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Research Article

THE NUMBER OF FORMED ELEMENTS IN THE URINARY SEDIMENT OF PATIENTS SUFFERING FROM HEART DISEASE, WITH PARTICULAR REFERENCE TO THE STATE OF HEART FAILURE

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It is well known that casts, red blood cells and white blood cells may be present in the urinary sediment of patients suffering from heart failure. In the manner that specimens of urine are usually obtained it is not possible to gain an accurate notion of the numbers of cells which are present, since variations in salt concentration and reaction of the urine may result in partial or complete disappearance of the formed elements of the urine. Addis (1) recommended a procedure which has for its object the secretion by the kidneys of urine of such high specific gravity and acidity that the integrity of the formed elements of the urine is maintained. By this means the number of elements in urinary sediment formed in a 12-hour period may be estimated. Addis (2) found that the number of casts passed in a 12-hour period varied in normal individuals between 0 and 4,270, the average being 1,040; the number of red blood cells between 0 and 425,000, the average being 65,700; the number of white blood and epithelial cells between 32,400 and 1,835,000, the average being 322,500. The casts were hyaline; granular casts were not observed.

The present study is concerned with the estimation of the number of formed elements in the urines of patients suffering from chronic heart disease, especially of the so-called arteriosclerotic type, more particularly with reference to the state of heart failure of the congestive type.

The patients were at rest in bed and were in water equilibrium. Observations were made in patients suffering from the congestive type of heart failure, and again in the same patients after the signs and symptoms of heart failure had disappeared. In others, observa-

tions could be made only during the stage of decompensation, while in others still, only after the return to the state of compensation. In addition there are data in a few patients who had never suffered from heart failure. Most of the patients were males; catheterization of females is necessary if accurate counts of the cells are desired. The sediment was studied according to the technique described by Addis (1). The procedure begins after breakfast. The patient is given no fluid following this meal until after the end of the test the next morning (6 a.m.). The patient voids at 6 p.m.; this specimen is discarded. The total night urine (6 p.m.–6 a.m.) is obtained at one voiding 12 hours later. The casts, red blood and white blood cells are counted in samples of this specimen.

OBSERVATIONS

The number of formed elements in the urine in the presence of heart failure of the congestive type. In 18 patients (tables 1 and 2), the number of casts in 12-hour samples varied between 0 and 463,740, the average number being 66,485 (table 3). In 6 instances the number was within the normal range (4 none, 2 high) and in the 12 remaining, greater than the highest normal value observed by Addis (2). Granular casts were found in approximately half the urines. The red blood cell counts ranged from 72,210 to 3,090,000, the average being 834,754. In 9 patients the number was normal (1 average, 8 high) and in the 9 remaining greater than the highest normal value. The white blood and epithelial cells varied between 70,000 and 17,877,000, the average being 3,089,302. In 13 patients the range was normal (1 average, 12 high), and in the 5 remaining greater than the highest normal value.

In the presence of heart failure of the congestive type, therefore, the number of casts was definitely increased in approximately two-thirds of the cases studied, the red blood cells increased in approximately one-half, and the white blood cells in approximately one-third. The average number of casts was 60 times and the average number of red blood cells and of white blood cells 10 to 15 times greater than in normal subjects.

The number of formed elements in the urine following recovery from cardiac decompensation. After recovery from heart failure in 16 patients the number of casts varied between 0 and 141,000 (tables 1

and 4), the average being 34,600 (table 3). In 4 instances the number was normal (4 none) and in 12, greater than normal. Granular casts were found in approximately 25 per cent. Red blood cells varied between 165,000 and 3,090,000, the average being 917,515. In 4 patients the number was normal (4 high) and in 12, greater than the highest normal value. The white blood and epithelial cells ranged between 304,000 and 2,520,000, the average being 1,151,187. In 13 patients the range was within normal limits (2 average, 11 high) and in 3, greater than the highest normal value.

In our experience, it appears therefore to be a fact that approximately 75 per cent of the patients who had recently recovered from heart failure of the congestive type passed in their urines a greater number of casts than normal individuals, an increased number of red blood cells, but in the case of white blood cells a number greater in one-fourth of the patients than the highest number in normal individuals.

Comparison of the numbers of formed elements present in the urine during heart failure and following recovery. When observations (11 patients) were possible during the stage of heart failure as well as after return to compensation (table 1), we found no fixed tendency of direction; that is to say, the casts, red blood cells and white blood cells were as frequently increased following the disappearance of signs of heart failure as they were decreased (see discussion). On comparison of the average numbers (table 3), however, it appears that casts and white blood cells were passed in approximately twice the quantity during decompensation as after recovery, but the red blood cells in approximately the same numbers.

The number of formed elements in the urine of patients who have not suffered from heart failure of the congestive type. In 7 cardiac patients who had not suffered from heart failure (table 5) the number of casts ranged from 0 to 80,000, the average being 17,792 (table 3). In 4 individuals, the range was normal (2 none, 2 high) and in 3, greater than the highest normal value. In approximately half the patients granular casts were found (table 5). The red blood cells varied between 22,250 and 428,000, the average being 162,531. In all instances the count was within the normal range. The white blood cells varied between 96,000 and 1,788,000, the average being 809,555. In each case the range was normal.

TABI

Comparison of the number of formed elements found in

Case number	Hospital number	Age and sex	State with reference to heart failure	Diagnosis*		
				Etiological	Anatomical	Ph
1	7106	40 M.	During failure (++++)† Recovered	Arteriosclerosis	Cardiac hypertrophy, mitral insufficiency, chronic myocarditis	Auricu tion
2	7054	47 M.	During failure (+++) Recovered	Arteriosclerosis	Cardiac hypertrophy, mitral insufficiency, chronic myocarditis	Auricu tion
3	7255	74 M.	During failure (+) Recovered	Arteriosclerosis	Cardiac hypertrophy	Auricu tion
4	7318	68 M.	During failure (++) Recovered	Arteriosclerosis	Cardiac hypertrophy, chronic myocarditis, VPL§	Norm C.F
5	7108	60 M.	During failure (+) Recovered	Arteriosclerosis	Chronic myocarditis	Norm C.F
6	6784	40 F.	During failure (++++) During failure (+++) During failure (++) Recovered	Hypertension, 180/130	Cardiac hypertrophy, mitral insufficiency, aortic roughening, VPL	Norm trai I-F
7	4692	58 M.	During failure (++) Recovered	Arteriosclerosis, hypertension	Cardiac hypertrophy, mitral insufficiency, chronic myocarditis	Auric tio
8	7091	34 M.	During failure (++++) Recovered	Rheumatic fever	Cardiac hypertrophy, mitral stenosis, mitral insufficiency, aortic roughening	Auric tio
9	7325	34 M.	During failure (+) Recovered	Rheumatic fever	Cardiac hypertrophy, mitral stenosis	Auric tio
10	7223	27 M.	During failure (++) Recovered	Rheumatic fever	Cardiac hypertrophy, mitral insufficiency and stenosis, aortic roughening	Auric tio
11	7311	40 M.	During failure (++++) Recovered	Rheumatic fever	Cardiac hypertrophy, mitral insufficiency and stenosis	Auric tio

* The diagnoses in this table as well as in tables 2, 4 and 5 conform to the nomenclature for cardiac dia

† The degree of heart failure is indicated by + signs in this table as well as in tables 2 and 4.

‡ In this table as well as in tabled 2 and 4, + and 0 indicate the presence or absence of the sign.

§ VPL = left ventricular preponderance in this table as well as in tables 2, 4 and 5.

C.H.F. = heart failure of the congestive type in this table as well as in tables 2, 4 and 5.

I-HB = incomplete heart block in this table as well as in tables 2, 4 and 5.

BLE 1

the urine during and after recovery from heart failure

	Signs of heart failure‡							Number of attacks of heart failure	Medication effective in relief of heart failure	Urea clearance	Phenolsulphonthalein excretion in 2 hours	Sediment test (Addis)				
												Casts			Red blood cells, number in 12 hours	White blood cells, number in 12 hours
hysiological	Edema	Hydrothorax	Rales	Cyanosis	Ascites	Liver	Dyspnea					Number in 12 hours	Hyaline	Granular		
										per cent of normal	*per cent*		*per cent*	*per cent*		
ular fibrilla-	+	+	+	+	+	+	+	1	Limitation of			0			292,500	1,023,750
n, C.H.F.§	0	0	0	0	0	0	0		fluids and rest in bed	93	74	91,400	25	75	1,050,000	2,520,000
ular fibrilla-	+	+	+	+	+	+	+	1	Digitalis	64	54	23,800	67	33	98,000	70,000
n, C.H.F.	0	0	0	0	0	0	0			55	59	65,920	67	33	3,090,000	834,000
ular fibrilla-	+	0	+	0	0	+	0	1	Digitalis			24,232	100		2,514,625	1,514,625
n, C.H.F.	0	0	0	0	0	0	0			62	36	9,240	100		165,000	577,500
al rhythm,	+	0	0	+	0	0	0	1	Limitation of			0			994,000	745,500
H.F.	0	0	0	0	0	0	0		fluids			22,110	50	50	904,500	603,000
al rhythm,	±	0	+	0	0	0	0	1	Limitation of	58	53	33,200	66	33	300,000	800,000
H.F.	0	0	0	0	0	0	0		fluids			59,400	75	25	674,000	1,215,000
al rhythm,	+	+	+	+	+	+	+	1				4,890	99	1	208,000	1,300,000
nsient	+	+	+	+	+	+	+			97	48	10,080	100		156,800	1,232,000
HB,§ C.H.F.	±	+	0	+	±	+	0		Digitalis	107	72	11,220	100		105,000	1,056,000
	0	0	0	0	0	0	0		Digitalis and theocalcin	160	62	141,600	100		480,000	2,257,500
ular fibrilla-	+	0	+	+	0	+	+	2	Digitalis	95	54	72,000	100		99,450	5,670,000
n, C.H.F.	0	0	0	0	0	+	0			77	67	16,400	100		157,000	2,201,000
ular fibrilla-	+	0	+	+	+	+	+	3	Digitalis	29		3,905	50	50	585,750	461,500
n, C.H.F.	0	0	0	0	0	0	0			32	53	19,740	100		705,000	1,938,750
ular fibrilla-	±	0	0	+	0	±	+	1	Digitalis	113	61	151,060	66	33	1,365,000	2,047,500
n, C.H.F.	0	0	0	0	0	0	0					0			630,000	1,050,000
ular fibrilla-	0	0	+	+	0	+	+	8	Digitalis			0			1,402,500	627,500
n, C.H.F.	0	0	0	0	0	0	0					12,600	100		1,462,500	1,912,500
ular fibrilla-	±	0	+	+	+	+	+	3	Digitalis			31,350	50	50	1,140,000	1,425,000
n	0	0	0	0	0	0	0					62,150	33	66	706,250	706,000

nosis recommended by the American Heart Association. Am. Heart J., 1926–27, ii, 202.

TABLE 2

The number of formed elements found in the urine during heart failure of the congestive type

Case number	Hospital number	Age and sex	State with reference to heart failure	Diagnosis			Signs of heart failure							Number of attacks of heart failure	Urea clearance	Phenolsulphonphthalein excretion in 12 hours	Sediment test (Addis)				
				Etiological	Anatomical	Physiological	Edema	Hydrothorax	Rales	Cyanosis	Ascites	Liver	Dyspnea				Casts			Red blood cells, number in 12 hours	White blood cells, number in 12 hours
																	Number in 12 hours	Hyaline	Granular		
															per cent of normal	*per cent*		*per cent*	*per cent*		
12	7078	48 F.	During failure (++++)	Arteriosclerosis, hypertension	Cardiac hypertrophy, aortic roughening	Normal rhythm, C.H.F.*	+	+	+	+	+	+	+	1			36,080	100	100	451,000	6,478,000
13	7184	68 M.	During failure (++++)	Arteriosclerosis, hypertension	Cardiac hypertrophy, chronic myocarditis	Auricular flutter, C.H.F.	+	0	0	+	+	+	+	1			144,375	90	10	393,750	656,250
14	7110	65 M.	During failure (+)	Arteriosclerosis	Cardiac hypertrophy, chronic myocarditis, VPL	Normal rhythm, APC, VPC,* C.H.F.	+	0	+	0	0	0	0	1	14	37	17,928	100		540,000	864,000
15	6911	54 F.	During failure (+++)	Arteriosclerosis, rheumatic fever	Cardiac hypertrophy, mitral insufficiency, aortic roughening, VPL	Normal rhythm, VPC, C.H.F.	+	+	+	+	+	+	+	1	69	50	280,000	100		183,750	3,675,000
16	7085	52 M.	During failure (++++)	Rheumatic fever	Cardiac hypertrophy, mitral insufficiency, mitral stenosis chronic myocarditis, VPR*	Auricular fibrillation, C.H.F.	+	+	+	+	0	+	+	1			463,740	90	10	2,478,000	17,877,000
							+	+	+	+	0	+	+				58,400	66	33	2,646,000	12,592,000
17	7323	27 M.	During failure (+++)	Rheumatic fever	Cardiac hypertrophy, mitral stenosis and insufficiency, cardiac dilatation	Auricular fibrillation, C.H.F.	+	0	+	+	+	+	+	9			0			1,402,500	627,500
18	7222	36 M.	During failure (++++)	Syphilis	Cardiac hypertrophy, aortic insufficiency	Normal rhythm, C.H.F.	+	+	+	+	+	+	+	1	70	89	29,925		100	72,210	4,132,250

* C.H.F. = heart failure of the congestive type
VPR = right ventricular preponderance
APC = auricular premature contractions
VPC = ventricular premature contractions
} in this table as well as in table 4.

TABLE 3

Summary of the numbers of formed elements found in the urine of cardiac patients

Type	Number of patients	Formed elements	Lowest number	Highest number	Average number	Distribution of patients
Patients who had not suffered from cardiac failure	7	Casts	0	80,000	17,792	4* N† (2 = 0†, 2 H†); 3 >‡ N
		Red blood cells	22,250	428,000	162,531	7 N (2 A,† 5 H)
		White blood cells	96,000	1,788,000	809,555	7 N (2 A, 5 H)
Patients after recovery from heart failure	16	Casts	0	141,600	34,600	4 N (4 = 0); 12 > N
		Red blood cells	165,000	3,090,000	917,515	4 N (4 H); 12 > N
		White blood cells	304,000	2,520,000	1,151,187	13 N (2 A, 11 H); 3 > N
Patients during heart failure	18	Casts	0	463,740	66,485	6 N (4 = 0, 2 H); 12 > N
		Red blood cells	72,210	3,090,000	834,754	9 N (1 A, 8 H); 9 > N
		White blood cells	70,000	17,877,000	3,089,302	13 N (1 A, 12 H); 5 > N

* Refers to number of patients.

† N = normal, A = average, H = highest normal, 0 none.

‡ > N = greater than normal.

TABLE 4

Urinary sediment of patients after recovery from heart failure of the congestive type

Case number	Hospital number	Age and sex	State with reference to heart failure	Diagnosis			Signs of heart failure							Number of attacks of heart failure	Medication effective in relief of heart failure	Urea clearance	Phenolsulphonphthalein excretion in 2 hours	Sediment test (Addis)				
				Etiological	Anatomical	Physiological	Edema	Hydrothorax	Râles	Cyanosis	Ascites	Liver	Dyspnea					Casts			Red blood cells, number in 12 hours	White blood cells, number in 12 hours
																		Number in 12 hours	Hyaline	Granular		
																per cent of normal	*per cent*		*per cent*	*per cent*		
19	7102	65 M.	During failure (++++) Recovered	Arterio-sclerosis	Cardiac hypertrophy, chronic myocarditis	Auricular fibrillation, C.H.F.	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	1	Digitalis	62	64	19,600	100		175,000	525,000
20	7234	58 M.	During failure (++++) Recovered	Arterio-sclerosis	Cardiac hypertrophy, chronic myocarditis, VPL	Normal rhythm, Rt.-I-V-HB.,* C.H.F.	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	1	Digitalis	71	52	0			540,000	810,000
21	7309	66 M.	During failure (++++) Recovered	Arterio-sclerosis	Cardiac hypertrophy, chronic myocarditis, VPR	Auricular fibrillation, C.H.F.	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	+ 0	1	Digitalis	70	64	33,440	50	50	912,000	304,000
22	7337	63 M.	During failure (+) Recovered	Arterio-sclerosis, hypertension	Cardiac hypertrophy, aneurysm of descending aorta, VPL	Normal rhythm, C.H.F.	+ 0	0 0	+ 0	+ 0	0 0	0 0	+ 0	1	Without medication	90	44	0			1,505,000	645,000
23	7266	26 M.	During failure (+++) Recovered	Rheumatic fever	Cardiac hypertrophy, mitral stenosis, mitral insufficiency, aortic insufficiency	Normal rhythm, C.H.F.	+ 0	0 0	+ 0	+ 0	+ 0	+ 0	+ 0	1	Without medication			0			1,650,000	330,000

* Rt. I-V-IHB = right intraventricular heart block.

TABLE 5

The urinary sediment of cardiac patients who have not suffered from heart failure of the congestive type

Case number	Hospital number	Age and sex	State with reference to heart failure	Diagnosis			Urea clearance	Phenolsulphonphthalein excretion in 2 hours	Sediment test (Addis)				
				Etiological	Anatomical	Physiological			Casts			Red blood cells, number in 12 hours	White blood cells, number in 12 hours
									Number in 12 hours	Hyaline	Granular		
							per cent of normal	*per cent*		*per cent*	*per cent*		
24	7074	67 M.	Compensated	Arterio-sclerosis	Cardiac hypertrophy, mitral insufficiency, VPL	Normal rhythm, anginal syndrome			33,600	67	33	229,500	1,377,000
25	7067	71 M.	Compensated	Arterio-sclerosis	Cardiac hypertrophy	Normal rhythm	48	38	4,895	100		22,250	912,250
26	7180	65 M.	Compensated	Arterio-sclerosis	Cardiac hypertrophy, chronic myocarditis	Normal rhythm, anginal syndrome	15	50	0			123,750	247,500
27	H. H.*	54 M.	Compensated	Arterio-sclerosis	Slight cardiac hypertrophy	Normal rhythm, anginal syndrome	64	62	0			337,500	1,181,250
28	E. H.*	45 M.	Compensated	Hypertension	Cardiac hypertrophy	Normal rhythm	137	36	6,100	100		119,000	1,788,000
			1 year later	Hypertension	Cardiac hypertrophy	Normal rhythm	56	47	4,708	75	25	428,000	642,000
29	6323	52 M.	Compensated	Hypertension	Cardiac hypertrophy, VPL	Normal rhythm	82	61	80,000	8	92	24,000	96,000
30	7128	45 M.	Compensated	Hypertension	Cardiac hypertrophy	Normal rhythm	47	61	13,032		100	116,250	232,500

* Out-patient.

In such patients the number of casts was therefore increased, the average being 20 times that in normal subjects; the increase was not so great, however, as in cases of heart failure of the congestive type. The red cell and white cell counts were, however, definitely less; the average numbers though twice as great as in normal individuals were, nevertheless, within normal limits.

Urinary sediment and renal function. Renal function was studied in certain patients by means of the urea clearance test (3) and the excretion of phenolsulphonphthalein, but no relationship was observed between the degree of renal impairment and the number of casts, and red and white blood cells passed in 12 hours (tables 1, 2, 4 and 5).

DISCUSSION

In cardiac patients who exhibited *no signs of heart failure* Stewart and McIntosh (4) found that renal function measured by the Van Slyke index of urea excretion (5) and phenolsulphonphthalein excretion was usually normal, without reference to whether they had previously suffered attacks of congestive heart failure. Although normal in these respects, diminution of function was detected, nevertheless, in these individuals by means of the concentration and dilution tests (4); their kidneys could not in many instances excrete urine of high or of low specific gravity. This impairment was most frequent after attacks of heart failure of the congestive type. It is of course well known that decrease in renal function as measured by the urea index and phenolsulphonphthalein excretion is frequently observed during heart failure of the congestive variety and that return toward normal takes place as the signs of failure disappear (6). This is commonly attributed to congestion of the kidneys. No studies have yet been published of the number of formed elements in the urine of such patients. Increase in albumin in the urine and presence of casts, red blood cells and white blood cells in heart failure are, as abnormality in the case of chemical tests, commonly attributed to congestion. The actual numbers we have now counted. The cases studied are too few for statistical treatment, but the degrees of heart failure encountered were sufficient, we think, to suggest the limits within which the numbers may be expected to fall.

The most consistent finding was increase in the number of casts, the

average being 20 to 60 times greater than normal, depending on the severity of the disease. The number was smallest when failure of the congestive type had not occurred, somewhat greater when it had, though at the moment no signs were present, and greater still when they were. Granular casts which Addis (2) did not find in the urines of normal individuals were found in approximately half the cases.

During heart failure and after recovery increased numbers of red and white blood cells occur but almost as frequently they are within the normal range. When heart failure has not taken place red and white blood cells are within normal range, although the averages are approximately twice those of normal individuals. But in patients who have experienced heart failure the numbers are 10 to 15 times greater than normal. In Addis's (2) opinion it is only the appearance of a

TABLE 6

Comparison of average numbers of casts, red blood cells and white blood cells found in the urine in different states of heart disease

Casts.....	No attacks of heart failure < Recovered from failure < During failure
Red blood cells.....	No attacks of heart failure < Recovered from failure = During failure
White blood cells.....	No attacks of heart failure < Recovered from failure < During failure

million or more red cells that can be regarded as significant. We could find no association, however, between the number of formed elements and the number of attacks of heart failure, nor between the degree of impairment of renal function (the urea clearance test and the phenol-sulphonphthalein excretion) and the number of formed elements in the urine. Etiology, so far as we could see, played no rôle, though the series is small to adopt an opinion on this point. Renal failure casts (Addis (7)) were not observed. On the whole it is surprising that the number of casts, red blood cells and white blood cells in the urines of cardiac patients is so small and that it is so little increased during cardiac decompensation (table 6), that there is, in short, so little alteration in function.

We wish to emphasize a point already made by Addis (2), namely

that the numbers of casts, red blood cells and white blood cells have no *individual significance.* In these cases furthermore the numbers of formed elements counted were small; they serve only to define the order of magnitude and to establish the limits or range of variation. It is only when they are large, as in Bright's disease, that the absolute numbers are significant. It is of course for this reason that the comparison between the stages of absence and presence of heart failure in the same patient sometimes shows decrease and sometimes increase; in this sense alone greater numbers of casts and white blood cells are found in the presence of heart failure, though the number of red blood cells is approximately the same.

SUMMARY

1. The number of *casts* found in 12 hours is usually increased in patients suffering from cardiac disease, although the number may be normal. If the average numbers are considered, the greatest numbers were passed by those patients suffering from heart failure of the congestive type; the numbers were fewer after recovery and fewer still in those who had never suffered from this illness. Granular casts were frequently found.

2. The number of *red blood cells* in the urine of patients who had experienced cardiac decompensation was frequently greater than the highest normal value, but within the limits in those who had never suffered from heart failure. The average number of red blood cells found in those cases which had never experienced heart failure was twice as great as that in normal individuals; in those who were suffering from heart failure or had recovered from it, however, the average number was 10 to 15 times as great as in normal individuals.

3. The number of *white blood cells* was normal in the urine of those patients who had not suffered from heart failure, but the average number was approximately twice the average observed in normal individuals. The number was usually within the normal range both during and after recovery from cardiac decompensation; the average number, however, was greater approximately 9 and 3 times respectively than that in normal individuals, the average being less in patients without heart failure than in those who had recently recovered from it and less than in those who were still suffering.

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