[ADDENDUM.—Since submitting this paper the three patients awaiting second valvotomy have had their operations and in each case the valve was tightly stenosed.]

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CALCIFIC MITRAL STENOSIS AND MITRAL VALVOTOMY

BY

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Approximately one-third of all patients submitted to surgery for the relief of mitral stenosis have calcium deposits on the valve leaflets (Sellers *et al.*, 1953; Wood, 1954; Goodwin *et al.*, 1955; Turner and Fraser, 1956; Bailey and Morse, 1957). Most authors stress the hazards of mitral valvotomy in the presence of heavy valve calcification. Calcific emboli may occur (Bailey, 1955; Turner and Fraser, 1956; Black and Harken, 1957), and valvotomy may be incomplete (Bailey, 1955; Turner and Fraser, 1956; Windsor, 1956). Wood (1954) concluded that heavy calcification is a serious drawback to surgery, not only because it suggests an appreciable degree of associated incompetence, but because it is also likely to favour the production of incompetence at operation. Black and Harken (1957) take a more optimistic view, stating that some of their best results were in patients with valvular calcification.

Calcification of the mitral-valve leaflets is a consequence of a previous rheumatic infection, is commoner after middle age, and occurs more often in males than females (Epstein, 1940; Turner and Fraser, 1956). Extension of calcium to the annulus in rheumatic cases is relatively uncommon and usually occurs after the age of 40 (Epstein, 1940). The mitral annulus alone can be involved in the absence of a previous rheumatic infection. It may be found in otherwise normal hearts after middle age, and in contrast to rheumatic calcifica-

tion is slightly commoner in women. Simon and Liu (1954) found annular calcification in 10% of unselected hearts examined at necropsy. Such calcification is functionally not significant; its importance is that it may be misinterpreted radiographically as being due to infiltration of the valve leaflets.

Calcium on the mitral-valve leaflets in a case of mitral stenosis is often suspected at the bedside, the associated valve rigidity modifying the characteristic auscultatory signs. The loud first sound tends to become normal or muffled, the opening snap disappears (Vaquez, 1894; Wolferth and Margolies, 1937; Wynn, 1953), and a systolic murmur is often present (Wynn, 1953).

The raised left atrial pressure in mitral stenosis causes the valve orifice to remain open until the onset of ventricular systole, when its sudden closure is audible as an accentuated first sound. With calcification and rigidity of the valve orifice, the edges are unable to snap together, so the first sound is characteristically normal or muffled. However, the first sound may be accentuated despite calcification (Wynn, 1953; Davies and Bucky, 1959). In Wynn's series of 60 patients with heavy mitral-valve calcification, the first sound was accentuated in 55%. In many patients with valve calcium a muffled first sound may become accentuated with tachycardia (Wynn, 1953).

The opening snap of the mitral valve occurs at the end of the period of isometric relaxation of the left ventricle, when the atrio-ventricular gradient is reversed. It may be due to sudden billowing of the aortic cusp into the left ventricular cavity (Sansom, 1881, 1892; Vaquez, 1894; Margolies and Wolferth, 1932), or to movement of the stenotic valve diaphragm deep into the left ventricle (Leatham, 1958). The latter is possibly the correct explanation, because rigidity and calcification of the valves does not always result in loss of the opening snap. Wynn found it to be present in 48%. The opening snap is absent in pure mitral incompetence (Brigden and Leatham, 1953).

The first sound may also be damped by associated mitral incompetence or a high pulmonary vascular resistance (Wood, 1954; Goodwin *et al.*, 1955). In addition to the above two factors, the opening snap may disappear in the presence of associated aortic incompetence, perhaps because the reflux into the left ventricle interferes with the sudden billowing of the aortic cusp of the mitral valve (Wood, 1954).

Calcium deposition on or around the valve orifice may also prevent effective closure during ventricular systole, hence some incompetence is often present despite otherwise severe stenosis. Wynn (1953) observed a systolic murmur in 80% of patients with heavy calcification. Goodwin *et al.* (1955) found that 10 of their 28 patients with mitral-valve calcification submitted to valvotomy had some incompetence. However, calcification is uncommon with pure incompetence (Goodwin *et al.*, 1955; Wood, 1956; Linko and Sysimetsä, 1958).

Radiology

Valvular calcification, if extreme, may be recorded on a telerradiogram. It is seen comparatively commonly in cases of calcification of the aortic valve, but rarely in the mitral. Klason (1921) was one of the first radiologists to report seeing mitral-valve calcium at fluoroscopy, after which fluoroscopy has remained the standard method of demonstrating intracardiac calcification. However, since Hohenner (1940) published a

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tomogram showing a partially calcified mitral ring, the use of body-section radiography has become increasingly more common. Davies and Steiner (1949) used tomography to demonstrate aortic-valve calcium, and Soloff *et al.* (1954, 1955) have emphasized its superiority in the demonstration of mitral calcium. Apart from making a permanent record of the calcium and allowing the clinician a more accurate and more leisurely assessment of its extent, tomography is more likely to show slight to moderate degrees of calcification than is radioscopy (Soloff *et al.*, 1955; Davies and Bucky, 1959).

Present Investigation

The object of this study was to examine the efficacy of mitral valvotomy in a series of patients with mitral-valve calcification.

Material.—A total of 109 patients were submitted to valvotomy from October, 1954, to October, 1958. Eight were excluded from the study either because aortic or tricuspid valvotomy was performed simultaneously with the mitral or because of severe aortic incompetence. The 101 patients finally analysed comprised 22 men and 79 women, and all had dominant mitral stenosis pre-operatively: if other valves were affected, their effect on cardiac function was judged to be minimal. Valvotomy was carried out by Mr. W. P. Cleland, Mr. L. L. Bromley, Mr. H. H. Bentall, or their associates.

Methods.—At operation the calcium on the mitral-valve leaflets was graded as slight (+) when only small particles were palpable, moderate (++) if one leaflet or commissure was moderately infiltrated, and heavy (+++) if one leaflet or commissure was heavily calcified, or if both leaflets or commissures were either moderately or heavily calcified. In the discussion, moderate and heavy calcification are referred to collectively as "significant." A jet of incompetence, when present, was graded as minimal (+) when it could just be felt, moderate (++) if more definite, and severe (+++) if it reached the atrial wall and produced a systolic thrill. The valvotomy was considered to be "good" if the final orifice diameter was greater than 3 cm., "fair" if it was 2.5–3 cm., and "poor" if less than 2.5 cm. Subjective improvement post-operatively was noted as "good" if there was marked improvement in effort tolerance with ability to do housework or to work full time, "fair" when effort tolerance was definitely improved but the patient required help with housework or was restricted to part-time work, and "poor" if effort tolerance remained unchanged.

Results

Mitral-valve calcium was found in 32 patients, and in 15 it was moderate or heavy. It was most common in the fifth decade, and occurred more often in men (see Chart). Of the 10 men with calcium, it was moderate or heavy in seven, whereas in the 22 women it was significant in only eight. Tomograms were performed in 14 of the 15 patients with moderate or heavy calcium, and it was visible in each case. In the 17 patients with slight calcification calcium was visible in three.

No evidence of incompetence was found at operation in 81 patients, and 28 of these developed a jet of incompetence after valvotomy, in each case an apical pansystolic murmur being audible subsequently. Mitral incompetence occurred more commonly in patients with

Mitral-valve calcification in 101 patients submitted to valvotomy.

significant calcification, but the difference is not great (Table I). Instrumental dilatation with a valvulotome, or more recently with a transventricular dilator, was carried out in 38 patients. A better split resulted from an instrumental than from a digital split (Table II), which was most striking in the case of calcified valves (Tables III and IV). However, mitral incompetence was more frequent after instrumental dilatation (Table V). A valvulotome was used in nine patients, and a transventricular dilator in 29. A good split was obtained in 26 of the 29 patients on whom the transventricular dilator was used, and in 21 the split was greater than 3.5 cm. The results were especially gratifying in five patients with significant calcifications, where the split was good in four, and greater than 3.5 cm. in two, whereas in 10 patients with significant calcification whose valves were dilated digitally the split was good in only four, and in none was it greater than 3.5 cm. Four of the five poor valvotomies obtained instrumentally followed the use of the valvulotome.

TABLE I.—Mitral Incompetence Produced at Valvotomy in Patients With and Without Valve Calcium

Patients Without Pre-operative Mitral Incompetence	No.	No. in Whom Incompetence was Produced
Valve calcium absent	57	19 (33%)
Calcium present { Slight	17	6 (35%)
{ Significant	7	3 (43%)
Total	81	28 (35%)

TABLE II.—Size of Split Obtained With Digital and Instrumental Dilatation

Method of Splitting Valve	No. of Patients	Split Obtained			Split > 3.5 cm.
		Good	Fair	Poor	
Digital	63	42	13	8	19 (30%)
Instrumental	38	29	4	5	22 (58%)
Total	101	71	17	13	41

TABLE III.—Size of Split with Digital and Instrumental Dilatation in 15 Patients with Significant Mitral-valve Calcification

Method of Splitting Valve	No. of Patients	Split Obtained			Split > 3.5 cm.
		Good	Fair	Poor	
Digital	10	4	4	2	—
Instrumental	5	4	1	—	2
Total	15	8	5	2	2

TABLE IV.—Seven Patients with Significant Mitral-valve Calcification and No Pre-operative Mitral Incompetence

Case	Age and Sex	Pansystolic Murmur Pre-operatively	Valve Calcium	Degree of M.I. Produced at Operation	Size of Split	Method of Splitting Valve	Pansystolic Murmur Post-operatively
A	53 M	0	++++	0	Poor	Digital	0
B	41 M	0	++++	0	Fair	"	0
C	54 M	0	++++	0	"	"	0
D	54 F	0	+++	0	Good	Instrumental	0
E	61 F	0	++++	+	Fair	Digital	Grade 1
F	53 F	0	++++	+	Good	Instrumental	" 1
G	56 F	0	++++	+	"	"	" 3

TABLE V.—Incompetence Produced with Digital and Instrumental Dilatation in 81 Patients with No Initial Mitral Incompetence

Method of Splitting Valve	No. of Patients	Incompetence Produced		
		+	++	+++
Digital	49	9	2	1
Instrumental	32	12	2	2

Associated mitral incompetence was diagnosed pre-operatively in 21 patients on the basis of an apical pansystolic murmur, and in 20 of these a systolic jet of valvular incompetence was felt at operation. Six of the patients were men and 14 were women. Five of the six men had significant calcium, whereas it was found in only 3 of the 14 women. One patient died 48 hours post-operatively after an aortic bifurcation embolus. Details of the remaining 19 are found in Table VI. The degree of incompetence was increased in 10 (Cases 1–10), and it remained unchanged in nine (Cases 11–19). Valvular calcification did not seem to increase the risk of making incompetence worse. Very few patients from this group have been followed for a sufficient period to enable any definite conclusions to be drawn regarding long-term results. However, the results so far are generally poor (Table VI) and do not appear to correlate with the presence or absence of calcium or the adequacy of the valvotomy, the important factor being the presence of significant mitral incompetence pre-operatively.

Ninety-five patients had critical mitral stenosis—that is, a valve diameter of 1.5 cm. or less—and in 31 the diameter was less than 1 cm. Three of the six patients

with valve diameters greater than 1.5 cm. had associated mitral incompetence.

Emboli occurred at operation in two patients with valvular calcium. Calcification in each case was slight; both patients died after embolectomy, and there was no operative or necropsy evidence of calcific emboli.

The classical auscultatory signs of mitral stenosis were found to be modified in about half of the 15 patients with significant valvular calcification. Out of seven with pure stenosis the first sound was accentuated in four and normal or diminished in three. The opening snap was absent in one patient only. In the eight patients with associated incompetence the first sound was accentuated in four, normal or diminished in three, and the opening snap was absent in three.

Discussion

Instrumental dilatation of the mitral valve was used in patients on whom valvotomy could not be obtained digitally. An adequate valvotomy was possible in practically every case, especially with the use of the transventricular dilator, even in patients with calcified valves. However, it does appear that instrumental dilatation may give rise to mitral incompetence more often than does digital dilatation.

The functional effects of minimal incompetence after mitral-valve surgery have not been adequately studied, nor has there been a long-term study of any large series of such patients. Bailey *et al.* (1954) and Belcher (1956) are of the opinion that it is of little or no consequence, and this view is commonly held. An adequately dilated yet slightly incompetent valve would seem to be preferable to one which is competent yet insufficiently split. A detailed appraisal of transventricular valvotomy is planned (Cleland *et al.*, 1960), for the value of this method is regarded as not yet finally proved.

There is some evidence that restenosis of the mitral valve is less likely to occur when both commissures are completely divided than when commissurotomy is incomplete (Wilcken, 1960).

The tendency to produce mitral incompetence does not appear to be greatly increased in the presence of calcium. If incompetence is present pre-operatively, the results of valvotomy are not good. The presence or absence of calcium, the size of the split obtained,

TABLE VI.—Nineteen Patients Who Came to Mitral Valvotomy With Associated Mitral Incompetence

Case	Age and Sex	Pansystolic Murmur Pre-operatively	Valve Calcium	M.I. Before Split	M.I. After Split	Size of Split	Method of Splitting Valve	Pansystolic Murmur Post-operatively	Result and Period of Follow-up
1	27 M	Grade 1	+++	++	+++	Fair	Digital	Grade 2	Good—3½ years
2	55 F	" 2	++	+	++	Good	"	" 4	Died of congestive cardiac failure after 1 year
3	63 F	" 2	+	+	++	"	Instrumental	" 4	Poor—3 months
4	47 F	" 2	0	+	++	"	"	" 4	Fair—6 "
5	50 F	" 2	0	+	++	"	Digital	" 4	No follow-up
6	43 F	" 1	0	+	++	"	"	" 2	Poor—6 months
7	32 F	" 3	0	+	++	Fair	"	" 3	" —7 "
8	41 F	" 2	0	++	++	"	"	" 4	" —4 years
9	44 F	" 2	0	++	+++	Good	Instrumental	" 4	" —2 "
10	41 M	" 1	+++	+	++	"	"	" 3	Good—6 months
11	32 M	" 3	+++	++	++	"	Digital	" 3	" —2 years
12	42 M	" 3	+++	+++	+++	Poor	"	" 3	Died of congestive cardiac failure after 3 years
13	52 M	" 1	+++	++	++	"	Instrumental	" 1	Fair—3 months (has severe emphysema and cor pulmonale)
14	52 F	" 1	+++	+	+	Fair	Digital	" 1	Poor—1 year
15	21 F	" 3	+++	++	++	Good	"	" 3	Fair—1 "
16	42 F	" 2	0	+	+	"	"	" 2	Good—1 "
17	52 F	" 3	0	++	++	"	"	" 3	Died of congestive cardiac failure after 6 months
18	30 F	" 2	0	+	+	"	"	" 2	Good—1 year
19	23 M	" 2	0	+	+	"	Instrumental	" 2	" —1 "

and the worsening of incompetence already present do not seem to have any influence on the final result. The poor results of valvotomy in this group of patients are probably due to destruction of the greater part of the valve by rheumatic disease, the mechanism of which cannot be restored by simple division of the commissures. However, in some cases with calcium deposition the leaflets are relatively supple and non-shrunken, the calcium being found mainly along the free edge and on the adherent commissures. Such leaflets are capable of function if they can be freed. Incompetence in these patients is due mainly to calcium along the valve orifice preventing effective closure during ventricular systole, rather than to destruction of the leaflets. This is the probable explanation of some of the good results which may be obtained in patients with heavy valve calcification and associated incompetence.

If valvotomy is indicated in a patient with pure mitral stenosis the presence of valvular calcium should not unduly influence the decision for surgery, but if there is associated mitral incompetence then a poor result is likely.

The danger from calcific emboli during valvotomy does not seem to be very great. Bailey (1955) is of the opinion that emboli are more likely to occur from valves where calcification is slight. In such valves small fine particles of calcium project on the valve edges which may be readily dislodged at operation. Such particles are likely to occur on mobile valves, so they are not suspected clinically, nor are they visible radiologically. The possibility of calcific emboli occurring in any given case is insufficient reason for withholding surgery.

Fourteen of the 15 patients with moderate or heavy calcification had tomograms done, and calcium was demonstrated in each case, confirming that significant valvular calcification is practically always visible by tomography. Calcification was also demonstrated by tomography in three other patients in whom valvular calcium at operation was found to be slight. The patients were a man of 47 and two women of 44 and 58 years, and it is considered that the calcium in these patients was in the annulus. In older patients annular calcium may be readily confused with valvular calcium. Conventional radiography and tomography are of little help in distinguishing its site. Study of the valve movements under the image intensifier may resolve this difficulty. It was not found possible to grade the degree of calcification seen on the tomogram in this series.

The occurrence of calcification more commonly after middle age, and more often in males in this study (Chart), is similar to the experience of other authors (Epstein, 1940; Turner and Fraser, 1956). Also, when calcium is found it is more likely to be moderate or heavy in men than in women.

Eight of the 15 patients with significant calcification had associated mitral incompetence—an incidence of 54%, which is the approximate incidence found in other surgical series (Wood, 1954; Mounsey and Brigden, 1954; Goodwin *et al.*, 1955; Turner and Fraser, 1956). Of the six men with mitral incompetence, five had moderate or heavy valve calcium, whereas, of the 14 women with incompetence, calcium was significant in only three. Men with dominant mitral stenosis and associated mitral incompetence appear to be much more likely to have significant calcium on the mitral valve than are women similarly affected. Valvular calcification is uncommon with pure mitral incompetence

(Goodwin *et al.*, 1955; Wood, 1956; Linko and Sysimetsä, 1958).

The presence of an opening snap in 11 of the 15 patients with significant calcification differs from the findings of Wynn (1953) and Davies and Bucky (1959), who found it in a considerably smaller proportion of their cases.

An apical pansystolic murmur was found to be the most reliable and consistent sign of associated incompetence in the presence of otherwise tight mitral stenosis. Incidental mitral incompetence was diagnosed prior to valvotomy in 21 patients on the basis of an apical pansystolic murmur radiating to the axilla and tending to diminish on inspiration. A jet of incompetence was felt at surgery in 20 of these patients, and no jet was felt in any patient without a pansystolic murmur. This finding is similar to that of Mounsey and Brigden (1954).

Summary

The incidence, pathology, functional effects, and surgical hazards of mitral-valve calcification are reviewed. In a series of 101 patients submitted to mitral valvotomy, 32 had valvular calcification, which was moderate or heavy in 15. About half the patients with significant calcium had associated mitral incompetence. Men with dominant mitral stenosis and associated incompetence are much more likely to have valve calcification than are women similarly affected.

Transventricular dilatation of the mitral valve has resulted in a good valvotomy in most of the patients where this method was used.

The incidence of post-operative mitral incompetence does not appear to be significantly greater in patients whose valves are calcified, compared with the non-calcified group. If incompetence is present pre-operatively the risk of worsening the incompetence is no greater in patients with valvular calcium. However, the results of surgery are generally poor in combined mitral stenosis and incompetence, and do not correlate with the presence or absence of calcium or the size of the valvotomy.

Tomography revealed calcium in every patient in whom it was moderate or heavy. The possibility of confusing annular calcification with valvular calcium is discussed.

In patients with significant calcification the first heart sound was normal or diminished in intensity in about half, and the opening snap was absent in about a quarter.

An apical pansystolic murmur was found to be the most reliable and consistent sign of associated mitral incompetence in the presence of otherwise tight stenosis.

The study was suggested by Dr. J. F. Goodwin, to whom I am indebted for his encouragement and advice. I am grateful to Mr. W. P. Cleland for allowing me to use his surgical records, and for his helpful suggestions. Thanks are also due to Dr. Aubrey Leatham and Dr. Arthur Hollman for offering valuable criticism, to Mr. L. L. Bromley for much useful discussion, and to Mrs. Angela Birbeck, who drew the illustration.

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INCIDENCE OF MITRAL VALVULAR DISEASE IN THE ELDERLY

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Rheumatic heart disease is usually regarded as a condition which occurs mainly in young subjects. There have, however, been several reports of the occurrence of mitral stenosis in elderly patients after rheumatic disease many years previously (White and Bland, 1941; Cookson, 1949; Appel and Kossmann, 1951; Hebbert and Rankin, 1954; Johnson, 1959).

In these reports possible factors prolonging life in such patients have been discussed, and it has been stressed that women may rear large families despite this disability. Nevertheless, from none of these studies is it possible to obtain an estimate of the relative frequency of mitral-valve disease in persons over the age of 50 or 60. During the last few months we have been impressed by the number of elderly patients admitted to this hospital and found to have rheumatic heart disease with

involvement of the mitral valve. We therefore decided to study the incidence of such disease of the mitral valve in different age-groups in this hospital; in an attempt to determine its relative frequency in persons in the later years of life.

Methods

The incidence of rheumatic disease of the mitral valve in patients dying in this hospital has been investigated by examination of consecutive post-mortem reports. We studied the records of 1,000 patients over 59 years of age, 500 patients aged between 40 and 59 years, and 250 patients between 20 and 39 years of age who died in the years 1947–58. In each of these groups we discovered between 22 and 32 patients with disease of the mitral valve which the pathologist, Dr. J. L. Edwards, considered to be of rheumatic origin. In all cases the valve cusps were thickened and deformed, with shortening of the chordae tendineae. In almost all specimens there was obvious stenosis of the valve and many were calcified.

Sheffield Royal Hospital is a general hospital for acute cases in which, over the past 11 years, necropsies have been carried out on 66% of the patients who died. There are approximately equal numbers of medical and surgical beds but no accommodation for the chronic sick or for patients with gynaecological or obstetrical complaints. Cardiac surgery is not carried out, and hence we believe that there is no special tendency for patients with mitral stenosis to be referred here. We have compared our findings with the figures given by the Registrar-General (1958) for deaths due to rheumatic disease of the mitral valve in England and Wales in 1957.

Results

Twenty-two cases of rheumatic disease of the mitral valve were found in 1,000 consecutive post-mortem studies of patients aged 60 or more. The incidence of disease of the mitral valve in patients aged 40 to 59 years was 6.4% and in patients aged 20 to 39 years it was 12.4% (Table I). In the older age-group the condition was found four times more frequently in females than in males, whereas in the younger patients mitral disease was approximately twice as common in females. In each age-group, and in both sexes, the incidence of mitral-valve disease found in this hospital was two or three times as great as that reported by the Registrar-General.

In our series the proportion of male patients dying from all causes was somewhat greater than that occurring in the Registrar-General's report and the proportion of younger patients was higher in our series (Table II).

Of the 22 patients aged 60 years or more who had mitral-valve disease, 15 were aged 60–69, six were 70–79, and one was 81. In 16 of the 22 patients the cardiac condition was diagnosed in life. However, the cardiac lesion seemed to be the primary cause of death in only

TABLE I.—Incidence of Rheumatic Mitral Valve Disease Found at Post-mortem Examination of Patients Dying in the Sheffield Royal Hospital

Age of Patient (Years)	Period of Survey	All Cases			Male			Female		
		Total	Mitral Disease		Total	Mitral Disease		Total	Mitral Disease	
			No.	%		No.	%		No.	%
60+	1958–1953	1,000	22	2.2 (0.7)	630	6	1.0 (0.5)	370	16	4.3 (1.0)
40–59	1958–1953	500	32	6.4 (2.8)	320	17	5.3 (1.6)	180	15	8.3 (4.8)
20–39	1958–1947	250	31	12.4 (4.6)	158	13	8.2 (2.9)	92	18	19.6 (7.7)

Figures in parentheses refer to the percentages reported by the Registrar-General for 1957.