The Bundle of His in Prosthetic Heart Valve Replacement*

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SUMMARY

The proximal portion of the His-Tawara system was examined in 27 patients who died after a heart valve replacement operation. Fifteen patients died 5 days or less after operation, and recent conduction tissue haemorrhage was found in 9 of these patients. There was no sign of recent conduction tissue haemorrhage in the 12 patients who died later than 5 days postoperatively, nor in 14 control hearts from routine autopsies. Direct damage to conduction tissue by surgical sutures was observed in 2 patients. This study confirms that the conduction system is at risk during valve replacement operations.

Haemorrhage into the conduction tissue is a frequent finding in patients dying within the first week after the operation.

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The present study was undertaken in an attempt to find a pathologic cause for some of the unexplained sudden deaths which occur following heart valve replacement. In our local cardiac surgery unit at Groote Schuur Hospital, the hospital mortality rate for aortic valve replacement with the University of Cape Town (UCT) aortic valve prosthesis between March 1963 and October 1968, was 12% according to Schrire *et al.*[1]

The main problems were sudden death and systemic embolism. Some of the sudden deaths were attributed to coronary embolism, but in many others no cause could be found, even at autopsy. These latter deaths were regarded as being due to arrhythmia. The hospital mortality rate was 14% for mitral valve replacement with the UCT mitral valve prosthesis.[2] The major complication was systemic embolism.

A frequent autopsy finding in hearts which have recently undergone a valve replacement operation, is a haematoma in the interatrial septum (Fig. 2a). In some instances the haematoma may reach a diameter of several centimetres and even extend downwards to the vicinity of the atrioventricular (AV) node (Fig. 2b) and bundle of His. The bundle is, in addition, at risk during valve replacement, as it penetrates the central fibrous body which unites the contiguous fibrous rings of the tricuspid, mitral and aortic valves.[3] In the light of this, it was decided to examine the vulnerable proximal portion of the His-Tawara system of patients who died following prosthetic heart valve replacement, to determine whether any lesion could be found to explain their demise.

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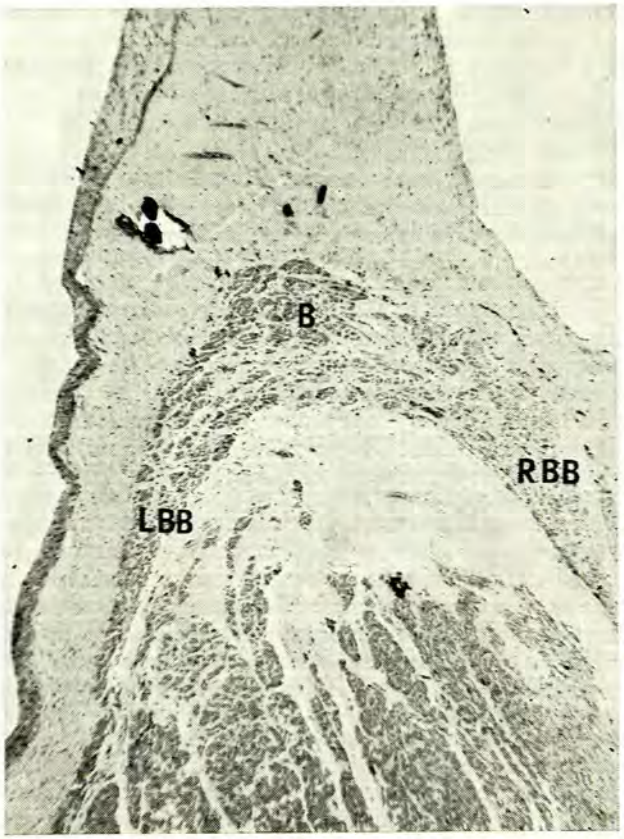

Fig. 1. The bifurcation of the bundle of His (B) into its left (LBB) and right (RBB) bundle branches in one of the control hearts is shown for purposes of orientation. (H. and E. × 8.)

PATIENTS AND METHODS

All patients were autopsied in the Pathology Department, Groote Schuur Hospital, apart from those dying within 24 hours after operation, who were autopsied at the State Mortuary. The hearts from these latter patients were submitted to the department for examination. The AV node, the bundle of His and the proximal portions

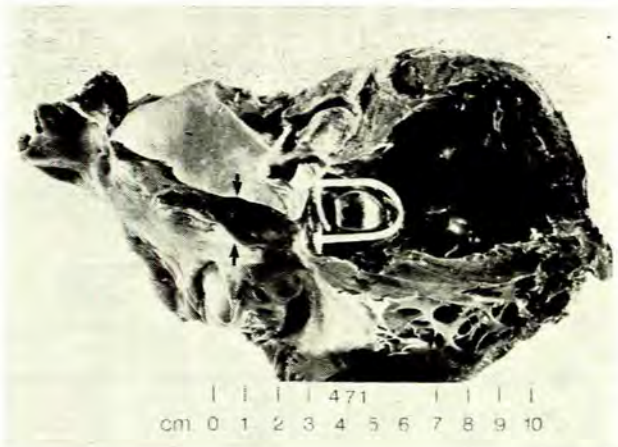

Fig. 2a. Patient 12, showing the Starr-Edwards prosthesis in the mitral position (the cloth covering was damaged during dissection), and a 2,5 cm haematoma (arrows) in the interatrial septum.

Fig. 2b. The haematoma in the interatrial septum has extended down to AV node (N). The haemorrhage is arrowed. (H. and E. × 4.)

of its right and left branches were examined microscopically in 41 hearts (Table I).

TABLE I. HEARTS EXAMINED

Valve replacement	27
Autopsy controls	14
Total	41

The cardiac surgeons have recently discontinued using the UCT mitral valve prosthesis in favour of the Starr-Edwards prosthesis, which gives a lower incidence of thrombo-embolism. Our study reflects this change in policy.

Twenty-seven hearts (Tables II and III) came from patients who died after heart valve replacement with a UCT or Starr-Edwards prosthesis. These 27 patients were divided into 2 groups. Group 1 (Table II) consisted of 15 patients who died 5 days or less after valve replacement. Group 2 (Table III) comprised 12 patients who died later than 5 days after operation. A further series of 14 control hearts from routine autopsies was examined in an identical manner. The latter patients had died of diseases such as carcinoma of the lung, ruptured aortic aneurysm and pneumonia.

The blocks for locating the AV node and bundle of His were fashioned according to the method of Hudson.[4] A vertical incision was made through the upper interventricular septum which transected the bundle of His. Blocks were then fashioned backwards and forwards, to include the whole of the bundle and the AV node, as well as the bifurcation of the bundle into its left and right branches. According to Davies,[5] in order to study the whole conduction system in an average case, 200 to 300 sections will have to be examined from the 6 000 to 9 000 serial sections which are available from this technique. Each case will provide about 5 days' work for a competent histology technician. Under standard laboratory conditions, it was impracticable to prepare serial sections of these 41 hearts. The technique was modified, so that the blocks of each heart were examined microscopically by looking at representative sections, cut at intervals of about 2 mm. Sections were stained by the haematoxylin and eosin and elastic van Gieson methods.

RESULTS

The main clinical and pathological findings in the 27 patients who came to autopsy following heart valve replacement, are summarized in Tables II and III. The patients in group 1 (Table II) ranged in age from 9 to 66 years and conduction tissue haemorrhage was observed in 9 of these 15 patients, mainly within the bundle of His. In 8 of the 9 patients, the blood was seen to track along the connective tissue within and around the conduction tissue in a manner similar to that described by Hudson.[6] The earliest death in the group 2 patients (Table III) occurred 2 weeks after

TABLE II. CLINICOPATHOLOGICAL DETAILS OF 15 EARLY POSTOPERATIVE DEATHS (GROUP 1)

Patient No.	Age (yrs)	Sex	Valves replaced	Prosthesis used	Post-operative survival	Cause of death	Microscopic changes in the His-Tawara system: AV node	His bundle	Left bundle branch	Right bundle branch
1	9	M	Mitral	Starr-Edwards	0	?	Haemorrhage	Haemorrhage	Normal	Haemorrhage
2	29	F	Mitral Aortic	Starr-Edwards UCT	0	?	Congestion	Haemorrhage	Haemorrhage	Normal
3	43	M	Mitral	UCT	3 hours	?	Normal	Normal	Normal	Normal
4	46	M	Mitral	UCT	4 hours	?	Normal	Normal	Normal	Normal
5	15	M	Aortic	UCT	7 hours	Electrolyte imbalance	Normal	Normal	Normal	Normal
6	16	M	Mitral Aortic Tricuspid	UCT UCT UCT	10 hours	Uncorrected pulmonary stenosis	Haemorrhage	Haemorrhage	Haemorrhage	Haemorrhage
7	58	F	Aortic	UCT	20 hours	Heart block	Congestion	Haemorrhage suture nearby	Divided by a suture	—
8	42	F	Mitral	UCT	1 day	?	Normal	Normal	Normal	Normal
9	31	M	Mitral Tricuspid	UCT Starr-Edwards	1 day	Thrombosed mitral prosthesis	Normal	Haemorrhage	—	Haemorrhage
10	60	M	Aortic	UCT	1½ days	?	Normal	Normal	Normal	Haemorrhage
11	28	F	Mitral	UCT	2 days	?	—	Normal	Normal	—
12	44	M	Mitral	Starr-Edwards	2 days	Cerebral embolus	Haemorrhage	Haemorrhage	Haemorrhage	Normal
13	66	M	Aortic	UCT	3 days	?	Normal	Haemorrhage	—	Haemorrhage
14	47	F	Mitral	Starr-Edwards	4 days	?	Haemorrhage	Haemorrhage	Haemorrhage	—
15	52	F	Mitral	UCT	5 days	Heart failure	—	Normal	Normal	Normal

TABLE III. CLINICOPATHOLOGICAL DETAILS OF 12 LATE POSTOPERATIVE DEATHS (GROUP 2)

Patient No.	Age (yrs)	Sex	Valves replaced	Prosthesis used	Postoperative survival	Cause of death	Microscopic changes in the His-Tawara system: AV node	His bundle	Left bundle branch	Right bundle branch
16	49	M	Aortic	UCT	2 weeks	Endocarditis	—	Abscess	—	Iron
17	41	M	Aortic	UCT	6 weeks	Endocarditis	—	Iron	Iron	—
18	57	F	Aortic Mitral	UCT Starr-Edwards	5½ months	Endocarditis	—	Normal	Normal	Normal
19	40	M	Mitral Tricuspid	UCT UCT	6 months	?	Suture Iron	Iron	Normal	—
20	35	M	Aortic	UCT	6 months	Detached prosthesis	Normal	Normal	Normal	Normal
21	36	F	Mitral	UCT	10 months	?	—	Normal	Normal	Normal
22	23	F	Mitral	UCT	16 months	Thrombosed prosthesis	Normal	Normal	Normal	Normal
23	52	M	Mitral Aortic	UCT UCT	18 months	Coronary thrombosis	—	Normal	Normal	—
24	34	F	Mitral	UCT	2 years	Cerebral embolism	Congested	Normal	—	—
25	61	M	Aortic	UCT	3 years	?	—	Normal	Normal	Normal
26	27	F	Aortic Mitral	UCT Starr-Edwards	5 years	Catheter perforation of aorta	Normal	Normal	Normal	—
27	46	F	Mitral Tricuspid	UCT Starr-Edwards	8 years	Thrombo-embolism	Normal	Normal	Normal	Normal

valve replacement, and the latest at 8 years. None of these patients showed evidence of recent conduction system haemorrhage. In most of these patients the cause of death was readily apparent at autopsy, apart from 3 patients (19, 21 and 25), in whom the cause of death was unknown. The haemosiderin within the conduction tissue in patients 16 and 17 probably indicates previous haemorrhage. Haemosiderin was also present in the conduction tissue of patient 19, but this appeared related to trauma by a surgical suture, which passed through the AV node (Fig. 7). All 3 patients were Whites, thus the problem of Bantu siderosis does not arise.

There was no sign of conduction tissue haemorrhage, past or present, in the 14 control hearts. The conduction tissue haemorrhage noted in group 1 patients, appeared separate in most instances from the larger and more obtrusive haemorrhage frequently observed in the interatrial septum. In several hearts the conduction tissue haemorrhage was small (Figs 2c, 2d and 3), whereas in others it was more extensive (Figs 4 and 6), and appeared to disrupt the conduction tissue. In some of these latter cases the haemorrhage was visible to the naked eye (Fig. 5).

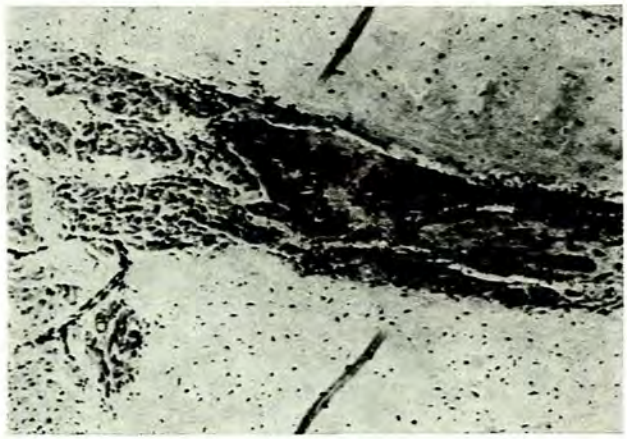

Fig. 3. A small haemorrhage within the left bundle branch of patient 9. (H. and E. × 110.)

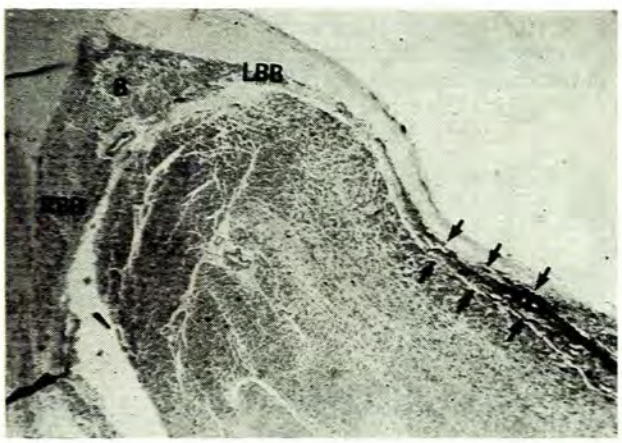

Fig. 2c. The bifurcation of the bundle of His (B) into its left (LBB) and right (RBB) branches. A small haemorrhage (arrows) is present in the left bundle branch. (H. and E. × 8.)

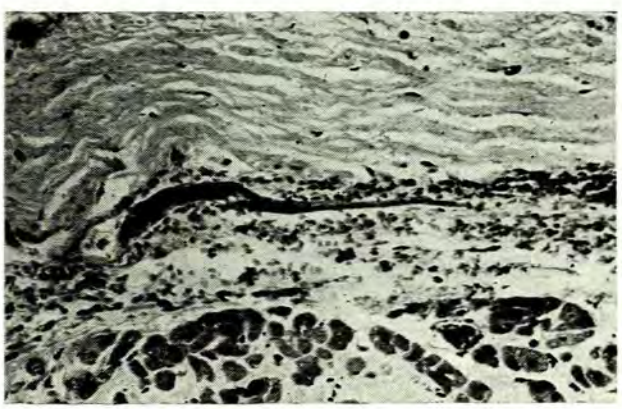

Fig. 2d. The same haemorrhage at a higher magnification. (H. and E. × 160.)

Although conduction tissue haemorrhage mainly involved the bundle of His, associated haemorrhage within the AV node was present in 6 of the 9 patients, showing haemorrhage within the bundle or its branches. A review of the clinical and pathological findings in the group 1 patients showed haemorrhage into the conduction tissue as the possible cause of death in 6 of the 15 patients. In 5 of the 9 patients with conduction tissue haemorrhage, no cause of death was found at autopsy. The other 4 patients did have other adequate cause of death. In none of the patients in group 1, did any of the sections from the ventricles show any changes in the myocardium that might have led to dysrhythmic death.

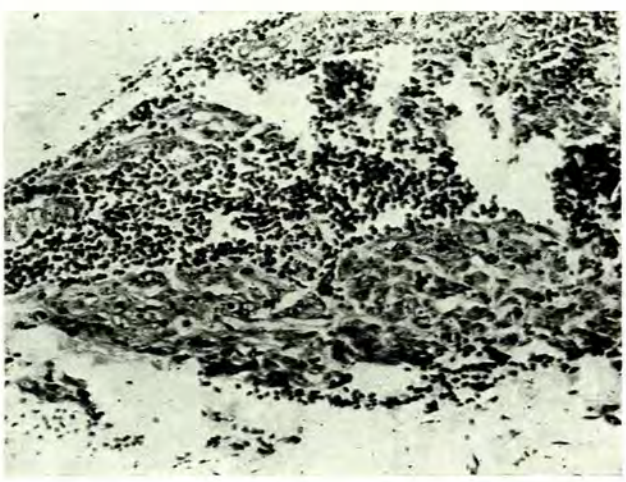

Fig. 4. A haemorrhage of moderate size in the bundle of His in patient 2. (H. and E. × 160.)

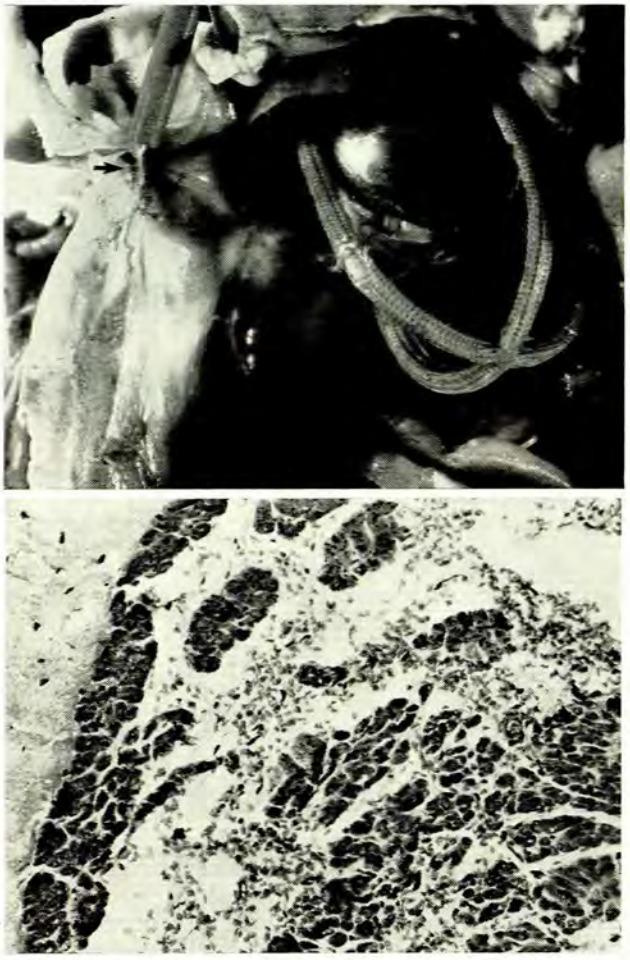

Fig. 5. Patient 1. Top: **A close-up view of an area of haemorrhage (arrow) at the summit of the muscular interventricular septum. The Starr-Edwards prosthesis is in the mitral position.** Bottom: **The haemorrhage is shown to be within the bundle of His. (H. and E. × 160.)**

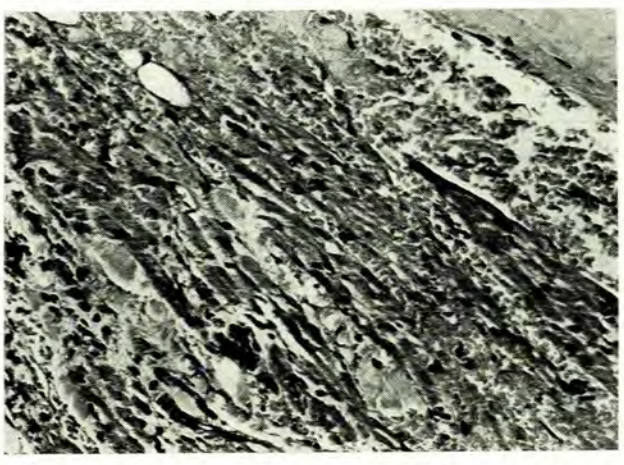

Fig. 6. Haemorrhage within the bundle of His of patient 13. (H. and E. × 110.)

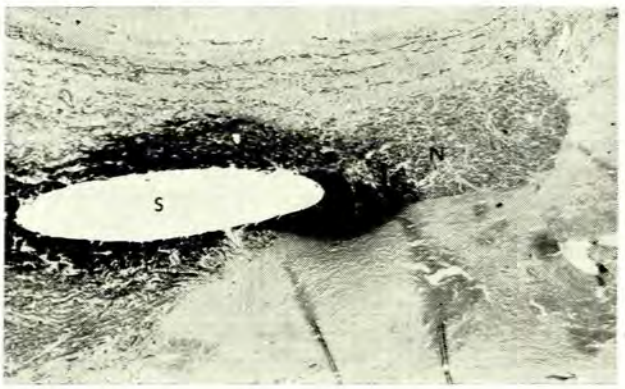

Fig. 7. The suture tract (S) through the atrioventricular node (N) of patient 19. The tract has been slightly enlarged due to displacement of suture material during cutting of the section. (H. and E. × 4.)

DISCUSSION

It is significant that recent haemorrhage within the conduction system was only found in patients belonging to group 1 (Tables II and IV). Such haemorrhage is likely to be related to the recent valve replacement operation. Although we were dealing with a small number of cases, there appeared to be no significant difference in the incidence of conduction tissue haemorrhage in the group 1 patients, when one compared mitral with aortic prostheses. Conduction tissue haemorrhage was present in all 5 patients in group 1 who had a Starr-Edwards prosthesis inserted.

TABLE IV. INCIDENCE OF CONDUCTION TISSUE HAEMORRHAGE IN 41 HEARTS

	Fresh haemorrhage	Haemosiderin
Group 1	9	0
Group 2	0	3
Controls	0	0

As mentioned previously, the central fibrous body and membranous septum constitute a continuous structure and are formed by the contiguous tricuspid, mitral and aortic valve rings. The bundle of His penetrates the central fibrous body in passing from atrium to ventricle, and is thus at risk in operations on these valves. The bundle is at greatest risk during aortic valve replacement.[6] Haemorrhage into the bundle of His may come about either as a result of direct surgical trauma, or as a result of anoxia. In patient 19, a suture passed through the centre of the conduction tissue in the region where the AV node becomes the bundle of His. One can only speculate as to whether the haemosiderin and suture material within the conduction tissue may have caused electrical instability, leading to fatal arrhythmia. In patient 7, a suture was observed to divide the left bundle branch and to run close to the bundle of His, which showed haemorrhage.

Anoxia seems the likeliest cause of the conduction tissue haemorrhage noted in the other 8 patients in group 1. Thung *et al.*[7] stated that the conduction tissue is the most heavily vascularized portion of the heart, and that hypoxia produces capillary wall changes, thereby increasing capillary permeability. Thus hypoxia may be expected to produce selective haemorrhage into this area. An analysis of the clinical course of their patients, indicated that in each patient with haemorrhage not related to direct injury, a significant period of hypoxia was a common denominator. They furnished experimental data to implicate hypoxia as a cause of haemorrhage into the cardiac conduction system, and emphasized the importance of adequate oxygenation in the post-thoracotomy patient. They also postulate that deposits of haemosiderin may remain within the conduction system, elicit scarring and produce arrhythmia.

Our 3 patients (Nos. 16, 17 and 19, of group 2) who had haemosiderin within the conduction tissue, survived 2 weeks, 6 weeks and 6 months, respectively. None showed signs of fibrosis. Patients 16 and 17 died of infection (endocarditis). Patient 19 showed no cause of death at autopsy and the only significant finding was a suture passing through the AV node.

Niles and Sandilands,[8] found haemorrhage in the atrioventricular conduction system in 18 out of 26 early deaths after valve replacement with a Starr-Edwards prosthesis. Such haemorrhage was also present in 6 out of their 36 late deaths. Most of their 24 cases of conduction tissue haemorrhage had shown an inadequate cardiac output, and they regard this haemorrhage as a possible cause of fatal postoperative heart failure. Our findings confirm their impression that some haemorrhage commonly occurs in the atrioventricular conduction tissue after valve replacement.

In 9 of 15 patients in group 1 no adequate cause of death was found at autopsy. The haemorrhage in the conduction system found in this study may have contributed towards the death of 5 of these 9 patients. In 3 of these 5 patients, the clinical mode of death had suggested an arrhythmia. It is possible that a more detailed examination of the conduction system might have revealed pathological changes (including haemorrhage) in the remaining 4 unexplained deaths. This possible error of omission does not detract from the positive finding of conduction tissue haemorrhage in 9 out of the 15 patients in group 1. A preliminary investigation of the His-Tawara system in patients who died after cardiac surgery for lesions not necessitating valve replacement (e.g. saphenous vein grafting of coronary arteries), but involving similar periods of time on bypass, showed instances of haemorrhage into the His-Tawara system in the latter cases. This would tend to indicate that the relative anoxia of the bypass procedure is of greater significance than direct surgical trauma in the aetiology of such haemorrhage.

CONCLUSION

This study confirms that the conduction system is at risk during heart valve replacement. Haemorrhage into the conduction tissue is a frequent finding in patients dying 5 days, or less, after such an operation. Anoxia would appear to be of greater aetiological significance than surgical trauma in the aetiology of such haemorrhage. Unexplained sudden death following valve replacement may in some instances be related to haemorrhage at this site. The present study does not enable one to make a firm decision in this regard. Although 5 of the 9 patients with haemorrhage showed no adequate cause of death at autopsy, the other 4 did have adequate cause of death. Thus one may argue that haemorrhage into the cardiac conduction system is commonly produced during valve replacement surgery, and that it is unrelated to the death of the patient. Death occurring later (i.e. outside the early postoperative period) is usually due to a cause which is readily apparent at autopsy, and fresh conduction tissue haemorrhage is not a feature. Patients undergoing multiple valve replacement operations or re-operation, appear to run a greater risk of conduction system damage.

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