P15

~~LIST OF PROCEDURES DONE~~

PROJECT REPORT

TITLE OF THE PROJECT:

QUANTIFICATION OF LEFT ATRIAL PRESSURE RECORDINGS USING AN INTRA-ESOPHAGEAL BALLOON - AN EXPERIMENTAL MODEL

NAME: K. SURESH

PROGRAMME: DM - CARDIOLOGY

MONTH & YEAR OF SUBMISSION: FEBRUARY 1985

Note:— (i) In the case compilation of procedures done, the contents and the subsequent pages should be made into different sections (a) Procedures done (b) Procedures assisted (c) Procedures participated (d) Procedures attended/participated etc in Other Centres. Each section should be preceded by a leaf carrying the name of the section that is succeeding.

(ii) The Contents page will carry into. as per model given under

PROCEDURES DONE

Closed Mitral valvotomy................................124 (say)
Patent ductus arteriosus-ligation................................10
Atrial septal defects..................................20
....
....

PROCEDURES ASSISTED

Closed Mitral valvotomy................................100 (say)
....

(iii) In the subsequent pages details of each procedure done/assisted should be given in the format given below:—

Heading: **Closed mitral valvotomy**

Date	Name of the patient	Age	Sex	Patient No.

(iv) In the case of Project Report in the page immediately following the Certificate page the under-mentioned details should be given:—

(a) Title
(b) Duration
(c) Aim and scope
(d) 50 word summary of work done

CERTIFICATE

I, Dr. K. SURESH hereby declare that I have actually performed ~~all the procedures listed/carried out~~ the project under report.

Signature K Suresh

Place: Trivandrum

Date: 5.2.1985

Name in capital letters K. SURESH

Recommended + Forwarded

[signature] 9/2/85

TITLE : QUANTIFICATION OF LEFT ATRIAL PRESSURE RECORDINGS USING AN INTRA-ESOPHAGEAL BALLOON - AN EXPERIMENTAL MODEL

DURATION TWO MONTHS

AIM, SCOPE THE AIM OF THE STUDY WAS TO FIND OUT WHETHER LEFT ATRIAL PRESSURES COULD BE RECORDED FROM THE ESOPHAGUS WITH ACCURACY, AND IF SO, WHETHER SUCH RECORDINGS CAN, IN CLINICAL PRACTICE BE USED AS A NONINVASIVE TECHNIQUE FOR LEFT ATRIAL PRESSURE MEASUREMENT

ABSTRACT AN EXPERIMENTAL SET UP WAS DEVISED TO ANALYSE THE CHARACTERESTICS OF PRESSURE WAVE TRANSMISSION BETWEEN ADJACENT INERFACES OF TWO CHAMBERS. IT WAS FOUND THAT CHANGES IN PRESSURE IN ONE CHAMBER WAS TRANSMITTED LINEARLY TO THE OTHER CHAMBER IN SPITE OF THE DIFFERENCES IN CHAMBER VOLUMES. THE PHYSICAL PRINCIPLES OF THIS MODEL AND THEIR UTILITY IN CLINICAL PRACTICE ARE DISCUSSED.

CONTENTS

Left atrial pressure measurements are of vital importance in the diagnosis and management of various cardiac conditions. Non-invasive assessment of left atrial hemodynamics lost a great deal of its significance with the advent of the superior and technologically more sophisticated invasive cardiac diagnostic procedures. However, the former has distinct advantages in its non-invasiveness, wide applicability, fair reliability and the ease with which it can be repeated.

Cardiac synchronous pulsations were recorded from the esophagus as early as 1877 by Luciani. Rosenthal (1886) and Kronecker (1883) during esophagoscopy observed esophageal pulsations and commented on its spatial and temporal relation to left atrial pulsations. Fredericq in 1887 recorded these pulsations in dogs and five years later Sarolea, a pupil of Fredericq made the first recording in man. Lasser (1952) demonstrated the excellent correlation between what he termed the 'esophageal piezocardiogram' and the directly recorded left atrial pressure wave pattern under varying conditions and experimentally produced valvar lesions. The term esophageal piezo cardiogram implies that the recording was made in the esophagus, it related to pressure events ('piezo') and that the origin was in the left atrial pulsations (cardiac). Over the subsequent decade several articles dealing with this procedure were published in literature.

Most of these early attempts, however were aimed at only a faithful reproduction of the left atrial pulse wave configuration. No stress was made on the quantitative relation between the pulsations recorded in the esophagus to their progenitors viz the pressure pulsations in the left atrium itself. This was because a number of diverse factors - anatomic, physiologic, mechanical, and hydraulic - influenced the absolute magnitude of the pressure pulse

This is a report of an investigation using an experimental model to assess the quantitative relation between the pressures as recorded in esophagus and the actual pressures in the left atrium. The main object of the study was to find out if the left atrial pressures, could, with a reasonable degree of accuracy, be predicted from the recordings obtained using an esophageal balloon - an information that could be invaluable in a variety of clinical settings.

PRINCIPLE

The aim of this experiment was to find out whether the pressures are transmitted across two or more interfaces linearly and proportionately at varying distending pressures. Two distensible chambers taken as analogues for left atrium and esophageal balloon were confined in a nondistensible space. The pressures in both chambers were measured by water manometers. The distending pressures of left atrial analogue were changed sequentially and the effect on the balloon pressure as reflected on the balloon water manometer were observed. The changes in the balloon ~~pressure~~ water manometer were then restored to the initial value by applying air pressure at its open end. This was done to minimise the effect of volume displacement from the balloon, and the pressure rise in the balloon with its volume restored to original values were noted in a third manometer. Finally the effect of application of such counter pressure to the esophageal balloon, on the left atrial analogue was also assessed.

METHODS MATERIALS

A glass beaker of capacity 300 ml was used as the non distensible chamber to simulate the thorax. A polythene bag of capacity 150 ml was used as the analogue of the left atrium. A small polythene balloon measuring 4·0 x 1·5 cm was taken as the esophageal balloon. Both chambers had polythene outlets, with an outer diameter of 4 mm, connected separately to two water manometers using polythene tubings. A third water manometer was connected separately to the esophageal balloon water manometer to reflect the pressure changes after counterpulsation. These manometers were fixed to a vertical immobile board of wood. The left atrial analogue had an inlet also, connected to a blood pressure apparatus hand pump so as to exert air pressure over the water level in the left atrial analogue. The esophageal ballon manometer was also similarly connected to a hand pump at its free end to apply counter pressure and negate the volume displacement factor. The compensated esophageal balloon pressure was then measured in the third manometer.

The balloon was placed at the level of the maximal circumference of the left atrial analogue and its position fixed. The beaker was filled with cotton material to keep both analogues erect and free in the chamber.

The left atrial analogue was then filled with water so as to have firm contact with the balloon. The esophageal balloon was completely filled with water, all air expelled from the system using a surface reacting agent, and connected to the manometer. The initial pressure levels were noted after keeping the pressure level in the left atrial analogue at zero. Methylene blue was added to the water before filling the systems, to facilitate identification of water column levels with ease.

Stages of the Experiment

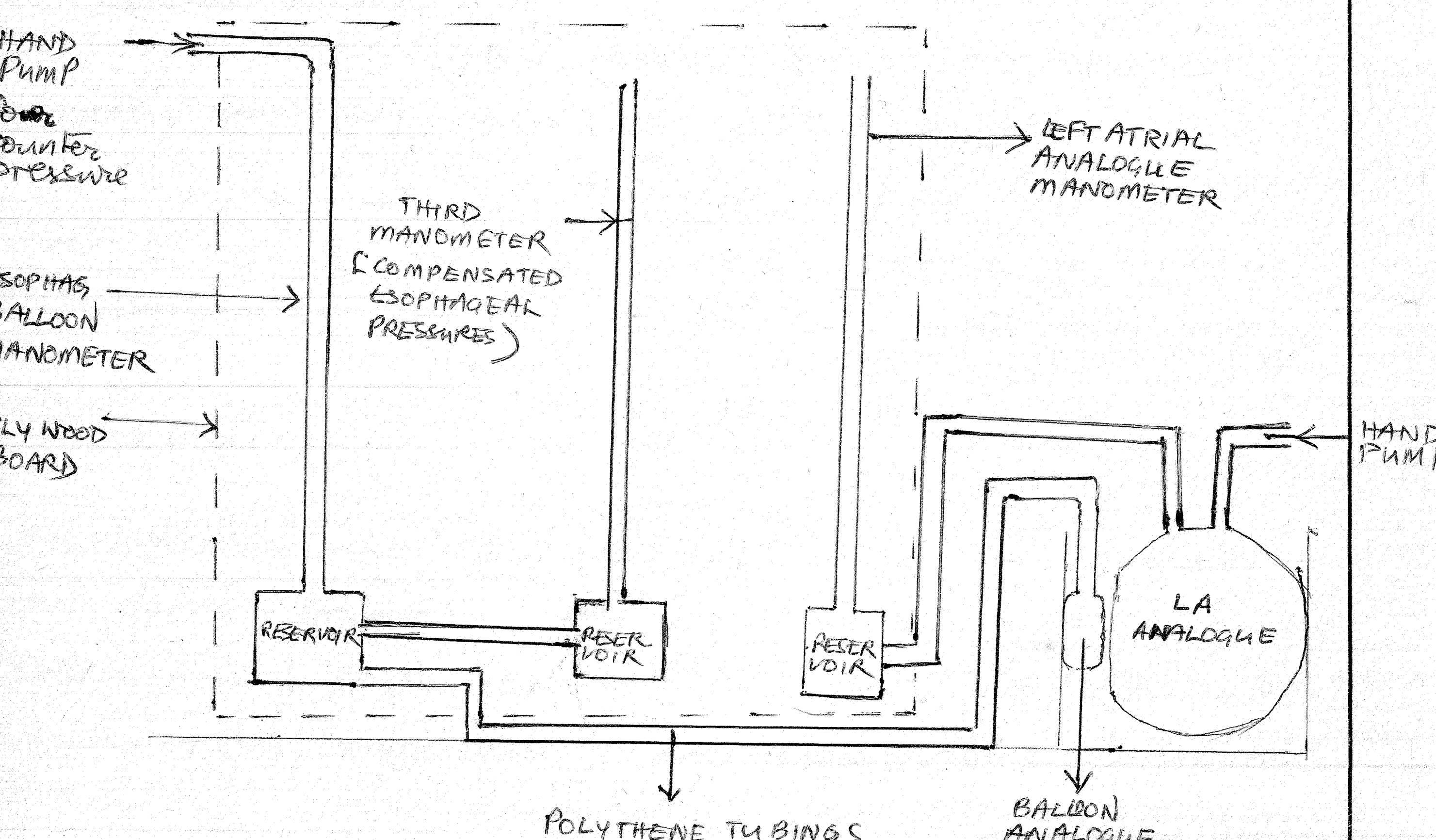
1. The initial pressures in the analogues of left atrium and esophageal balloons were noted
2. The pressure in the left atrial analogue increased by pumping in air through the inlet and the rise in pressure in the manometer connected to left atrium noted
3. The change in pressure in the esophageal balloon is recorded from the esophageal balloon manometer.
4. Counter pressure is exerted by pumping air into the balloon esophageal manometer to restore its level to initial settings.
5. The rise in pressure in the balloon when the volume displacement has been so negated is recorded from the third manometer
6. The pressure level in the left atrial analogue after

counter pressure is rechecked to find out if a rise in esophageal balloon pressures without significant volume displacement has affected the left atrial analogue pressures.

7. The procedure was repeated with varying increments of pressure in the left atrial analogue with the system half filled and fully filled with water.

Figure 1

Experimental model used for analysing the pressure transmission between left atrial analogue and esophageal balloon analogue



RESULTS

The pressures in the left atrial analogue, when fully filled with water were successively increased from 3cm to 9cm water and the transmission into the esophageal balloon manometer recorded. Five sets of observations were made at each pressure level to confirm the reproducibility of findings. Results are shown in Table 1. It was found that the system, at each level of left atrial pressure increment, reflected a linear direct relation with the actual pressure increment. There was consistently an augmentation of approximately three fold when the pressures were transmitted from the left atrium to the balloon analogue. To eliminate the factor of volume displacement counter pressure was applied and balloon pressures measured after compensation. This produced a further amplification of the actual pressure rise by almost five fold. Measurement of the pressures in left atrial analogue found that after compensation the rise in pressure in balloon did not significantly affect in reverse the pressure in the left atrium.

When the system was half filled with water, and half with air, the results predictably were not consistent. The uncompensated balloon pressures increased, but there was a wider scatter in the findings. After compensation, the balloon pressures were even more inconsistent with an increase in the scatter of individual observations.

Table 1. Relationship of pressures in the ~~left atrial~~ and balloon analogues, before and after ~~counter pressure~~ – ~~fully filled with water~~

Left atrial pressure rise cms/H2O	Balloon pressure rise (uncompensated) cms/H2O	Mean	Balloon pressure after compensation	Mean	Left atrial pressure after compensation
3 cm	9.6	9.5	15.5	15.3	3.2
	9.4		15.4		3.2
	9.4		15.2		3.2
	9.5		15.0		3.2
	9.5		15.4		3.2
4 cm	12.8	12.8	20.4	20.4	4.2
	12.6		20.0		4.2
	12.7		21.0		4.2
	13.0		20.5		4.2
	13.0		20.2		4.2
5 cm	16.8	16.4	25.7	26	5.2
	16.2		25.7		5.2
	16.7		26.4		5.2
	16.0		25.7		5.2
	16.4		26.3		5.2
6 cm	18.8	19.0	30.6	31.1	6.3
	19.0		30.8		6.3
	19.0		31.2		6.3
	19.0		31.6		6.3
	19.2		31.2		6.3
7 cm	22.7	22.6	36.2	36.2	7.5
	22.7		36.1		7.4
	22.4		35.9		7.3
	22.4		36.9		7.3
	22.6		36.0		7.5
8 cm	25.4	25.4	41.5	41.4	8.5
	25.6		41.4		8.4
	24.4		41.5		8.5
	25.4		41.6		8.6
	25.2		41.1		8.5
9 cm	27.2	27.2	45	45.6	9.5
	27.5		46		9.4
	26.8		47.5		9.5
	27.4		43.5		9.5
	26.6		45.8		9.6

Table 2. Relationship of pressures in the left atrial and balloon analogues, before and after counterpressure - half filled with water

left atrial pressure rise cms/H2O	Balloon pressure rise (uncompensated) cms/H2O	Mean	Balloon pressure after compensation	Range	left atrial pressure after compensation
3	4 3 4·4 5·0 4·7	4·5	9 7·2 10·0 6·6 10·7	6·6 to 10·7	3·2 3·2 3·2 3·2 3·2
4	8·3 10·5 10·7 9·5 10·0	9·7	10·2 15·4 20·0 15·0 16·0	10·2 to 20·0	4·2 4·2 4·2 4·2 4·3
5	12·2 11·0 12·3 12·0 13·2	12·3	21·0 17·7 17·0 19·4 21·0	17·0 to 21·0	5·3 5·2 5·3 5·2 5·2
6	15·0 15·5 15·7 15·7 16·4	15·7	22·5 22·0 23·5 24·5 26·0	22·0 to 26·0	6·3 6·3 6·4 6·3 6·3
7	17·2 16·8 17·4 17·1 17·2	17·1	28·2 26·9 25·1 27·2 29·6	25·1 to 29·6	7·4 7·4 7·3 7·3 7·3
8	19·3 19·8 19·5 19·8 19·0	19·5	28·4 31·0 29·5 31·5 29·5	30	8·4 8·4 8·3 8·4 8·2
9	22·6 21·8 21·7 22·4 22·5	22·2	35·9 35·4 37·2 31·4 34·3	31·4 to 37·2	9·4 9·4 9·5 9·4 9·5

DISCUSSION

The amplitude of pressures as recorded from the esophageal balloon is variable as it is considerably influenced by a host of other factors which include

- elasticity of the system
- amount of fluid in the system
- nature of fluid in the system
- initial pressure in the system
- intra atrial pressures
- position of the heart in the chest
- level of diaphragm in different phases of respiration
- relation of esophagus to left atrium
- presence of hypertrophy of atrial walls and the
- presence of mediastinal disease

Elasticity of the system

The elasticity of the system used in the recording device influences not only the pulse wave transmission, but also the absolute pressures. If the system is highly elastic substantial volume displacements are permitted. They record volume changes but do not accurately portray pressure variations. For enhanced sensitivity to pressure wave changes, the volume displacement permitted should be minimal. Polythene permits less volume displacement as compared to the previously employed latex systems. The left atrial and esophageal analogues in the present experiment were therefore constructed from polythene, as were the tubings to the manometers.

The amount of fluid

The amount of fluid present initially in the balloon, determines the degree of pressure transmission through it. It has been observed that as the balloon is distended with successive increments in volume of fluid, a point is reached, beyond which equal increments in volume result in decreasing increments of pressure. There is thus a range of initial distending volume of the balloon over which a constant pressure volume relation is maintained. Moreover, to faithfully record and transmit the left atrial events, particularly in vivo, the balloon must be relatively small or else the tracings can be distorted by pressure volume changes occurring at other than the left atrial level.

The nature of fluid

Previous workers have employed both water filled and air filled balloons in recording left atrial pressures. Air filled systems have the disadvantage of permitting substantial volume displacements. In contrast completely water filled systems more accurately reflect the pressure variations. Moreover they can be more readily standardised and calibrated unlike the air filled systems. Our findings also substantiate earlier observations on the unreliability of air filled systems as indicated by the wide scatter of observations made with half air filled system.

The intraatrial pressure

The actual pressure in the left atrium depends on the relation of mean tensile strength of left atrial wall and atrial volume at that instant. Transmission of the intraatrial pressures and its variations to the recording device is dependent on

- the degree to which the balloon is compressed by the left atrium against a nonyeilding surface like the vertebra in the clinical setting.
- the degree of resistance of the balloon and/or esophagus to the change in shape imposed upon it by the first force.

In this experimental study some of the fluid dynamics were analysed. The main purpose of this study was to find out whether it is possible to transmit the pressures from one chamber to another, separated by two interfaces and confined to a nonyeilding or partially yeilding chamber. In this experimental set up the esophageal balloon has one of its surfaces facing the nonyeilding surface of the beaker and the other surface in contact with the left atrial analogue - more or less approximating the in vivo arrangement. Using a partially air filled left atrial analogue altered the degree of approximation of both chambers and also the distensibility characteristics.

The results show that when the left atrial analogues is fully filled with water, the pressure transmission is linear and reproducible, but not so when it is only half filled with water. Counter pressure applied to the esophageal balloon altered the left atrial analogue pressures only minimally, but augmented the corresponding balloon pressure by five fold.

The study thus establishes the fact that an experimental model as used in this set up is capable of reflecting the pressure rise in left atrial aneurysm with an augmented response. The augmentation of the pressure response, which was much more evident when the volume displacement factor was negated, is probably related to the difference in surface area of the two chambers involved.

CONCLUSION

This study establishes the physical basis for the assessment of left atrial pressure using an esophageal balloon. A good correlation has been found between the pressure rise in the left atrial analogue and the consequent rise in pressure in the balloon analogue. However this only reflects on the adequacy of the recording system in reproducing consistently the pressure fluctuations. In a clinical setting other anatomic and physiologic factors enter into the picture. Further studies are obviously needed before it can be concluded that the esophageal balloon pressure recordings can be extrapolated to yeild absolute hemodynamic parameters.

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