome. Presumably, in the stage of exhaustion the adrenal function becomes deficient when the structure of the gland breaks down."

Selye (1950) noted, however, that in chronically ill and debilitated patients the corticoid secretion (p. 223) as well as the 17-ketosteroid excretion (p. 227) is low. He felt that this corresponded to the stage of resistance when corticoid secretion is less intense than during the alarm reaction. Almy *et al.* (1950), in a similar group, noted a poor eosinopenic response to adrenaline which led him to suspect that inadequate adrenal function may play a part in determining the course of illness. Furthermore, the clinical picture of the terminally ill debilitated patient resembles that of Addison's disease.

Thus the meagre evidence available at the present time suggests that the adrenal cortex breaks down during the exhaustion stage of the general adaptation syndrome, and this failure may be involved in, or even lead to, the death of the organism. On the other hand, the evidence is not unequivocally in favour of this hypothesis, and some of the studies seem to indicate that there is actually adrenal hyperfunction during this stage. A clarification of this enigma would have obvious clinical significance. If the adrenals were proved to be in a state of failure in the terminal stages of illness, treatment with the available cortical hormones would be expected to prolong life, and in some cases might actually prevent death by maintaining the resistance of the organism until the stress could be eliminated.

An accurate method for measuring adrenal cortical activity has been added to the medical literature—the measurement of the circulating eosinophil level (Thorn *et al.*, 1949). This index was used when functional studies were carried out during some phases of the adaptation syndrome. A pronounced eosinopenia