

THE EXTRACELLULAR FLUID IN CONGESTIVE HEART FAILURE

by

P. Nagpal

Defence Science Laboratory, Delhi

ABSTRACT

The influence of cardiac failure and the establishment of compensation on the volume of extracellular fluid has been determined in a variety of heart diseases known to be associated with salt and water retention. Significant elevation above normal values were found in all groups. It is concluded that congestive heart failure even after apparent recovery causes considerable elevation of extra-cellular fluid.

Introduction

It has been a consistent finding reported from time to time that the values for the extracellular fluid (E.C.F.) are considerably elevated in congestive heart failure (C.H.F.) even though no oedema may be evident clinically. It has been postulated that as much as 6 litres of fluid can be accommodated in the extracellular space before the dependant pitting oedema of heart failure makes its appearance¹. However, very little data is available regarding the magnitude of the E.C.F. in cases showing clinical improvement and recovery with the disappearance of oedema after an authentic attack of congestive heart failure.

The object of this paper is to report a study of the fluid metabolism and the character of the indicator dilution curves in patients with cardiac failure and systemic venous congestion.

ABBREVIATIONS USED

C.H.F.	..	..	Congestive heart failure.
Conc.	..	..	Concentration.
E.C.F.	..	..	Extra Cellular Fluid.
H/O.	..	..	History of.
NaSCN	..	..	Sodium Thiocyanate.
I.V.	..	..	Intra Venous.
S.G.	..	..	Specific gravity.
R.B.C.	..	..	Red blood cells.

Material and methods

Eleven patients recovering from CHF resulting from various underlying causes have been studied. This group of patients has been statistically compared to a group of 5 normal subjects; a group of 2 patients during cardiac failure and a group of 2 cardiac cases without history of decompensation to serve as controls.

The method employed for the determination of E.C.F. being the indicator-dilution method using sodium thiocyanate as the indicator substance². The age and sex distribution of the cases studied is shown in Table I.

TABLE I—*Age-Sex distribution of the cases studied with respect to Etiology*

ETIOLOGY	SEX		AGE				TOTAL
	Males	Fe- males	21—30 years	31—40 years	41—50 years	51—60 years	
Rheumatic	4	1	2	2	0	1	5
Emphysema	1	2	0	2	1	0	3
Hypertensive	1	2	1	1	0	1	3
Syphilitic	2	0	1	0	1	0	2
Pericarditis & Misc. ..	2	0	0	1	1	0	2
Total	10	5	4	6	3	2	15

The standard optical density curve is shown in Fig. 1. In order to obviate the necessity of determination of the thiocyanate lost in urine the semilog extrapolation method of Hamilton and co-workers³ was employed. Certain assumptions have to be made when the above method is adopted viz.

- the cardiac output is constant during the recording of the dilution curve.
- the flow past the sampling site is a constant fraction of the cardiac output at any given time.
- at some point between the injection and the sampling site complete mixing takes place in the vascular system.

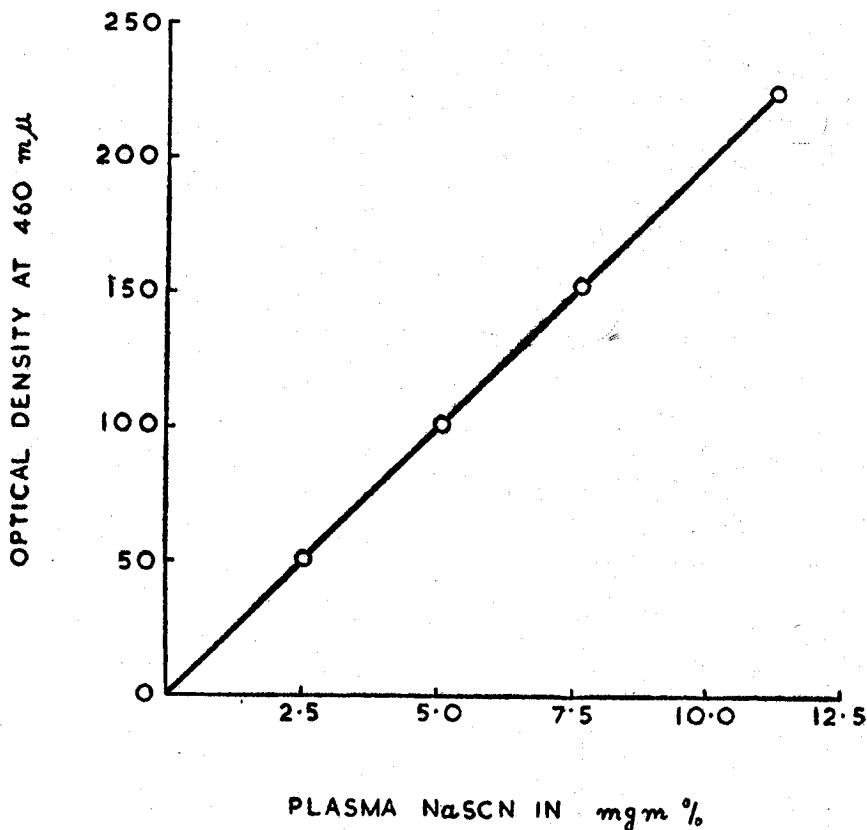


FIG. 1—Standard Optical Density Curve

A couple of indicator dilution curves are shown. (Fig. 2ab) Magnified semi-log paper was used in order to obtain accurate Plasma thiocyanate concentration at zero hour. (Fig. 3.)

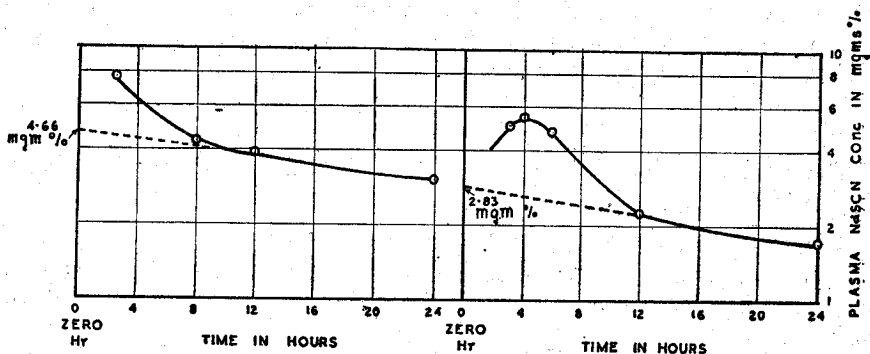


FIG. 2 (a)—Indicator Dilution Curve (case studied after recovery from CHF)

FIG. 2 (b)—Indicator Dilution Curve (case studied during CHF)

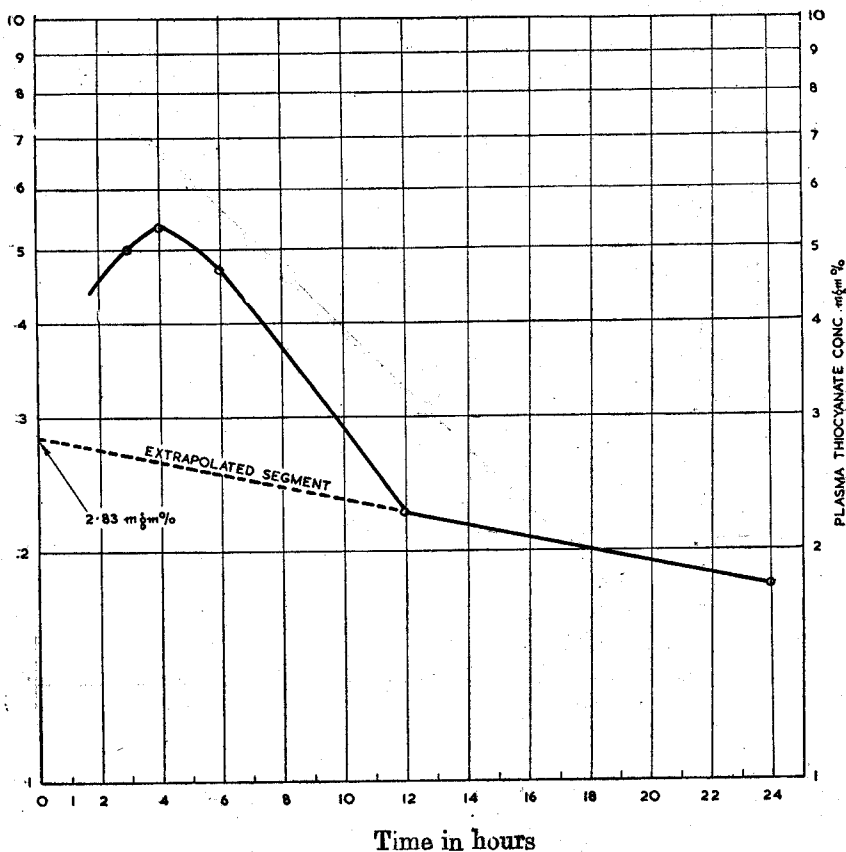


FIG. 3—Indicator Dilution Curve. [FIG. 2 (b) reproduced on (Magnified semilog paper)]

No corrections are essential for the thiocyanate entering R. B. C. but the S. G. of plasma was determined individually for each case by the copper sulphate method⁴ to enable accurate conversion of the absolute values of E.C.F. into percentage of body weight.

Result

The results obtained in the various groups studied have been presented in Table II (a), (b) & (c).

An abnormally elevated E.C.F. value is obtained in the group of cases studied before relief of failure; the highest value recorded being 39.72 per cent of the total body weight. Unusually high values are also obtained in cases recovering from hypertensive heart failure; the highest value recorded in this group being 36.67%. [Table 2 (a), (b) & (c)]. Though both absolute values for E.C.F. and the E.C.F. expressed as a percentage of body weight show considerable elevation above the normal values the latter figures show greater correlation.

TABLE 2(a)—Presentation of data in Recovered (Group A) Cases

Serial No Date	Name Age Sex	S.G. plasma	E.C.F. in Litres	Oedema	E.C.F. As % age of B.W.	Remarks
(1) 3-8-60	B. R. 32 years M	1026	11.40	Nil	32.99	
(2) 13-9-60	N. S. 60 years M	1026	14.86	Nil	33.89	
(3) 22-9-60	C. R. 50 years M	1026	13.33	Nil	32.38	
(4) 17-10-60	B. D. 35 years M	1025	12.71	Nil	32.57	
(5) 24-10-60	K 25 years F	1025	12.50	Nil	36.67	*Hypertensive patient B. P. 220/110 B. P. not responding well to any form of therapy instituted so far.
(6) 27-10-60	K 40 years M	1023	14.89	Nil	31.90	
(7) 31-10-60	D. D. 50 years F	1025	16.67	slight	35.79	*Oedema was very slight. The pt. could not be placed in the next group.
(8) 14-11-60	P 30 years F	1025	13.37	Nil	34.32	*Hypertensive patient B.P. 180/105.

Serial No Date	Name Age Sex	S.G. plasma	E.C.F. in Litres	Oedema	E.C.F. As % age of B.W.	Remarks
(9) 18-11-60	K. D. 36 years F	1025	13.04	Nil	32.68	
(10) 25-11-60	M. S. 45 years M	1025	12.25	Nil	29.07	
(11) 28-11-60	H. P. 30 years F	1026	9.09	Nil	30.19	*This case gave no H/o oedema during the entire course of the disease.

For Group A: Mean=32.95%

7.60% Standard Deviation

TABLE 2 (b)—Presentation of data in cases during failure Group B

Serial No Date	Name Age Sex	S.G. of Plasma	E.C.F. in litres	Oedema	E.C.F. As % age of B.W.	Remarks
(1) 19-9-60	G. R. 60 years M	1026	22.44	+	39.72	This group comprises the cases studied during congestive failure. Oedema in both cases involved the feet and ankles but did not extend beyond the knees.
(2) 10-11-60	S. L. 40 years M	1024	18.18	+	38.64	Diet: salt free for both cases.

For Group B : Mean=39.18%

TABLE 2 (c)—Presentation of data in the control Group (Group C)

Serial No Date	Name Age Sex	S.G. of Plasma	E.C.F. in Litres	Oedema	E.C.F. as % age of B.W.	Remarks
(1) 22-8-60	S. P. 27 years M	1026	15.58	—	29.58	This group comprises the cases with an obvious cardiac lesion but in full compensation. There was no H/o decompensation earlier. Dietary intake of water and salt normal.
(2) 1-9-60	J. R. 22 years M	1026	11.00	—	30.28	

For Group C : Mean=29.93%

The figures obtained for the elevation of E.C.F. values above normal may be considered as somewhat less than actual as it is likely that in some cases therapy directed against the etiological factor and symptomatic treatment tended to cause a reduction of the E.C.F. Volume, *viz.*, salt free diet and bi-weekly Parenteral mercurial diuretics were being administered to almost every case recovering from C.H.F.

Obviously :—

The Mean Elevation of E.C.F. above Normal for group A is 6.95%
 „ „ „ for group B is 13.18%
 „ „ „ for group C is 3.93%

The values obtained in the group of 5 normal subjects which was comprised mostly by laboratory technicians and student volunteers fell in the range of 25.02 per cent to 26.98 per cent.

Values up to 27 per cent of the body weight can be regarded as normal. Mean Normal being 26.00 per cent of body weight.

Discussion

The question arises why the E.C.F. should remain elevated after establishment of compensation. Speculating on the cause a number of suggestions have been put forward from time to time.

1. It has been suggested that tissue necrosis as a result of passive congestion results in considerable impairment of kidney function⁵ and failure of the circulatory kinetics to return to normal, may cause the E.C.F. values to persist at abnormally elevated levels for as long as 4 months after apparent recovery⁶.

2. In contrast to the above hypothesis it has been shown by Yates et al⁷ that derangements of Na^+ , Chloride and water metabolism manifested in part by an increased E.C.F. volume is frequently associated with congestive heart failure and other clinical states involving passive venous congestion of the liver. At least in the dog, water and NaCl retention can occur in the presence of normal glomerular filtration rates of these plasma constituents.
3. Although water retention in congestive heart failure may in part be caused by ADH, oedema and ascites can occur with a deficiency of this hormone. Therefore it has been suggested⁷ that Na^+ retaining corticoids are responsible for a sustained augmentation of tubular reabsorption of these electrolytes and water in C.H.F. and that ADH and the medullary hormones and the glucocorticoids of the adrenal cortex are not primarily involved. This hypothesis has been supported by the increased urinary excretion of aldosterone or closely allied substances in some patients⁸. It has also been possible to produce a chronic expansion of the E.C.F. by repeated administration of the sodium retaining adrenal steroids⁹.

The result of these studies has led to the conclusion that in syndromes characterised by passive venous congestion of the liver, the rate of hepatic inactivation of the adrenal cortical hormones may be severely diminished and the physiologic effects of these secretions considerably enhanced. This metabolic defect may be in part responsible for the secondary aldosteronism associated with C.H.F.

Evidently, to support the above concept, *in vitro* studies of the enzymatic reduction of the several adrenal steroids including aldosterone should be available. Data regarding this subject is too scanty—a few figures only being available¹⁰.

Besides, at present there is no evidence that renal handling of aldosterone is altered in C.H.F. and allied states causing passive venous congestion of the liver.

Although in the present study the E.C.F. has been correlated with heart disease with venous congestion the possibility that hyper volemia of the E.C.F. may be just incidental to heart disease, cannot be altogether ignored. Further studies to establish the influence of cardiovascular lesions on the volume and distribution of body fluids are in progress.

The data thus supports the concept that cardiac failure causes long term impairment of hepatorenal function and disturbance of vascular dynamics in general, including salt and water metabolism; in spite of the institution of early adequate therapy. Possibly the duration of the state of passive venous congestion determines the extent of final irrecoverable damage¹⁰. The study of chronic residual haemodynamics on patients recovering from C.H.F. has been well done by Selzer et al¹¹.

Summary

In the present study the influence of cardiac failure and the establishment of compensation on the volume of E.C.F. has been determined in a variety of heart diseases known to be associated with salt and water retention. Significant elevation above normal values were found in all groups *viz.*

% Elevation of E.C.F. in terms of body weight:—

Group A.	Cases recovering from C.H.F.	6.95%
Group B.	Cases during Decompensation	13.18%
Group C.	Cases with no history of Decompensation	3.93%

It is concluded that C.H.F. even after apparent recovery causes considerable elevation of E.C.F. Heart disease *per se* being partly responsible for the elevation as suggested by the results obtained in the control group C.

Acknowledgement

Thanks are due to Dr. H. P. Vaishnava, Dr. P.C. Dhanda and Col. B. L. Taneja of Irwin Hospital for permission to study their patients. Thanks are also due to the Junior Staff Members of the Hospital for their co-operation and help.

Thanks are also due to Dr. V. Dutt Mullick and Dr. O. P. Bagga of Lady Hardinge Medical College for permission to carry out the Biochemical procedures under their guidance.

Thanks are also due to Teddington Chemical Factory for their generous supplies of sterile ampoules of Sodium thiocyanate.

Thanks are due to Dr. D. S. Kothari for permitting me to carry out the investigation at the above institutions.

References

1. Micks, R. H., *Essentials of Material Medica*, Pharmacology and Therapeutics, Churchill, 6th Ed. 1954.
2. Visschner, M.B., *Methods in Medical Research*, Vol. 4, 1951.
3. Hamilton, W.F. et al., *Amer. J. Physiol.*, **84**, 338, 1928.
4. Gopalan, C. et al., *Met. II*, **4**, 335, 1953.
5. McGinnis, A.E. et al., *Am. J. Med. Sc.*, **225**, 599, 1953.
6. Pincus, G., *Lourention Hormone Congress*, No. VIII, Academic Press Inc., New York, 1950.
7. Yates, F.E. et al., *Amer. J. Physiol.*, **194**, 57, 1958.
8. Davis, J.O. et al., *Circulation Research*, **3**, 252, 1955.
9. Relman, A.S. et al., *Yale. J. Biol. and Med.*, **24**, 540, 1952.
10. Yates, F.E. et al., *Amer. J. Physiol.*, **194**, 65, 1958.
11. Selzer, A. et al., *Am. J. Med.*, **28**, 337, 1960.