Choosing a catheter system for measuring intra-oesophageal pressure

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Abstract—The choice of catheter systems for the measurement of oesophageal pressure in respiratory physiology is discussed and the merits and drawbacks of liquid- and air-filled systems described. Tests to determine the dynamic characteristics of various systems were performed and it was found that air-filled balloon catheters have a better performance in both phase and amplitude characteristics than most liquid-filled catheters. Tests were also made to find whether the balloons deteriorated significantly in controlled conditions and it was found that they had a useful working life.

Keyword—Respiratory physiology

1 Introduction

STUDIES OF lung mechanics have become a pre-requisite of rational approaches to therapy in adults (PRIDE, 1971) and could be vital in improving our understanding of respiratory disorders in infancy (KARLBERG et al., 1960; HARRISON et al., 1968). Computation of the airways resistance and lung compliance requires the measurements of volume, flow rate and thoracic pressure to be free from amplitude and phase distortion (KRieGER, 1963; AHLSTROM, 1974).

The first criterion of choice for the pressure-measuring catheter is that it can be passed through a nostril and into the oesophagus without obstructing the airways or damaging delicate tissues. Additionally, the catheter should not modify respiratory behaviour or cause artefacts due to movement. These requirements preclude the use of anything but a soft catheter of external dimensions less than about 5 mm. It would be quite feasible to mount a strain-gauge transducer in the catheter tip, but the flexibility required would cause the connecting wires to be repeatedly stressed and may lead to a short working life. Also the problem of zeroing the trans-
Provided the system chosen is driven at frequencies less than the natural resonant frequency, amplitude distortion will be low. Phase errors will be approximately proportional to frequency, making the inherent time lag straightforward to compute. The bandwidth required is unknown but the range of breathing frequencies encountered is reported to be from about 17 beats/min in adults to about 136 beats/min in infants (Hjalmarson and Olsson, 1974). The latter rate represents an upper frequency of approximately 2-3 Hz. Most physiological pressure waves have a spectral power of about 1% at the 10th harmonic and from consideration of the mechanics of chest movement, it seems unlikely that a significant amount of energy is contained in frequencies above 23 Hz. Using this as a guide, the flat amplitude and near linear-phase response should extend to about 23 Hz when dealing with patients who are breathing rapidly.

The fluid-filled catheter and pressure transducer, which are widely used in the direct measurement of blood pressure (McDonald, 1974), have been used in essentially unmodified form for oesophageal studies. However, an appropriate frequency response for infants or rapidly breathing adults requires the transducer-catheter system to be of low compliance and a system of adequate bandwidth tends to be too rigid (Fig. 1), preventing a nasolaryngeal approach. The soft p.v.c. catheter would be just adequate for some subjects, but like all open-ended fluid-filled systems, it suffers from the disadvantage that the pressures recorded would vary according to the vertical distance between the catheter tip and the transducer fluid chamber. Because small changes in pressure are being recorded, movement of the tip due to respiration or other factors would introduce errors. If air entered the fluid column, the dynamic performance of the measuring system would deteriorate and further errors may be introduced.

An alternative method which uses an air-filled balloon catheter (Fig. 2) is often disregarded, possibly as a consequence of the problems associated with air bubbles in liquid-filled systems. But such a system does have unique merits for oesophageal pressure measurement.

2 Characteristics of balloon catheters

Although the compliance of balloon catheters is large, this is not important when measuring pressures in the oesophagus—the compliance of the oesophagus is so much greater. Fortunately, as the moving masses in an airfilled system are small by comparison with those in a liquid-filled system it is still possible to obtain a high natural resonant frequency. The softness of the catheter wall has little influence on the resonant frequency of the system and with the small diameters of catheters used, the resonant peak is well damped.

The balloon will only transmit pressures correctly if it is not stretched by excessive internal inflation or externally constricted by the wall of the oesophagus. An appropriate balloon must therefore be chosen to suit the subject being measured; for infants this means a diameter of about 6 mm and for adults about 20 mm diameter.

It is necessary to obtain the pressure-volume curve to determine the appropriate range of working volumes for each balloon. To do this, the balloon is partially evacuated by a single stroke of a syringe of volume similar to the internal volume of the balloon catheter, and air is then introduced in 0.1 ml increments using a 1 ml glass syringe connected to a side branch of the balloon tap. With each incremental change in balloon volume, the corresponding pressure is measured by a suitable transducer. This procedure is repeated until a plot of the pressure-volume relationship over the range -16 to +16 mmHg is obtained (Fig. 3).

Two dynamic tests were used to assess the performance of the balloons. In the first test, the balloon catheters were suspended in a chamber sealed at one end by a rubber membrane. The chamber was pressurised to about 20 mmHg and the

![Fig. 2 Typical balloon-catheter system. The transducer is an Elcomatic EM750A](image)