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Chronic haemolysis after Lillehei-Kaster valve replacement

Comparison with the findings after Björk-Shiley and Starr-Edwards mitral valve replacement

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ABSTRACT Nineteen female and sixteen male patients who have had their heart valves replaced with Lillehei-Kaster valves were investigated for haemolysis four to 18 months after operation. Investigations included serum lactic dehydrogenase, serum haptoglobins, and urine haemosiderin. Red cell survival, using autologous red cells labelled with ^{51}Cr, was measured in 12 patients. No patient showed manifest anaemia. The serum lactic dehydrogenase levels were raised in 66% of the mitral valve patients, 81% of the aortic valve patients, and in all the double valve patients. The serum haptoglobins were decreased in 66% of mitral patients, 68% of aortic valve patients, and in 75% of the double valve patients. All the 12 patients studied had lower than normal red cell survivals. No correlation was found between the incidence of haemolysis and the size of the valve. In isolated mitral valve replacement 66% showed compensated haemolysis compared with 42% in Björk-Shiley valves ($p < 0.05$), 85% in Starr-Edwards valves (composite seat) ($p < 0.01$), and none in frame-mounted irradiated homografts (previous study) ($p < 0.001$).

The incidence of chronic intravascular haemolysis after prosthetic heart valve replacement depends on valve construction and haemodynamic performance. The Lillehei-Kaster valve, a free-floating pivoting disc valve with an opening angle of 80°, was introduced in 1970 and has a sound haemodynamic performance.[1 2] We have studied the incidence of chronic haemolysis in our patients who had their valves replaced with Lillehei-Kaster valves.

Patients and methods

Thirty-five patients with Lillehei-Kaster valves were investigated four to 18 months after operation. Fifteen patients had had mitral valve replacement, 16 aortic valve replacement, and four double valve replacement. There were 19 women and 16 men.

The incidence and severity of haemolysis after isolated mitral valve replacement with Lillehei-Kaster valves (15 patients) has been compared with haemolysis after mitral valve replacement with Björk-Shiley (24 patients), Starr-Edwards composite seat valves (32 patients), and irradiated frame-mounted aortic homograft valves (30 patients).

All patients were examined clinically to exclude any paravalvar leak and to confirm good valve function. Myocardial ischaemia was excluded by electrocardiographic and enzyme studies. Investigations included haemoglobin, haematocrit, reticulocyte count, red cell fragment count, serum lactic dehydrogenase (LDH), serum haptoglobins, serum iron, osmotic fragility, Hams' test, direct anti-human globulin test (DCT), and glucose-6-phosphate dehydrogenase screening. Red cell survival studies were carried out on 12 patients.

Haemoglobin was estimated using the Coulter counter S. A micromethod with ultracentrifugation was used to measure the haematocrit. A peripheral blood film was stained with Leishman's stain and the red cell fragments were counted on 1000 red cells. Reticulocytes were counted on a film stained with brilliant cresyl blue.

The radio-immunodiffusion method of Nyman[3] was used to measure the serum haptoglobin. The

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serum lactic dehydrogenase (LDH) was estimated by the method of Wroblewski and La Due.[4] Dade kits were used to estimate the glucose-6-phosphate dehydrogenase. The direct antihuman globulin test (DCT) was done using a broad spectrum Coombs' reagent. Osmotic fragility and Hams' test were done using standard methods.[5] A haemostix was used to test for haemoglobinuria. Haemosiderinuria was quantitated by a modified method of Slater and Fell[6] and graded 0 to ++++.

Red cell survival was determined with autologous red cells labelled with ^{51}Cr.

Results

LILLEHEI-KASTER VALVE STUDY

The mean haemoglobin was 14·1±0·86 g/dl in patients who had mitral valve replacement, 14·03± 0·99 g/dl in patients who had aortic replacement, and 12·82±1·16 g/dl in patients who had double valve replacement. One patient who had double valve replacement had a haemoglobin valve of 11·4 g/dl. The mean haematocrit valve was 0·41±0·02 in both the mitral and aortic valve replacements and 0·37±0·03 in patients who had double valve replacement.

The serum haptoglobins were either low or absent in 66% of the patients who had mitral valve replacement, in 68% of the patients who had aortic valve replacement, and in 75% of patients who had double valve replacement (table 1).

The serum lactic dehydrogenase levels were raised in 10 (66%) of the mitral valve patients, 13 (81%) of aortic valve patients, and in all (100%) the double valve patients. The mean serum LDH was 426·66±120·33, 514·06±209·67, and 513·75± 231·20 in the patients who had mitral, aortic, and double valve replacements respectively (table 2).

Haemosiderinuria ranged from + to +++ in five of the mitral valve patients. Six patients had only a trace and four patients had no haemosiderinuria. Of the patients with aortic valve replacement, four had haemosiderinuria ranging from + to ++. Six had only a trace and six had none. Two patients with double valve replacement had + haemosiderinuria, one had a trace, and one had none (fig 1).

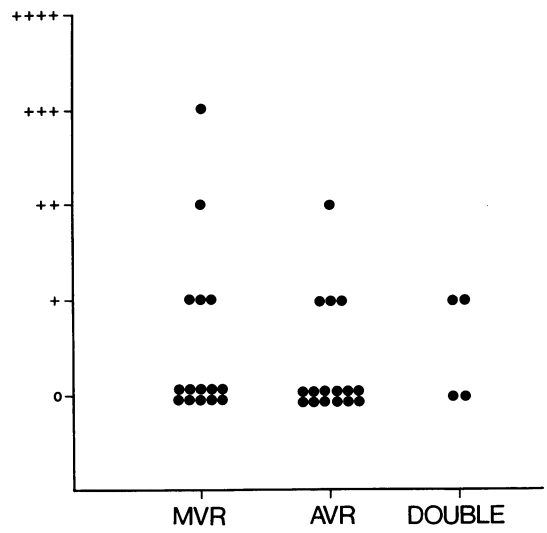

Fig 1 *Lillehei-Kaster valves. Haemosiderinuria in patients who had mitral (MVR), aortic (AVR), and mitral and aortic (double) valve replacement.*

Red cell survival studies were carried out on 12 patients who had isolated mitral valve replacement. All the patients studied had lower than normal red cell survival, the half-life of ^{51}Cr ranging from 20 to 24·5 days (table 3).

The reticulocyte count, red cell fragment count, glucose-6-phosphate dehydrogenase screening, DCT, Hams' test, and osmotic fragility were normal in all the patients.

COMPARISON OF HAEMOLYSIS CAUSED BY VALVES IN THE MITRAL POSITION

The serum LDH levels were raised in 66% of patients with Lillehei-Kaster valves, in 42% of patients with Björk-Shiley valves ($p < 0.01$), in all (100%) the

Table 1 *Serum haptoglobin (normal > 0·225 g/l)*

	0	*< 0·225 g/l*	*> 0.225 g/l*
Mitral valve replacement	3	7	5
Aortic valve replacement	1	10	5
Double valve replacement	1	2	1

Table 2 *Serum lactic dehydrogenase (normal range 150–360 u/l)*

	< 360 u/l	*> 360 u/l*	*Mean*
Mitral valve replacement	5 (33%)	10 (66%)	426 ± 12
Aortic valve replacement	3 (19%)	13 (81%)	514 ± 20
Double valve replacement	0	4 (100%)	513 ± 23

Table 3 *Red cell survival in mitral valve prostheses (normal range 25–30 T_{50} Cr days)*

	< 15 days	*15-20 days*	*20-25 days*	*> 25 days*
LK	0	0	12	0
B	0	0	8	4
S	0	6	5	1
H	0	0	0	12

LK = Lillehei-Kaster valve.
B = Björk-Shiley valve.
S = Starr-Edwards composite seat valve.
H = Frame-mounted irradiated homograft.

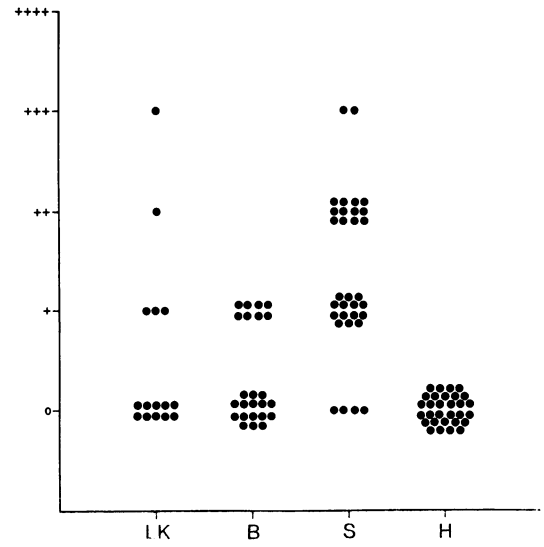

Fig 2 *Haemosiderinuria. Comparison between Lillehei-Kaster (LK), Björk-Shiley (B), Starr-Edwards composite seat (S), and frame-mounted irradiated homograft (H) valves in the mitral position.*

patients with Starr-Edwards composite seat valves ($p < 0.01$), and in 10% of the patients who had irradiated frame-mounted homografts ($p < 0.001$).

Haemosiderinuria was observed in 33% of the patients with Lillehei-Kaster valves, in 33% of the patients with Björk-Shiley valves, in 87·5% of the patients with Starr-Edwards composite seat valves ($p < 0.001$), and in none of the patients with homografts ($p < 0.01$) (fig 2).

The half-life of ^{51}Cr labelled autologous red cells varied from 20·0 to 24·5 days (mean 22·0 days) in Lillehei-Kaster valves, 20·5 to 27·0 days (mean 23·5 days) in Björk-Shiley valves ($p < 0.05$), 15 to 25·5 days (mean 20·4 days) in Starr-Edwards composite seat valves, and 26·0 to 29 days (mean 27·2 days) in the irradiated frame-mounted homografts ($p < 0.001$) (table 3).

Discussion

Chronic haemolysis after prosthetic valve replacement is not uncommon.[7-12] However, overt haemolysis manifesting as anaemia is rare. The haemolysis is intravascular. Trauma and fragmentation of red cells during their passage through the prosthetic valve is known to be the cause of haemolysis, though the exact mechanisms of such trauma are not yet clearly defined. Haemolysis has been observed in haemodynamically defective valves and where prosthetic surfaces remain unendothelialised.[13] Turbulence, cavitation, shear stress, reflux, and mechanical crushing effect all contribute to red cell trauma. An autoimmune mechanism has also been postulated.[14] However, none of our patients showed evidence of an autoimmune mechanism. The flow characteristics of the valve and the inertness of the prosthetic material are considered to be the significant factors in the trauma to the red cells.

In this study, though no patient had clinically manifest anaemia, two-thirds of all our patients had compensated haemolysis. Lillehei[15] reported normal mean serum LDH levels in his aortic and mitral patients and only a slight increase after double valve replacement. However, in Nitter-Hauge's studies, 75% of aortic and 43% of mitral valve patients had raised serum LDH values.[11 12] In isolated mitral valve replacement, we found compensated haemolysis in 42% of Björk-Shiley valves, 66% of Lillehei-Kaster valves, 85% of Starr-Edwards (composite seat) valves, and in none of the frame-mounted irradiated homografts.[16]

We also compared the relation of valve size to haemolysis. We have used mitral valve size 20M in four patients, 22M in six patients, and 25M in five patients. In the aortic position we have used size 14A in six patients, 16A in four patients, 18A in five patients, and 20A in one patient. There was no correlation between the size of the valve and the incidence of haemolysis.

In vitro tests have shown that at lower opening angles the Lillehei-Kaster valve was more obstructive compared with the Björk-Shiley valve and was only superior to the latter valve at an opening angle of 75° or more.[1] Although the Lillehei-Kaster valve has been designed to open at an angle of 80°, in vivo studies have shown that the disc opens only to 57° to 74°,[1] causing larger gradients. In addition, in the Björk-Shiley valve the disc does not overlap the ring, whereas in the Lillehei-Kaster valve it rests on a discontinuous biplanar seat which could have a greater mechanical crushing effect.

The Lillehei-Kaster valve produced inapparent haemolysis in a number of our patients, but there was chronic loss of fractional amounts of iron in the form of haemosiderinuria. However, the haemolysis was so mild and well compensated, that all patients maintained normal serum iron, haemoglobin, and haematocrit. This prosthetic valve is marginally more traumatic to the red cells than the Björk-Shiley valve.

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