OBSERVATIONS ON THE SITES OF REMOVAL OF BACTERIA FROM THE BLOOD IN PATIENTS WITH BACTERIAL ENDOCARDITIS

By PAUL B. BEESON, M.D., EMMETT S. BRANNON, M.D., AND JAMES V. WARREN, M.D.

(From the Medical Service of Grady Hospital and the Department of Medicine, Emory University School of Medicine, Atlanta)

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The number of bacteria in the peripheral blood of a patient with bacterial endocarditis is nearly always relatively small, despite the fact that organisms appear to have free access to the circulating blood. This indicates that some mechanism is constantly at work to remove them from the blood. Opinions on the means of this removal have differed; some have considered a bactericidal action of the blood itself to be responsible, while others have held that the circulating bacteria are arrested in particular parts of the body.

If bacteria are removed from the blood in certain organs, one would expect to find fewer organisms in venous blood which has just passed through those organs than in the blood entering them, while if a bactericidal action of the blood is responsible there should be no marked difference in the bacterial content of the blood in different parts of the body. The present communication deals with quantitative arterial and venous blood cultures in six patients with bacterial endocarditis. Blood was obtained not only from peripheral arteries and veins but also from such locations as the right auricle, the venae cavae, the hepatic, and renal veins. A comparison of the colony counts obtained in serial samples from these areas has provided information in regard to the mechanism of removal of bacteria from the blood.

Methods

In all tests the plan was to obtain paired samples of blood at intervals from two different locations in the blood stream; usually the pairs consisted of one arterial and one venous sample, although occasionally two venous ones were taken. All arterial blood was drawn from femoral arteries, on the assumption that the bacterial content of blood in all arteries (excepting the pulmonary) would be approximately the same at any one time. It is realized that this may not always be the case, since infected particles which break off from the vegetations would not be distributed equally in the arterial tree.

Each pair of samples was collected by two persons, and every effort was made to maintain a uniform time relationship between them; *i.e.*, to collect the arterial blood about 5 seconds before the venous blood. When two venous samples were being paired they were drawn simultaneously. Technical difficulties were encountered occasionally so that this time relationship was not obtained in every instance. A separate dry sterile syringe was used for each sample.

In obtaining blood from vessels in the extremities an inlying needle of the Ungar type was used. This needle has a snug-fitting stylet which can be withdrawn to permit a syringe to be

attached, then after blood has been taken the stylet can be replaced. This allows repeated sampling from one vessel without multiple punctures.

To obtain blood from the right auricle, venae cavae, renal, and hepatic veins, the technique of right auricular catheterization developed by Cournand and his associates (1) was used. In this procedure a special flexible radiopaque ureteral type catheter is inserted into an antecubital vein and is passed, under fluoroscopic guidance, through the veins of the arm and axilla into the superior vena cava and from there on into the right auricle. In order to prevent clotting of blood in the catheter a slow drip of physiologic saline is run through it from a reservoir attached to the side arm of a three-way stop-cock. When blood is to be taken the flow of saline is switched off, and suction is applied to the catheter by means of a sterile syringe. The capacity of the catheter is approximately 1.0 cc., and in order to avoid dilution of the test specimen by saline in the catheter, the first 3.0 cc. which are withdrawn are discarded. A fresh sterile syringe is then attached and the specimen of blood to be examined is drawn into it. Following this the flow of saline through the catheter is resumed.

By an extension of the foregoing method specimens of blood were also obtained from the hepatic and renal veins. Technical details have been given elsewhere (2, 3).

The volume taken for each culture was 1.5 to 2.0 cc. of blood. This was transferred to a sterile test tube containing 25 mg. dry sodium citrate, and the mixture was agitated sufficiently for thorough mixing of the anticoagulant. The tube was then labeled and placed in a rack in ice water, where it remained until the conclusion of the sampling.

One agar pour plate was made from each sample. One cc. of blood was measured in a serologic pipet and transferred to a Petri dish. The blood was then mixed with 20 cc. of warm agar base (Difco). The mixture was allowed to solidify at room temperature, and then incubated at 37° C. for 48 to 72 hours.

Each colony count was made, with the aid of a modified "Quebec" colony counter, by two persons. In most instances the two results were very close, and the mean was the figure accepted. In a few instances where the difference was greater than 10 per cent the counts were repeated until better agreement was obtained.

EXPERIMENTAL

Patient 1.—No. 142778. A 43 year old negro male, admitted to Grady Hospital on July 22, 1943. There was no history of rheumatic fever or syphilis. His illness had begun 6 months previously, with weakness, fever, headache, nausea, and pains in fingers and toes. While in the hospital his temperature ranged between 101 and 103° F. Physical examination disclosed typical signs of aortic insufficiency, petechial hemorrhages in skin and conjunctivae, and palpable spleen. Urine usually contained red blood cells. The Kahn test was positive on two occasions. Eleven blood cultures all yielded *Streptococcus viridans*. Sulfadiazine therapy had no obvious effect on the disease. The studies on his bacteremia reported here were done on Aug. 4, 1943. He died on Aug. 9, 1943, following a cerebral embolism. Permission for autopsy was not granted.

The results of a series of 31 blood cultures on this patient during a period of 69 minutes are shown in Table I. Sixteen of the samples tested were from the femoral artery; these were paired with blood from the femoral vein, the hepatic vein, the superior vena cava, and the right auricle. The colony counts on the arterial blood during the entire period ranged from a low of 357 to a high of 642. The first comparison was with femoral vein blood, where the colony counts in 4 samples were found to be somewhat lower than in arterial blood, ranging

between 235 and 319. Next, 4 samples of blood from one of the hepatic veins were tested, and here a striking difference resulted. Colony counts in the liver blood were, respectively: 6, 10, 9, and 6. These figures are all less than 3 per cent of the level prevailing in arterial blood throughout the experiment. Four samples of blood from the superior vena cava gave counts varying between 283

TABLE I

Patient 1. Colonies per Cubic Centimeter in Blood from Femoral Artery, Femoral Vein, Hepatic Vein, Superior Vena Cava, and Right Auricle

Time	Femoral artery	Femoral vein	Hepatic vein	Superior vena cava	Right auricle
a.m.					
10:43	357				
10:45	375				
10:48	448				
10:50	476				
10:52	545	244			
10:54	377	Cl.			
11:02	482	235			
11:03	446	295			
11:05	486	319			
11:25	Cl.		6		
11:27	440		10		
11:30	374		9		
11:32	466		6		
11:38	401			283	
11:40	Cl.			294	
11:41	449			310	
11:43	Cl.			346	
11:50	642				279
11:51	Cl.				287
11:52	387				239

Cl.—specimen lost because of clotting.

and 346, while in 3 samples of mixed venous blood from the right auricle the counts were found to be 239, 279, and 287.

Patient 2.—No. 146223. A 17 year old negro girl, admitted to Grady Hospital on July 20, 1943. Her illness had begun 4 months previously, with fever and polyarthritis. Examination disclosed typical signs of mitral stenosis, petechiae in conjunctivae and skin, and palpable spleen. Her temperature varied between 100 and 102° F. Seven blood cultures were negative. On sulfadiazine therapy she improved somewhat, and returned to her home. She continued to have fever, however, and gradually developed signs of cardiac decompensation. On Nov. 6, 1943 she had a cerebral accident and became comatose. Was readmitted Nov. 8,

1943. Blood cultures were then positive for *Streptococcus viridans*. The studies on her bacteremia reported here were done on Nov. 10, 1943 and Nov. 11, 1943. She died on Nov. 14, 1943. Autopsy revealed rheumatic mitral stenosis, with vegetations on the mitral leaflets and also on the adjacent wall of the left ventricle.

The first studies on this patient's bacteremia are shown in Table II. Cultures were made from blood in a femoral artery, a femoral vein, an hepatic vein, and the right auricle. Thirty-four samples of blood were collected from these

TABLE II

Patient 2. Colonies per Cubic Centimeter in Blood from Femoral Artery, Femoral Vein, Hepatic Vein, and Right Auricle

Time	Femoral artery	Femoral vein	Hepatic vein	Right auricle
a.m.				
9:22	143	68		
9:29	161	63		
9:35	116	46		
9:46	118	56		
9:52	106	85		
9:58	112	67		
10:10	123	94		
10:18	Cl.	88		
10:32	125	140		
10:43	128	115		
11:18	193		9	
11:21	201		3	
11:24	196		7	
11:28	182		6	
11:30	Cl.		7	
11:32	122		2	
11:41	192			119
11:44	154			109

Cl.—specimen lost because of clotting.

locations during a period of 142 minutes. Colony counts in 16 specimens of arterial blood ranged from 106 to 201. In 10 samples of femoral vein blood the range was from 46 to 140, and in all but one instance (10:32 a.m.) the count on the venous blood was below that of the corresponding arterial sample. In the next portion of this period 6 samples of hepatic vein blood were cultured, and here the colony counts varied between 2 and 9. In each instance this was less than 5 per cent of the count on the arterial sample with which it was paired. At the conclusion of the period 2 samples of mixed venous blood from the right auricle were cultured. These gave considerably lower colony counts than the

corresponding samples of arterial blood—119 and 109, contrasted with 192 and 154.

On the following day samples from the femoral artery and the antecubital vein were cultured. The results are shown in Table III. Unfortunately one of the venous blood cultures was contaminated and could not be counted. Very little difference was found between blood samples from these sources: in 3 of the 4 pairs the results were almost identical, while in the fourth the venous colony count was approximately 80 per cent of the arterial.

Patient 3.—No. 163684. A 40 year old negro male, admitted to Grady Hospital on Jan. 21, 1944. Ten days previously he had developed a respiratory infection, and 5 days later he had become acutely ill, with severe headache, stiff neck, and fever. On admission he had signs of meningitis, which were found to be due to pneumococcus Type 24. He was given sulfadiazine by mouth and penicillin intrathecally. Signs of meningitis improved, but he continued to have fever, and blood cultures were repeatedly positive for pneumococcus Type 24. Antibodies for this organism were present in his blood serum. He had physical signs of aortic insufficiency. The studies on his bacteremia reported here were done on Jan. 25, 1944, Feb. 2, 1944, and Feb. 5, 1944. He died on Feb. 11, 1944. Autopsy revealed vegetations of bacterial endocarditis located on the mitral and aortic valves.

TABLE III

Patient 2. Colonies per Cubic Centimeter in Blood from Femoral Artery and Antecubital Vein

Time	Femoral artery	Antecubital vein
a.m.		
8:58	203	194
9:00	228	181
9:02	226	Contam.
9:10	164	163
9:14	175	176

Contam.—contamination of culture.

Three separate studies were done on this patient's bacteremia. The first is shown in Table IV. Thirty-six samples of blood were taken from the femoral artery, the inferior vena cava, the hepatic vein, and the right auricle during a period of 54 minutes. There appeared to be more fluctuation in the colony count in the arterial blood of this patient than in the other subjects, since during the period of observation the range in colony count was from a low of 53 to a high of 697. The first 6 samples of venous blood were taken from the inferior vena cava, at a point between the level of the renal veins and the heart. In the first 2 the venous colony count was higher than the arterial, while in the last 4 it was about equal or lower. Obviously no conclusion can be drawn from this result. The next samples of venous blood were taken from one of the hepatic veins. During the period of time these were being taken there was a marked

variation in the arterial colony count. A similar pattern of change also held for the hepatic vein colony count, although it was considerably lower in each instance, being from 10 to 25 per cent of the corresponding arterial count. In the final part of this study 6 samples of mixed venous blood were taken from the right auricle. The first of these gave a higher count than its arterial mate, the next was slightly lower, and in the remaining 4 the level was considerably lower, although not so low proportionately as in the case of hepatic vein blood.

TABLE IV

Patient 3. Colonies per Cubic Centimeter in Blood from Femoral Artery, Inferior Vena Cava, Hepatic Vein, and Right Auricle

Time	Femoral artery	Inferior vena cava	Hepatic vein	Right auricle
p.m.				
2:34	144	246		
2:36	104	226		
2:38	305	203		
2:40	247	244		
2:42	201	187		
2:44	246	172		
2:52	63		7	
2:57	197		50	
2:59	673		103	
3:02	697		121	
3:04	377		55	
3:06	109		11	
3:15	86			161
3:17	98			91
3:22	100			58
3:24	76			36
3:26	92			63
3:28	53			34

Table V contains the results of another series of blood cultures in the same patient. First femoral arterial blood was compared with blood from the right renal vein. In 10 pairs of cultures the arterial colony count was higher than the venous count 9 times, although in some of these the difference was slight, and in no instance was the venous count less than 60 per cent of the arterial. In the second part of this study a comparison of femoral vein and antecubital vein blood was made. Nine pairs of samples were obtained, and in 8 of these the antecubital vein count was considerably higher than the femoral vein count. In only one pair (2:38 p.m.) was the count higher in femoral vein blood and here the figures were almost the same: 110 and 112.

TABLE V

Patient 3. Colonies per Cubic Centimeter in Blood from Femoral Artery, Renal Vein, Antecubital Vein, and Femoral Vein

Time	Femoral artery	Renal vein	Antecubital vein	Femoral vein
p.m.				
1:50	303	249		
1:52	356	248		
1:55	216	316		
1:57	366	357		
1:58	203	144		
2:00	288	214		
2:02	312	294		
2:04	304	201		
2:06	248	179		
2:07	301	270		
2:25			152	114
2:29			121	81
2:31			156	92
2:33			107	80
2:38			110	112
2:39			101	71
2:41			149	65
2:43			84	41
2:45			83	58

TABLE VI

Patient 3. Colonies per Cubic Centimeter in Blood from Femoral Artery and Antecubital Vein

Time	Femoral artery	Antecubital vein
p.m.		
1:00	266	228
1:03	264	251
1:05	300	285
1:07	358	256
1:08	399	397
1:11	340	358
1:13	397	344
1:15	298	318
1:17	332	342
1:20	552	533
1:23	671	534

The third series of observations on patient 3 is presented in Table VI. This consisted of a comparison of arterial and antecubital vein blood. Eleven pairs of samples were taken. In 8 of these the arterial count was higher than the

venous, while in 3 the venous count was higher. It should be noted that in 4 of the instances in which the arterial count was higher the difference was comparatively small, and that in no pair was the venous count less than 70 per cent of the corresponding arterial sample.

Patient 4.—No. 200706. A 20 year old negro woman, admitted to Grady Hospital on Feb. 10, 1944. She gave a history of rheumatic fever at the age of 6 and a diagnosis of aortic insufficiency had been made when she was 18. She stated that she had felt well until Feb. 9, 1944, the day before admission to the hospital, when she noted fever, headache, and joint pains. During the next 3 days her temperature ranged between 101 and 103° F. and 4 blood cultures yielded *Streptococcus viridans*. The studies of her bacteremia reported here were done on Feb. 13, 1944. She was treated with sulfadiazine for the next 8 days. This caused a drop in temperature, but blood cultures remained positive. She was then given penicillin, 250,000 units daily, for 14 days. Blood cultures became negative and have remained so since. When last examined, on Sept. 2, 1944, she was afebrile and showed no other sign of return of the infection.

During one period of 52 minutes, 46 samples were secured for culture. Arterial blood was paired successively with that from a renal vein, an hepatic vein, and the right auricle. The results are given in Table VII. In the first 7 pairs colony counts on arterial blood ranged from 89 to 132, while those on renal vein blood ranged from 92 to 114. In one instance the venous count exceeded the arterial, in another the counts were exactly the same, and in the remaining 5 pairs the venous counts were 79 to 89 per cent of the arterial counts. These figures do not warrant definite conclusions, but they suggest that in general the colony count in blood which has passed through the kidneys is slightly lower than the colony count in arterial blood.

In the next series of 8 pairs, samples of blood were collected from an hepatic vein as well as from the femoral artery. During this time the arterial colony counts varied between 80 and 110, whereas in liver blood the range was from 25 to 57. In actual percentages the hepatic vein counts were 25 to 71 per cent of the arterial. In this patient the proportionate number of colonies in hepatic vein blood was higher than was found in any of the other patients in this series; nevertheless, even here there appeared to be a very considerable reduction in the bacterial content of hepatic vein blood.

Finally 8 observations were made on the difference between arterial blood and mixed venous blood from the right auricle. During this period arterial colony counts varied between 92 and 121, while the figures for auricle blood were from 64 to 97. Considering individual pairs, the right auricle counts were 67 to 83 per cent of the corresponding arterial levels. Here then, as in all other cases in this series the bacterial content of mixed venous blood returning to the heart was consistently found to be lower than that of the arterial blood.

Patient 5.—No. 158290. A 27 year old negro woman, admitted to Grady Hospital on Jan. 23, 1944. Her illness had begun 11 weeks previously, with fever and polyarthritis. On the

day before admission she suffered a subarachnoid hemorrhage. Examination revealed stiffness of the neck, petechial hemorrhages in conjunctivae, signs of mitral stenosis and aortic insufficiency, palpable spleen. Spinal fluid was blood-tinged. Blood culture yielded *Streptococcus viridans*. The studies on her bacteremia reported here were done on Jan. 28, 1944. She died on Feb. 11, 1944. Autopsy revealed rheumatic heart disease, and extensive vegetations of bacterial endocarditis on both valves of the left heart.

TABLE VII

Patient 4. Colonies per Cubic Centimeter in Blood from Femoral Artery, Renal Vein, Hepatic Vein, and Right Auricle

Time	Femoral artery	Renal vein	Hepatic vein	Right auricle
p.m.				
3:37	89	114		
3:42	113	101		
3:44	102	102		
3:46	116	92		
3:48	132	114		
3:49	115	98		
3:52	113	94		
3:56	80		57	
3:58	95		50	
3:59	81		32	
4:01	102		38	
4:03	101		25	
4:04	106		46	
4:06	92		40	
4:08	110		36	
4:18	109			91
4:19	108			87
4:21	95			64
4:22	104			85
4:24	105			97
4:25	121			92
4:26	92			72
4:29	107			86

In Table VIII are the findings in 46 blood cultures taken during a period of 91 minutes. Arterial blood was paired with venous blood from the inferior vena cava, the right auricle, and an hepatic vein; then several samples were collected from a femoral vein and an antecubital vein. The general level of the bacteremia in this patient was the lowest in this series; furthermore there appeared to be a greater proportionate variability in the colony counts from minute to minute than had been observed in the other subjects.

The colony count in samples from the inferior vena cava (below the level of

the renal vein) exceeded that of arterial blood in one instance, it was the same in another, while in the remaining 4 pairs the arterial count was higher than the venous. The colony counts in 4 of 5 samples of mixed venous blood from the right auricle were considerably lower than those of the corresponding arterial samples; in the fifth pair the venous count was 5 when the arterial count was 4.

TABLE VIII

Patient 5. Colonies per Cubic Centimeter in Blood from Femoral Artery, Inferior Vena Cava, Right Auricle, Hepatic Vein, Femoral Vein, and Antecubital Vein

Time	Femoral artery	Inferior vena cava	Right auricle	Hepatic vein	Femoral vein	Antecubital vein
p.m.						
1:31	9	6				
1:33	12	12				
1:35	9	8				
1:36	5	3				
1:38	11	13				
1:40	17	9				
1:51	15		8			
1:52	9		4			
1:54	4		5			
1:55	12		4			
1:57	19		6			
2:21	8			0		
2:22	6			2		
2:24	11			1		
2:26	15			1		
2:28	9			2		
2:48					20	21
2:50					10	18
2:52					15	11
2:54					10	14
2:59					12	16
3:01					7	18
3:02					19	21

A definite reduction in colony count in hepatic vein blood was observed in this patient. In 5 samples the colony counts were: 0, 1, 1, 2, and 2; during the same period the femoral artery colony counts varied between 6 and 15.

Lastly, femoral vein samples were compared with blood from an antecubital vein. Seven specimens were obtained from each source. In one instance the count was higher in femoral vein blood, but in the remaining 6 pairs it was higher in antecubital vein blood. This is in line with the previous observations,

that the bacterial content of blood in an antecubital vein is nearer to the arterial level, than that of blood from a femoral vein.

Patient 6.—No. A99095. A 20 year old white woman, admitted to Grady Hospital on Apr. 17, 1944. She gave no history of rheumatic fever. Her illness had begun 6 months previously, with fever and malaise, later there was a polyarthritis which varied in intensity. On two occasions she had suffered paralyses of the extremities, both of which had cleared almost entirely. She had noted painful spots in the tips of her fingers. Her temperature varied from 101 to 104° F. Physical examination revealed pallor, clubbing of the fingers, signs of mitral stenosis and insufficiency, and palpable spleen. She had a leucocytosis. Four blood cultures were positive for *Streptococcus viridans*. She was given a trial of sulfadiazine; this caused a reduction in fever, but blood cultures continued to be positive. She was then given a course of penicillin, 200,000 units daily for 21 days. Blood cultures became negative and her fever subsided during that treatment, but she became progressively more decompensated and died in severe congestive failure on June 15, 1944. Autopsy revealed healing vegetations on the mitral valve. The studies on her bacteremia reported here were done on Apr. 19, 1944.

TABLE IX

Patient 6. Colonies per Cubic Centimeter in Blood from Femoral Artery, Renal Vein, Hepatic Vein, and Right Auricle

Time	Femoral artery	Renal vein	Hepatic vein	Right auricle
p.m.				
1:45	195	194		
1:47	245	195		
1:49	199	180		
1:51	226	174		
1:53	223	196		
1:55	236	210		
1:57	209	188		
1:59	286	210		
2:03	188		5	
2:05	220		6	
2:06	266		12	
2:08	276		8	
2:10	249		6	
2:12	227		5	
2:14	277		4	
2:16	288		7	
2:20	284			186
2:22	253			207
2:24	283			151
2:26	319			156
2:28	259			173
2:30	250			203
2:32	322			230
2:34	297			209

Forty-eight specimens were obtained during a period of 49 minutes from the femoral artery, the renal and hepatic veins, and from the right auricle. The findings are presented in Table IX. When arterial and renal vein blood were compared the counts were found to be higher in arterial blood, although the differences were not great, venous figures being 73 to 99 per cent of the arterial levels.

In the next 8 pairs arterial and hepatic vein blood were examined. The counts in arterial blood during this time ranged between 188 and 288, while those in blood from the liver varied between 4 and 12. In every instance, therefore, the bacterial content of hepatic vein blood was less than 5 per cent of that of arterial blood.

The last 8 pairs in this study included arterial and right auricular blood. Arterial counts ranged from 250 to 322, while the mixed venous blood gave colony counts from 151 to 230. In individual pairs the venous counts were from 49 to 82 per cent of the corresponding arterial levels.

DISCUSSION

Previous to this there have been few investigations of the mechanism of removal of bacteria from the blood in human beings. Some workers have reported results of arterial and venous colony counts in the peripheral blood of patients with bacterial endocarditis, but these observations usually consisted of a single pair of samples from each patient (4, 5). Touroff has recently reported an investigation on a human being which he cites as evidence that the lungs remove bacteria from the blood in man (6). During an operation for ligation of an infected patent ductus arteriosus he took simultaneous cultures from the aorta and from the pulmonary artery. The aortic blood contained 51 colonies per cc., while the sample from the pulmonary artery contained "innumerable" colonies. Touroff offers this observation as proof that the lungs play an important part in the removal of bacteria from the blood. We are hesitant to accept such a conclusion, principally because it is based on a single pair of samples. The chance presence of an infected embolic particle in the blood from the pulmonary artery could account for the large number of colonies present in that blood; indeed, the very fact that "innumerable" colonies were found suggests that this may have been the case, since it is certainly uncommon to find so many colonies in the peripheral blood of a patient with left-sided endocarditis. Unfortunately, our own studies do not provide any information on the question of removal of bacteria by the lungs.

A considerable amount of work has been done on the mechanism of removal of bacteria from the circulating blood in experimental animals. The principal findings have been reviewed by Ottenberg (7). The results have not all been in agreement, but in the various experiments it appeared that organisms may be removed by the liver, the spleen, the bone marrow, the lungs, and the skeletal

muscles. Certain differences have been noted according to the kind of experimental animal; furthermore all bacteria do not appear to be disposed of in the same way. An important factor is the presence or absence of immunity to the infecting organisms. In that connection it should be stressed that the findings reported here apply to a disease in which a high degree of immunity to the infecting organism is nearly always present. In other types of bacteremia the pattern of disposal of bacteria may be somewhat different.

As would be expected in bacterial endocarditis, the colony counts in our patients were higher in arterial blood than in venous blood. That a considerable portion of the bacterial content of blood disappears during one circuit of the body is shown by the fact that mixed venous blood in the right auricle usually had a colony count only one-half to two-thirds as high as the corresponding arterial level. Possibly still further reduction takes place during passage through the lungs. In any event these studies indicate that a new supply of bacteria is constantly being added to the blood from the endocardial vegetations. An interesting feature of that replenishing is the fact that it appears to consist of a constant discharge of organisms, and not a series of bacterial "showers." No doubt such "showers" may occur, but none happened to take place at the time of any of the numerous arterial cultures on these 6 patients. Instead, the arterial colony count maintained a remarkably constant level from minute to minute.

The most striking finding in this study was the small number of bacteria in blood obtained from the hepatic veins. In every one of the six patients a marked difference was found between arterial and hepatic vein colony counts, although the difference appeared to be proportionately greater in some than in others. In patients 1, 2, and 6 the colony counts in liver blood were less than 5 per cent of the arterial, while in patients 3 and 4 the difference was not quite so marked, and in patient 5 the reduction below the arterial level was only about half. It is perhaps relevant that the duration of illness was longest in patients 1, 2, and 6 and was shortest in patient 5. The efficiency of the removal mechanism may be influenced by patients' immunity to the infection.

Although it is true that some of the blood in the hepatic vein has previously passed through the capillaries of the spleen or the gastrointestinal tract, approximately 25 per cent of the blood supplied to the liver comes from the hepatic artery (8). It appears justifiable, therefore, to conclude that some bacteria are removed in the liver itself, since the removal of all bacteria which pass through the spleen, stomach, and intestines could not lower the colony count of blood in the hepatic vein by as much as 95 per cent.

The difference in bacterial content of blood from the antecubital and femoral veins is an interesting one. Femoral vein blood showed a fairly marked reduction below arterial blood, while antecubital vein blood was usually not much different from arterial blood. This difference between two peripheral veins is

probably referable to the character of the tissues drained by them. The antecubital vein drains blood principally from skin and superficial tissues. The circulation to the skin of the hands is unusual in that relatively little oxygen is extracted; indeed when the hands are warm much of the blood passes through special small arteriovenous shunts. It would seem that there is little opportunity for the removal of bacteria under these circumstances. The femoral vein, on the other hand, drains a large proportion of deeper tissues: muscles and bone marrow, both of which have been shown in experimental animals to be capable of removing bacteria from the circulating blood. From a practical standpoint, these studies indicate that there is little advantage to arterial, in preference to antecubital vein, cultures in routine clinical practice, since the number of organisms in antecubital vein blood is essentially the same as in arterial blood. It is conceivable, however, that if a patient were cold or emotionally disturbed, with vasoconstriction in the skin of the hands, the blood in the antecubital veins would contain fewer organisms since it would then consist of a greater proportion of blood which had passed through deeper tissues.

SUMMARY

In 6 patients with bacterial endocarditis studies were made of the bacterial content of arterial and venous blood. Paired samples were collected, approximately simultaneously, from two different locations in the circulatory system, and colony counts were determined. As many as 48 specimens were taken for culture during a single period of study. Venous blood was drawn not only from different locations in the extremities, but also from the superior and inferior venae cavae, the right auricle, and the hepatic and renal veins.

As would be expected, colony counts were highest in arterial blood.

Blood from the antecubital veins gave colony counts only slightly lower than arterial blood. In the femoral veins, on the other hand, there were appreciably fewer organisms. This difference is attributed to the type of tissues drained by the two veins.

Colony counts in blood from the superior and inferior venae cavae were also lower than arterial counts, the ratio being comparable to that found in femoral vein blood.

In the renal veins colony counts were only slightly below the arterial level indicating that few organisms are removed from the blood during passage through the kidneys.

The greatest reduction in bacterial content was found in hepatic vein blood. In 3 of the 6 subjects this reduction amounted to more than 95 per cent, and in all subjects the difference was very considerable.

Mixed venous blood in the right auricle of the heart gave colony counts which were usually one-half to two-thirds as high as in corresponding samples of arterial blood.

An interesting finding in these studies was a remarkable constancy of the bacterial content of arterial blood, during periods of 1 or 2 hours. Despite the fact that a considerable portion of the bacteria which leave the heart in arterial blood appear to be removed during a single circuit of the body, the number of bacteria in successive samples of arterial blood shows little change. This indicates that in bacterial endocarditis organisms are discharged into the blood from the endocardial vegetations at a comparatively even rate, rather than in a haphazard fashion as a result of the breaking off of infected particles.

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