Title: DYNAMIC RESPONSE: THE KEY TO OBTAINING QUALITY INFORMATION USING PULMONARY ARTERY CATHETERS

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Introduction. Since its conception in 1970, the pulmonary artery catheter and related technology has developed into a common diagnostic and therapeutic tool. Information from this type of catheter, if obtained properly, has proven to be invaluable to clinicians worldwide. Most often the pressure waveform data is obtained inaccurately, without the knowledge or consent of the user. The dynamic response of a monitoring system can be a major contributor in obtaining false information.[1] Four pulmonary artery thermodilution catheter-transducer-tubing systems were studied under various conditions to determine both dynamic response and accuracy.

Methods. The following systems were tested: Pulmonary Artery Catheters (4 Lumen, 110 cm length): Sorenson Research (Abbott Labs, #41223-01); Arrow International (Critikon Catheter, #JC-607); Bard (U.S.C.I., #008542); Gould (Spectramed, #SP5107). Transducer Tubing System: Cobe CDX III disposable transducer tubing kit. Damping Device: Accudynamic (Sorenson Research).

The transducer-tubing system was set up in two configurations, a pole mount and a patient mount. The pole mount system was composed of a transducer, damping device, flush device, two stopcocks, 48-inch connecting tubing and 6-inch tubing extension. The patient mount version had the 48-inch connecting tubing and one stopcock removed. Each transducer-tubing kit version was connected with the pulmonary artery catheters distal lumen producing a 97-inch pole mount and a 49-inch patient mount system. Three samples were obtained from each manufacturer.

Invitro Studies. The dynamic response studies were performed in the laboratory using three new samples, each tested three times. A Hewlett-Packard sine wave generator, pressure amplifier/monitor/chart recorder, and a Biotek 601 simulator were used to collect the data. The natural frequency (Fn) and damping factor (Df) were obtained from the following equations:[2]

$$Df = \left(\frac{1 - \sqrt{1 - (1/amp.ratio)^2}}{2}\right)^{0.5}$$

$$Fn = \frac{F\ peak}{\sqrt{1 - 2(Df)^2}}$$

Each complete system was tested in six different setups: 1) pole mount; 2) patient mount; 3),4) pole/patient mount version with a small air bubble (0.03 ml) inserted close to the transducer; and 5),6) pole/patient mount utilizing the Accudynamic (adjustable damping device).

Invivo Studies. Pulmonary artery pressure waveform recordings were obtained from various patients in the operating room undergoing surgery. Systolic/diastolic pressures were recorded at various damping adjustments. One pulmonary artery catheter (Spectramed) in the pole and patient mount version was used in the clinical studies.

Results - Invitro. The average natural frequency and damping factor for the four catheter systems were as follows: Pole mount - Fn 10.6, Df 0.37; Patient mount - Fn 17.4, Df 0.25; Pole mount air - Fn 5.5, Df 0.48; Patient mount air - Fn 5.5, Df 0.47; Pole mount damping - Fn 11.0, Df 0.38; Patient mount damping - Fn 20.4, Df 0.43. These results were plotted into a dynamic response graph developed by Dr. R. Gardner[1] to determine if the system had an 'adequate' or 'optimal' dynamic response and, therefore, accuracy. The patient mount damping adjusted systems were the only versions plotted into the 'optimal' response wedge of the graph.

Results - Invivo. In the clinical trials, only the patient mount damping adjusted system produced acceptable response and waveforms for clinical measurement under all physiological conditions. The other trials produced gross waveform distortion and large errors in the pressure recordings when the damping device was not used.

Discussion. The variations in dynamic response of the different systems tested are due to changes in the natural frequency and damping factor because of:

1) increased inductance of the fluid complicated by the compliance due to the length of the catheter-tubing system, and
2) the presence of a small air bubble.[3]

The invitro studies demonstrated that all systems are underdamped and manipulations of the damping factor are essential for obtaining quality information. This was also evident in the invivo studies because errors of 55% in the systolic and 43% in diastolic pressures were found to exist. The pole mount damping adjusted system (bubble free) may be 'adequate' for some physiological conditions, but the 'optimal' or preferred method is the patient mount damping adjusted system.

References.

1. Gardner, RM: Direct pressure measurement - dynamic response requirement. Anesthesiology 1981, 54-227-36.
2. Thomson, WT: Vibration Theory and Applications. Englewood Cliffs, NJ. Prentice-Hall Inc. 1965, pp 51-66.
3. Hunziker, P: Accuracy and dynamic response of disposable pressure transducer-tubing systems. C.J.A. 1987, 34-409-14.