DYNAMIC ANALYSIS OF THE INFLUENCE OF REANIMATION TREATMENT IN BURNED PATIENTS.

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ABSTRACT

A non-lineal mathematical model of capillary dynamic has been constructed to study the reanimation stage and the effect that different treatments have on burn patients.

This analysis allows a qualitative and quantitative knowledge of the dynamic behaviour of variables very difficult to quantify in daily practice, like plasma volume, net liquid shift in burned and non-burned areas, etc.

The value and fidelity of the model was obtained by comparison of the reckoned results with those measured in a serie of patients of the Burn Unit of a General Hospital.

INTRODUCTION

It is known that burn injury causes an alteration that consists in an increment of protein and liquid shifts from plasma to interstitial compartment. If the shifts are important, characteristic in burns of considerable extension, a shock by decrease of plasma volume appears, Artuson (1979a, 1984b).

The protein shifts, related to burn surface area (BSA), decrease the plasma oncotic pressure, and oedema develops in non-burned areas by increment of liquid shifts. Commonly, the protein shifts have been related with the molecular weight, in the way that those of less diameter would have more facility to extravasation (Carvajal 1979a, 1980b).

The greatest change occurs in the three first hours after injury and return with time to initial values.

We present a mathematical model of capillary permeability to make a dynamic analysis of initial reanimation and of the influence that protein and liquid administration have in burn patients, with special emphasis in dynamic behaviour of the variable plasma oncotic pressure. The results obtained by simulation are compared with those measured in a series of burn patients.

MATERIAL & METHODS

Construction of the model.

The methodology followed in model construction has been the dynamic system approach, Forrester (1968), and three consecutive stages have been developed:

1) Construction of a model of capillary dynamic in normal conditions for a mean person.

The extracellular space considered has been divided in two compartments, plasma and interstitium. The simplified causal diagram, where the relations between the variables that take place in liquid exchange at capillary level are defined, is shown in Figure 1. The equations of state variables, which define the mathematical model, are based on the assumptions considered in the majority of macroscopic hemodinamic studies, Leonard (1973), Abbrecht (1980) and Roa (1982):

$$dPV/dt = Qf - Que - Qs + Qreab + Qlimph \quad (1)$$

$$dIV/dt = Qs - Qreab - Qee - Qlimph \quad (2)$$

$$dPP/dt = Jf - Js + Jlimph \quad (3)$$

$$dIP/dt = Js - Jlimph \quad (4)$$

Where PV = plasma volume, IV = interstitial volume, PP =plasma proteins, IP = interstitial proteins, Q = liquid flows, J = protein-flows, (f = intravenous fusion, ue = urine eliminated, s = shifts, reab = reabsortion, limph = flow by limph, ee= eliminated by evaporation).

The different behaviours of the model are obtained acting over the control variables: intravenous fusion of liquids and proteins and diuresis.

The validity of the model has been contrasted by comparison of the obtained results with the measured by different authors Guyton (1971).

The sensitivity of the model has been analysed by the sucessive passages and the Montecarlo methods, verifying how the behaviour depends on the structure of the model, independently of the values of the initial conditions and parameters; meanwhile these remain in phisyological limits.

2) Burn injury adaptation for different person.

From weight and height values of the patient, the initial conditions are obtained in Topley and Jackson Tables (1962). In this stage two zones are planed in the model: burned and non-burned areas. The burn surface area (BSA), obtained in Lund and Browder (1944) Charts, is added to control variables.

3) Simulation of treatments.

Knowing the alterations of burn injury, a factor to be taken into account in the initial stage of treatment is the quantity and quality of protein administration. In this way, to calculate the plasma oncotic pressure in function of every plasma protein fraction we propose the following equations:

$$POPf = a + b * PPTf + c * PPTf^2 + d * PPTf^3 \qquad (5)$$

$$POP_T = \sum_{i=1}^{i=5} POPf$$

Where POPf = plasma oncotic pressure of a protein fraction, PPTf = plasma protein fraction in plasma, POP_T =plasma oncotic pressure; a,b,c and d are the adequated coefficients for every fraction (Table I).

Clinical Study

A series of patients has been studied with burns comprised between 15 and 95 % of BSA. As part of the usual diagnostic and control procedures in this type of patients were determined frequently, during the first hours after the burn injury, the hematocrit value, plasma protein concentration, intravenous fusion of liquids and proteins and diuresis, among other parameters. Moreover, the evolution of the weight of the patients was registered continously by means of a bed scale.

RESULTS

In constrast of the validity and utility of the mathematical model we present the results obtained in a patient, that were verified in the ramainder cases.

In Figure 2 the variations, during the 15 hours after burn, of the values of hematocrit, as measured and as obtained by simulation, are represented, showing that the behaviour of this variable, that defines the proportion between red blood cells and plasma, is characterized by an increment, expression of liquid shifts after burn injury.

In Figure 3, the behaviour of variable plasma protein concentration, as measured and as simulated, shows a decrease, meanwhile the hemoconcentration, indicative of protein shifts from plasma to interstitium.

In Figure 4 the evolution of variables increment of patient's weight and variation of calculated extra cellular volume are represented. The evolution is consistent with the oedema that this patient experimented.

The dynamic behaviour of variables like plasma volume, plasma oncotic pressure, liquid shifts from plasma to interstitial compartment in burned and non-injuried area, all of them very difficult to quantify in daily practice, are represented in

Figure 5.

CONCLUSIONS

The mathematical model, that we present, provides a vision from a macroscopic and global point of view of the dynamic capillary alterations in burned patients. It permits a qualitative and quantitative knowledge of the dinamic behaviour of variables very difficult to quantify in daily practice that are very indicatives of the real situation of the rehydratation of the patient.

It emphasises the dynamic behaviour of the system in front of the different intravenous fusion of liquids and proteins, that can be of significant importance in the reanimation treatment of these patients.

The results obtained agree with the consulted references and integrate in an homogenous block the conclusions of different authors on this subject.

The described mathematical model permits to study a priori what will be the behaviour of the real system, the patient, in front of a treatment and what would be the result if it were modified.

One advantage which must be emphasized is its accessibility to people not expert in computer sciences.

ACKNOWLEDGEMENTS

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REFERENCES

Abbrecht, P.H. (1980) Regulation of extracellular fluid volume and osmolality. Ann. Biomed. Engineer. 8:461-480.

Arturson, G. and Lousson, C.E. (1979a). Transcapillary transport after thermal injury. Scand. J.Plast. Reconstr. Surg., 13: 29-36.

Arturson, G., Groth, A., Hedlund, A. and Zaar, B. (1984b). Potential use of computer simulation in treatment of burns with special regard to oedema formation. Scand. J. Plast. Reconstr. Surg., 18: 39-47

Carvajal, H.F., Linares, H.A. and Brouhard, B.H. (1979a). Relationship of burn size to vascular permeability changes in rats. Surg. Gynecol. Obstet. 149: 193-198.

Carvajal, H.F. and Linares, H.A. (1980b). Effect of burn depth upon oedema formation and albumin extravasation in rats. Burns, 7: 79-83.

Forrester, J.W. (1968). Principles of systems, Wringht-Allen Press.

Guyton, A.C., Granger, H.J. and Coleman, T.F. (1971). Auto-regulation of the total sytemic circulation and its relation to control of cardiac output and arterial pressure. Circul. Res., 29/1: 93-97.

Leonard, J.I. and Abbrecht, P.H. (1973). Dinamics of plasma-interstitial fluid distribution following intravenous fusion in dogs. Experimental and Computer simulation study. Circul. Res., 33: 735-748.

Lund, C. and Browder, N. (1944). The estimation of areas of burns. Surg. Gynecol.& Obst., 79: 352-359.

Topley, E., Jackson, D., Mac, G. and Cason, J.S. (1962). Assesment of red cell lossin the first two days after burns. Ann. Surg., 155: 581-586.

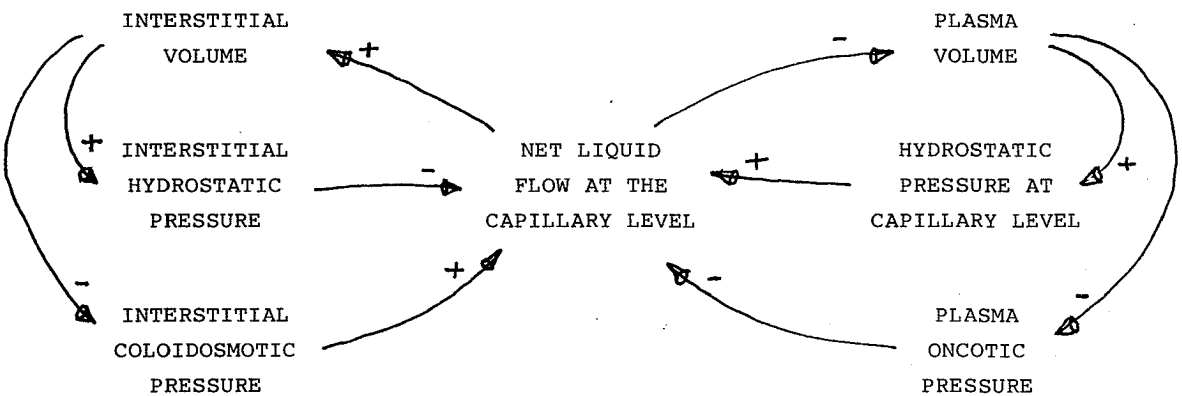

Fig. 1: Simplified causal diagram of liquid exchange at the capillary level.

TABLE I: Coeficients of equation (5) to calculate the plasma oncotic pressure of a protein fraction (Pf)

Pf	a	b	c	d
α_1	.1166378	2.538474	1.124984	-3.018779E-02
α_2	-8.407558E-03	1.20017	9.419518E-02	8.718739E-03
β	9.488872E-03	.6527875	.1246588	-1.485755E-03
γ	4.562615E-02	.1889091	.1967993	-6.295053E-03
Alb.	-2.924623E-02	2.271142	.1336642	1.512775E-02

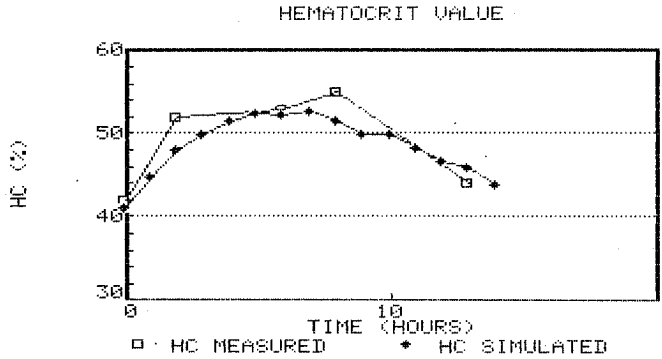

Fig. 2: Dynamic behaviour of variable hematocrit value.

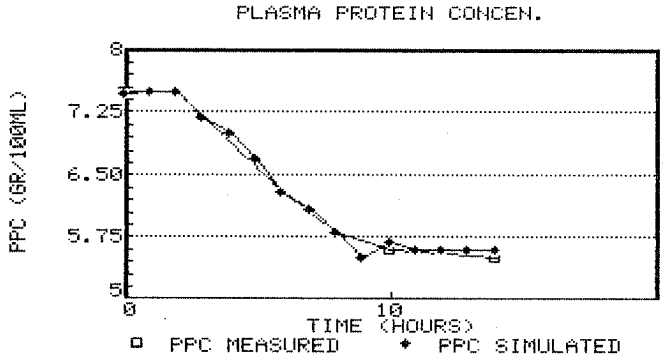

Fig. 3: Dynamic behaviour of variable plasma protein concentration.

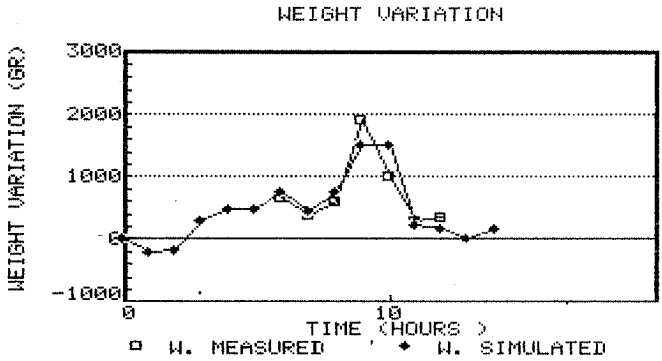

Fig. 4: Dynamic behaviour of weight variation.

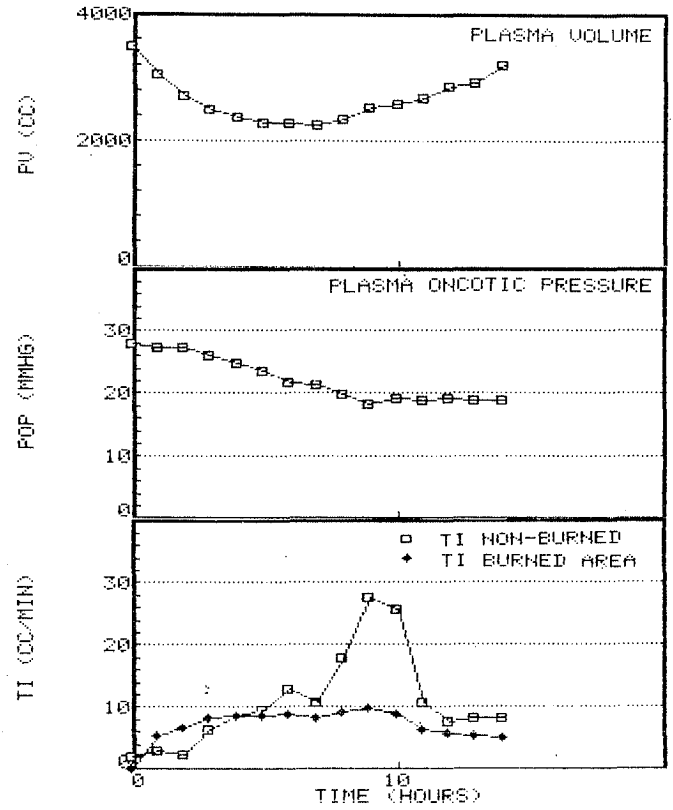

Fig. 5: Variables obtained by simulation.