Systemic embolism in mitral valve disease

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The analysis of a series of 839 cases of mitral valve disease has shown the following. (a) Systemic embolism is as common with mitral regurgitation as with mitral stenosis. (b) Atrial fibrillation, with clot formation in the atrium, is the main cause predisposing to systemic embolism. (c) Mitral valve calcification is important only in that it predisposes to operative emboli. (d) Atrial appendage size has no influence on the occurrence of systemic embolism, and atrial appendagectomy has no influence on the occurrence of post-operative embolism. (e) Only in patients with atrial fibrillation and an operable valve, is there any reduction in the number of emboli after surgery.

Certain guide-lines with regard to treatment are suggested.

Peripheral arterial embolization is a serious, sometimes fatal, complication of mitral valve disease. Askey (1957) and Askey and Bernstein (1960) state that a first recognized embolus is fatal in about one in six so affected, and that one-half of the survivors die within three years, half of these because of recurrent embolism. Surgical measures designed to improve valve function, and to remove potential sources of clot formation, have been advocated for the prevention of this hazard. Among the many reports are those of Madden (1949), Belcher and Somerville (1955), Glover (1956), Turner and Fraser (1956), Ellis, Harken, and Black (1959), Baker and Hancock (1960), and Learoyd *et al.* (1960). Kellogg *et al.* (1961) and Taber and Lam (1960) emphasized the possible hazards of emboli occurring at operation, but Ellis and Harken (1961) in a further review of their patients reasserted their belief in the protective value of mitral valvotomy against further emboli. They also thought that where mitral stenosis was present, the occurrence of a systemic embolus was in itself an indication for operation.

Subjects

This paper is based on 839 cases of rheumatic mitral valve disease seen at the Liverpool Regional Cardiac Centre between 1952 and 1965. Where follow-up was possible, assessments were made at 6-monthly intervals by at least one of the authors. We have attempted to study the incidence of arterial embolism, together with possible factors in its causation; and where cardiac operation

has been undertaken, we have tried to evaluate its usefulness in the prevention of systemic emboli.

Of the 839 patients, 28 had systemic emboli before coming under review, but each of these patients was known to have had mitral valve disease before the embolism, and in no case was mitral valve disease recognized because of the occurrence of an embolus. For the purpose of this review, those patients having had systemic embolism as a result of bacterial endocarditis were excluded.

As judged by the usual criteria, i.e. clinical, electrocardiographic, and radiological, 737 patients had predominant mitral stenosis, and 102 had mitral regurgitation. This was an arbitrary division, and occasionally it was difficult to decide which was the dominant lesion, but stenosis was always considered the most important lesion in those cases put forward for closed mitral valvotomy.

In all, 74 patients (8.8%) had more than trivial aortic valve disease, and 17 of these had closed mitral and aortic valvotomy; 8 patients were found to have organic tricuspid valve disease, the diagnosis being based mainly on catheter findings, and in 3 of the 8, closed mitral and tricuspid valvotomy was performed.

Results

The total incidence of embolism is shown in Table 1 for mitral stenosis and in Table 2 for mitral regurgitation, with reference to the cardiac rhythm, the age of the patient, and disability graded according to the classification of the New York Heart Association (1964).

In both groups, there is an increasing incidence of embolic episodes with increasing age and with atrial fibrillation, but not

TABLE 1 Incidence of systemic emboli in 737 cases of mitral stenosis

Disability grade	Sinus rhythm				Atrial fibrillation				Sinus rhythm and atrial fibrillation combined
	Age 35 and below		Age 36 and above		Age 35 and below		Age 36 and above		All ages
	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli	Total cases
0, 1, 2	146	6	128	17	32	10	158	64	464
3	41	2	52	5	12	2	83	19	188
4	10	1	15	0	7	2	53	12	85
Totals	197	9	195	22	51	14	294	95	737

TABLE 2 Incidence of systemic emboli in 102 cases of mitral regurgitation

Disability grade	Sinus rhythm				Atrial fibrillation				Sinus rhythm and atrial fibrillation combined
	Age 35 and below		Age 36 and above		Age 35 and below		Age 36 and above		All ages
	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli	Total cases
0, 1, 2	25	0	10	2	7	0	16	3	58
3	1	0	1	0	5	1	16	6	23
4	1	1	1	0	7	2	12	2	21
Totals	27	1	12	2	19	3	44	11	102

with a worsening disability. With dominant mitral stenosis, emboli occurred in 31 out of 392 patients with sinus rhythm (8%), and in 109 out of 345 with atrial fibrillation (31.5%). With dominant mitral regurgitation, emboli occurred in 3 out of 39 patients with sinus rhythm (7.7%), and in 14 out of 63 with atrial fibrillation (22%).

The incidence of embolism is similar in both groups, and when considered together, the figures range from 10 emboli in 224 patients aged 35 or less in sinus rhythm (4.4%), to 106 emboli in 338 patients aged 36 or more with atrial fibrillation (31.6%).

Of the 157 patients with emboli, 32 (20%) were in sinus rhythm when examined. None of these patients gave a history of paroxysmal dysrhythmia, though this diagnosis could not be excluded. It was not possible to determine the rhythm at the time of embolization in 18 (11.5%), and 107 (68.1%) were in atrial fibrillation when examined. Nine (5.8%) had the atrial fibrillation for less than one month, and 60 (38.1%) for more than one month when embolization occurred. In 38 (24.1%) it was not possible to determine the duration of the atrial fibrillation.

In all, 28 patients with known rheumatic

mitral valve disease were referred only after a major embolus had occurred. Of the 28, 9 were in sinus rhythm, and 19 in atrial fibrillation; 24 had a disability of grade 2 or less, and 4 were aged 35 or less.

Pre-operative emboli, atrial thrombus, and atrial appendage size In most cases, embolism must be related to the formation of thrombus in the left atrium or ventricle, and certainly if clot is present it must increase the risk of producing emboli at operation. Unfortunately, a history of embolism does not help in predicting the presence of clot discoverable at operation, since, in this present series, such clot was found in only 17 of 114 patients where emboli had occurred (15%), and in 75 of 440 patients with no history of embolism (17%).

It has been thought that the size of the atrial appendage has a direct influence on the clot formation therein, and hence the risk of embolus formation, both before and during operation (Somerville and Chambers, 1964). If this could be proved true, then it would be of considerable value both prognostically and in the planning of operation. We have tried to elucidate this problem by an attempted radiological assessment of

the left atrial appendage size in two different groups of patients.

The radiological assessment of the left atrial appendage from a standardized 6-foot postero-anterior x-ray was accomplished with reference to an imaginary line drawn from the left border of the aortic knuckle to the cardiac apex. Thus, grade 0 is where no atrial appendage shadow can be seen, grade 1 is where the appendage is visible on the left cardiac border but does not extend closer than 2 mm. to this line, grade 2 is where the left border of the appendage shadow lies from 2 mm. medial to 7 mm. lateral to the line, while grade 3 is where the appendage shadow extends beyond the lateral limits of grade 2, and often has a separate outline of its own.

Pre-operative x-rays were assessed in 104 patients known to have had systemic emboli, and 53 were found to have an atrial appendage size of grade 1 or less; only 21 were of grade 3. To view the problem in another way, we also assessed the pre-operative left atrial appendage size in a different, random sample of 104 patients known to have mitral valve disease, where the radiological grading was made without knowledge of the clinical findings. Of this second group of patients, 43 had small appendages, of grade 1 or less, and 10 of the 43 had a history of embolism (23%); 36 had large appendages (grade 3), of whom 5 gave a history of systemic embolism (14%).

These figures show that systemic embolism occurs with any size of left atrial appendage, and a large appendage is not necessarily associated with an increased risk of embolus formation.

Pre-operative embolism and valve calcification Table 3 shows the relation between valve calcification (assessed at operation), pre-operative embolism, and cardiac rhythm in all types of cases, i.e. both

TABLE 3 Incidence of pre-operative embolism in all cases operated upon, correlated with valve calcification and cardiac rhythm

Rhythm	Pre-operative embolism		No pre-operative embolism	
	Calcification present	Calcification absent	Calcification present	Calcification absent
Sinus	10	11	81	183
Atrial fibrillation	37	56	78	98

mitral stenosis and those cases in which exploratory cardiotomy was performed. Operation was carried out on 206 patients with valve calcification, 47 having had pre-operative emboli (23%); 348 patients without valve calcification included 67 who had suffered pre-operative emboli (19%). This difference is not significant, but the Table again shows the clear relation between atrial fibrillation and systemic embolism.

Valve calcification has a much more significant effect upon the production of embolism at operation, as will be shown later.

Operative embolism We have adopted the criterion of Ellis and Harken (1961) that an operative embolus is one that occurs in the operating room or any time before the patient is discharged from hospital after operation. Atrial clot, valve calcification, the type of operation, and the severity of the patient's disability have been considered as factors influencing the incidence of operative embolism.

(a) Atrial clot

As would be expected, the risk of operative embolism is much greater in the presence of atrial clot, occurring in 14 of the 90 patients where such clot was found (15.5%) (Table 4

TABLE 4 Relation between cardiac rhythm, valve calcification, clot, and operative embolization in dominant mitral stenosis

Rhythm	Operative findings							
	(a) No calcification or clot		(b) Calcification only		(c) Clot only		(d) Calcification and clot	
	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli	Total cases	Emboli
Sinus	187	2	86	6	2	0	4	0
Atrial fibrillation	103	3	66	6	40	7	44	7
Totals	290	5	152	12	42	7	48	7

cols. (c)–(d)). Only 17 of 442 patients without clot formation had an operative embolus (3.8%) (Table 4, cols. (a)–(b)). The problem is how to predict the presence of atrial clot. It has been shown that a history of embolism does not help, and indeed the incidence of systemic embolism at mitral valvotomy, where there was a history of pre-operative embolism, is no higher than where no embolism had occurred before operation. Of 114 cases with pre-operative embolism, 4 had further emboli at operation (3.5%), and in 442 patients without a history of pre-operative embolism, 27 operative emboli occurred (6.1%).

The figures in Table 4 show that clot formation is closely related to the presence of atrial fibrillation; only 6 of 279 patients with sinus rhythm had discoverable clot at operation (2.2%) compared with 84 of 252 patients with atrial fibrillation (33%), and from a total of 31 operative emboli, 23 occurred in patients with atrial fibrillation. Theoretically, pre-operative anticoagulation could reduce the incidence of atrial clot found at operation. Among the 114 patients having had pre-operative emboli, 21 were in sinus rhythm, and only 3 were given anticoagulants before operation. None of the 21 had discoverable atrial clot at operation.

Anticoagulants were given to 47 patients with atrial fibrillation and a history of systemic embolism before operation, and atrial clot was found in 6 (12.8%). Anticoagulants were *not* given to 46 similar patients with atrial fibrillation and a history of systemic

embolism, and atrial clot was found in 11 (24%), but this apparent difference is not statistically significant.

(b) Valve calcification and type of operation

With both digital and instrumental valvotomy, the presence of valve calcification clearly increases the risk of operative embolism. Table 4 shows that operative emboli occurred in 19 of 200 patients with valve calcification (9.5%), compared with 12 emboli in 332 patients without valve calcification (3.6%).

In 135 finger-split operations 5 emboli occurred (3.7%), 2 of which were in the 39 with calcified valves (5%). In 397 instrumental valvotomies, 26 embolic episodes were produced (6.5%), but 17 occurred in the 162 patients with valve calcification, a frequency of 10.5 per cent (Table 4). It is probable that the greater force used with instrumental valvotomy accounts for the higher incidence of embolic episodes with this type of operation.

There is evidence in these figures, therefore, to suggest that valve calcification and instrumental valvotomy both increase the risk of operative embolism, as does the presence of atrial clot.

(c) Grade of disability

It might be expected that increasing disability, associated often with increasing age, atrial fibrillation, and valve calcification, would be associated with an increased incidence of operative embolism, but this is not so, though the operative mortality increases.

TABLE 5 Systemic emboli in follow-up: incidence per patient-year

Group of patients	Cases followed up	Total No. of patient-years in follow-up	Average No. of patient-years in follow-up	No. of emboli in follow-up	Incidence of emboli as per cent per patient-year
Finger-split without appendagectomy	61	431	7	4	0.92 (1:108)
Finger-split with appendagectomy	65	388	6	7	1.8 (1:56)
Instrumental split with appendagectomy	318	1088	3.4	14	1.3 (1:78)
For mitral regurgitation					
(a) Appendagectomy only	9	57	4	3	5.3 (1:19)
(b) Appendagectomy and Glover's operation*	5				
Mitral stenosis, no operation	166	646	3.9	24	3.7 (1:27)
Mitral regurgitation, no operation	68	256	3.8	5	1.9 (1:51)

*Glover's operation consisted of an attempt to reduce the circumference of the mitral annulus by tightening a ligature passed around the annulus from the outside.

Of 326 patients with grade 2 disability or less, 18 had operative emboli (5.5%), counting both types of operation, and of the 13 operative deaths in this group (4%), only one was attributable to an embolus. With the more severely disabled patients in grades 3 and 4, 13 emboli occurred when operating upon 206 patients (6.3%), and of 27 operative deaths (13.2%), 5 were embolic in nature.

Emboli occurring during follow-up observations (Table 5) The period of follow-up of these patients varied from less than a year to over 13 years. The earlier finger-split valvotomies were not combined with atrial appendagectomy, unlike the later finger-split operations and the instrumental valvotomies.

The figures for the different types of valvotomy do not confirm the view that appendagectomy plays any part in the prevention of systemic embolism, since those operations without appendagectomy do not show a greater incidence of post-operative embolism (0.92% per patient year) than either the finger-split (1.8% per patient year) or the instrumental valvotomies (1.3% per patient year) where appendagectomy was performed. In addition to this evidence, it can be seen from Table 5 that where operation was predominantly exploratory, i.e. where mitral regurgitation was found, and atrial appendagectomy was performed but the state of the mitral valve was not fundamentally changed, the incidence of post-operative embolism was higher still (5.3% per patient year). In all cases where it was performed, appendagectomy was complete. In no case where Glover's operation was performed was there any evidence that the regurgitation had been modified.

Post-operative emboli and adequacy of valvotomy It is possible that systemic embolism after mitral valve surgery is related to the adequacy of the operation. This of course will depend upon the mobility of the valve and chordae, a heavily fibrosed and calcified valve with shortened chordae being most likely to give an unsatisfactory result, but our records have not been clear enough for these detailed factors to be assessed. We have regarded a satisfactory valvotomy as one where the valve orifice measured more than 3.0 cm. in diameter at the end of the operation, and where no more than a minor degree of regurgitation was produced. A valvotomy was judged unsatisfactory where the diameter of the valve orifice was left at 3.0 cm. or less, or where the

surgeon assessed regurgitation at the end of the operation as moderate or severe. Because of the lack of information about valve mobility, these assessments are incomplete, and it could be that the different groups of operations have not been composed of the same types of valve.

Of 61 finger-split valvotomies without appendagectomy, 52 were unsatisfactory operations, and 4 emboli occurred in the follow-up years in this group; there were no emboli in the 9 patients with a satisfactory operation. Of 65 finger-split operations with appendagectomy, 33 were unsatisfactory valvotomies, and 5 of these 33 had emboli; 2 emboli occurred in the 32 patients with satisfactory valvotomies. Of 318 instrumental valvotomies, 32 were unsatisfactory, and one had a post-operative embolus; 13 emboli occurred in the 286 patients following satisfactory operations.

Taking the three groups as a whole, there were 117 patients with unsatisfactory valvotomies, and 10 emboli occurred in this group, or 1 per 68 patient-years, an incidence of 1.5 per cent per patient-year. Of the 327 with a satisfactory operation, 15 had post-operative emboli, or 1 per 82 patient-years, an incidence of 1.22 per cent per patient-year.

Allowing for the methods of assessment used, therefore, we cannot say that the incidence of post-operative emboli is influenced by the adequacy of the operation, of whatever type.

Emboli in non-surgical cases Follow-up assessments were available on 166 patients with dominant mitral stenosis, and 68 with dominant regurgitation, and the figures are shown in Table 5.

(a) *Mitral stenosis*

The 166 patients in this group were observed for a total of 646 patient-years, and 24 emboli occurred, 1 per 27 patient-years, or 3.7 per cent per patient-year. They were a selected group, being either too ill to be considered for operation, or too well, that is they had mitral stenosis but little or no disability. A small number in this group had refused the offer of operation. In all, 52 patients aged 35 or less were followed for a total of 252 patient-years, and no emboli occurred in this group, 40 of them still being in sinus rhythm. Of the remaining 114 patients, only 30 were still in sinus rhythm; 24 emboli occurred in this group of 114 aged 36 and over, 21 in patients with atrial fibrillation. The total follow-up was 403 patient-years, and the

emboli occurred at a rate of 6 per cent per patient-year. Altogether 44 patients died, 7 deaths being directly caused by systemic embolism.

(b) *Mitral regurgitation*

The 68 patients with mitral regurgitation were observed for a total of 256 patient-years; 34 were aged 35 or less, and over a total of 164 patient-years no emboli occurred, 24 of the 34 being in sinus rhythm. Over the age of 35, there were 34 patients, followed for a total of 102 patient-years, with 5 embolic episodes, i.e. a rate of almost 5 per cent per patient-year. There were 21 deaths, 3 being the result of systemic embolism, and atrial fibrillation was present in 28 of the 34 cases.

Taking together the patients with mitral stenosis and mitral regurgitation, who were treated medically, no emboli occurred in the 86 aged 35 or below, whatever the cardiac rhythm, for a total follow-up of 416 patient-years. In the 148 patients aged 36 or over who were observed for a total of 505 patient-years, 29 emboli occurred, 26 in patients with atrial fibrillation, a rate of almost 6 per cent per patient-year; 10 of these emboli were fatal.

Multiple emboli occurring before follow-up There were 79 patients who had more than one recognizable embolus, 24 of them having more than one recurrence, the most being in one patient who had in all 7 pre-operative embolic incidents. Seven of the patients were in sinus rhythm throughout, and in this small group only one of the recurrences was within 6 months of the original embolism. Three patients had sinus rhythm when examined after the first embolus and atrial fibrillation with the subsequent incidents.

At the time of the first embolus 69 patients had atrial fibrillation, 59 having had atrial fibrillation for at least 6 months, one for less than a month, and in 9 the duration of the arrhythmia was not known. However, the tendency of emboli to recur over a short period was shown by 23 patients with atrial fibrillation, who had two or more emboli within a month of each other.

Recurrence of emboli during follow-up

Operations were carried out on 100 patients who had a systemic embolus, 97 having a mitral valvotomy and 3 an exploratory operation with atrial appendagectomy only. In their follow-up, 11 had a recurrence of the embolism (11%).

Of the 97 patients who had a mitral valvotomy following systemic embolism, 9 had further emboli in the follow-up period, which represented a total of 359 patient-years. Of these patients, 86 had atrial fibrillation, and in this group 7 emboli occurred in 319 patient-years, a rate of 2.2 per cent per patient-year. The 11 patients with sinus rhythm had a total follow-up of 40 patient-years and 2 emboli, a rate of 5 per cent per patient-year.

The other 3 patients with an atrial appendagectomy only had 2 emboli in a follow-up of 12 patient-years, a rate of 17 per cent per patient-year.

By comparison, 27 patients with recurrent emboli were not operated upon. Of these, 20 with atrial fibrillation had 6 further emboli in a total follow-up of 54 patient years, a rate of 11 per cent per patient-year; and of the 7 still in sinus rhythm, one had a further embolus in a follow-up total of 32 patient-years, a rate of 3 per cent per patient-year.

Discussion

Systemic embolism in mitral valve disease is a major problem. Our figures, combined for mitral stenosis and regurgitation at all ages, show an incidence of 18.7 per cent, compared with the figures of Wood (1954) who quoted an incidence of 13 per cent, Askey and Bernstein (1960) who referred to 25–30 per cent of all patients with chronic rheumatic heart disease having fatal results from systemic embolism, and Szekely (1964) who reported an incidence of 10 per cent in a large series of patients.

The figures for mitral stenosis alone have varied from the 13 per cent given by Stephenson (1966), to 35 per cent quoted by Taber and Lam (1960). Between these extremes are figures given by Ellis *et al.* (1959), Bannister (1960), Kellogg *et al.* (1961), Casella, Abelman, and Ellis (1964), Somerville and Chambers (1964), Parker *et al.* (1965), and Bakoulas and Mullard (1966).

There is a higher incidence of embolism with increasing age, a point also brought out by Bannister (1960), and with valve calcification, but the latter is probably a manifestation of the length of time the disease process has been established. It is made clear by our figures that atrial fibrillation is the main factor in the production of systemic embolism, and since the incidence of atrial fibrillation increases with the length of time the valve pathology has been present, it follows that increasing age and atrial fibrillation make systemic embolism a common feature of mitral valve disease. Thus,

mitral stenosis with sinus rhythm gives an embolic incidence of 8 per cent over-all, 4.4 per cent below the age of 35, while atrial fibrillation is accompanied by systemic embolism in 31.5 per cent of cases over-all, the figures being much the same when confined to patients aged 36 and over. These figures again broadly agree with those of the authors quoted above, plus Daley *et al.* (1951), Jordan, Scheifley, and Edwards, (1951), and Turner and Fraser (1956).

Atrial fibrillation is associated with systemic embolism because it predisposes to clot formation in the atrium; 83 of the 90 patients in this series with atrial clot had atrial fibrillation. Turner and Fraser (1956) showed similar results, since 46 of their 48 patients, with discoverable atrial clot at operation were also in atrial fibrillation, and Lowther and Turner (1962) quoted an incidence of atrial clot at operation in 48 per cent of their patients who had atrial fibrillation.

In necropsy studies, Jordan *et al.* (1951) reported 51 cases of mitral stenosis with atrial clot and systemic embolism, over 80 per cent of which had atrial fibrillation.

Using radiological techniques involving left atrial angiography, Fisher *et al.* (1965), Lewis, Criley, and Ross (1965), and Parker *et al.* (1965) were all able to show the close relation between left atrial clot and atrial fibrillation.

Accepting that left atrial clot formation is common with atrial fibrillation, it is important to show, if possible, the site where the clot formation is likely to be, first to aid the surgeon in the prevention of operative embolus formation, and secondly to decide whether or not atrial appendagectomy is a worth-while procedure. We were unable to analyse our operative findings from this viewpoint, but in necropsy studies Daley *et al.* (1951) showed that clot formation was equally common in the body and the appendage of the left atrium, and Jordan *et al.* (1951) noted the same. Wallach, Lukash, and Angrist (1953) found left atrial clot in 36 per cent of patients with severe mitral stenosis. It was confined to the appendage in 20 per cent of the patients where clot was found, to the body in 23 per cent, and present in both body and appendage in the rest.

The left atrial angiography performed by Fisher *et al.* (1965) on 482 patients showed that clot was present as commonly in the body of the left atrium as in the appendage, and Parker *et al.* (1965), also using left atrial angiography, found 10 patients with atrial thrombi, in only 2 of whom was clot confined to the appendage.

The findings of Somerville and Chambers (1964), that large left atrial appendages were associated with systemic embolism, have not been confirmed by our results which show that systemic embolism is as common with small as with large appendages, a finding in agreement with Wood's observations (1954).

So far, we have shown that systemic embolism in mitral valve disease is as common with mitral regurgitation as with stenosis, and that it becomes commoner with increasing age and with atrial fibrillation, presumably because of atrial stasis leading to clot formation in the atrium. We have not been able to predict the site of clot formation, and have not been able to show that atrial appendage size, as assessed radiologically, has any influence on the presence of clot therein. It seems probable that only atrial angiography will solve this problem, and certainly there could be justification for routine left atrial angiography in all patients with mitral valve disease, who have atrial fibrillation, and in whom mitral valve surgery is contemplated.

Pre-operative embolism does not increase the probability that left atrial clot will be present at operation, and hence that the risk of operative embolism will be increased, our findings being similar to those of Wood (1954). Turner and Fraser (1956) and Askey and Bernstein (1960) disagreed with Wood's findings, and thought that patients having had a systematic embolism were exposed to increased risk at operation.

Removal of the atrial appendage will reduce the possible sites of thrombus formation, but the earlier cases in our series, where mitral valvotomy was performed without atrial appendagectomy, have shown no greater tendency to post-operative embolism, than the later cases, where appendagectomy was routine. It is possible, of course, that the atrial suture line itself, after appendagectomy, may be a source of further thrombus formation, as described by Stewart and Glenn (1959). The value of atrial appendagectomy in the prevention of systemic emboli has been overestimated, and it should never be undertaken as an isolated procedure. Our small series of patients who had lone atrial appendagectomy had a higher incidence of embolism in follow-up than any other group of our patients, surgically or medically treated.

There is a danger of producing emboli at operation, either from left atrial clot, or from fragments of calcium when this is present. Figures quoted for operative embolism include those of Wood (1954) in 10 per cent

of all mitral valvotomies, Kellogg *et al.* (1961) in 6.2 per cent of all valvotomies, and Lowther and Turner (1962) in 10 per cent of all cases with atrial fibrillation.

Valve calcification, while not related to the incidence of emboli before operation, increases the incidence during operation, our series showing an over-all increase from 3.6 to 9.5 per cent, when non-calcified valves are compared to those that are calcified. With instrumental valvotomy the incidence of operative emboli in calcified valves exceeded 10 per cent, suggesting that fragments of calcium may be more easily broken off by the metal dilator. Fraser and Kerr (1961) did not hold this view, and found operative emboli commoner with finger-split operations than with instrumental valvotomies.

Pre-operative anticoagulation may reduce the number of cases where clot is found at operation, but will not prevent emboli caused by fragmented calcium, a point not made by Smith *et al.* (1965) when discussing the place of anticoagulation in mitral valve surgery.

Mitral valve surgery reduces the incidence of systemic embolism, whether or not appendagectomy is performed, and this satisfactory result does not appear to depend upon the adequacy of the valvotomy, at least so far as our criteria of 'adequacy' are concerned. This suggests that neither stasis nor appendagectomy are the sole factors involved. Mitral valvotomy, however inadequate, will reduce stasis to some extent, since none of the other factors involved, including left atrial wall injury and abnormal blood clotting mechanisms, are affected by operation. It is also possible that the length of follow-up in this series is still too short to estimate the embolic incidence after operation, and that mitral valvotomy may have no influence at all on the production of emboli.

However, the total incidence of post-operative embolism in our series, compared with medically treated patients, as shown in Table 5, suggests that mitral valvotomy with or without appendagectomy, at least in the short term, will diminish but not abolish the occurrence of systemic embolism. If the results are further subdivided, the incidence of emboli when atrial fibrillation is present will be reduced from 11 to 2.2 per cent per patient year by mitral valvotomy. When sinus rhythm is present, valvotomy has no influence on the production of emboli.

Owren (1963), using figures from a small medically treated series, and Casella *et al.* (1964) have suggested long-term anticoagulation as a method of preventing systemic em-

bolism. Our limited experience supports this view, the recurrence rate in those patients who have had systemic emboli and are being treated with anticoagulants, being 2.3 per cent per patient year, a figure very close to that of the surgical series. The problem is how long to continue the treatment; Wood and Conn (1954) offered no advice on this, but Szekely (1964) found that 66 per cent of recurrences were present within a year of the original embolus, so that anticoagulation for 18 to 24 months appears a reasonable course.

From the evidence provided in this series of patients, we think it possible to offer certain guiding principles of treatment with regard to the embolic risks in mitral valve disease.

1 When atrial fibrillation is present, the risk of systemic embolism is high. If the valve is operable, surgery will lessen this risk considerably, and should be considered even if there are few other symptoms. If embolism has occurred, then an operation is clearly indicated, and we have not been able to show that pre-operative anticoagulation reduces the number of cases where atrial clot is found at operation.

2 When sinus rhythm is present, when there is a disability of grade 2 or less, and when the patient is aged less than 35, mitral valvotomy does not lessen the risk of embolism, and 'prophylactic' valvotomy cannot be recommended on these grounds in these patients. Above the age of 35, still with sinus rhythm, and even if embolism has already occurred, valvotomy does not significantly lower the incidence of further emboli, and here the embolic risk cannot be used alone as an argument for operative intervention. In these cases long-term anticoagulation is probably the treatment of choice.

3 Instrumental valvotomy produces operative emboli in 10 per cent of patients with calcified valves, and while not an absolute contraindication to closed mitral valve surgery, the presence of calcification visible on the x-ray is certainly an indication not to proceed with operation if this is to be done mainly to prevent emboli in the future.

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