

A Technique for the Determination of Systolic Pressure Variation in the Systemic and Pulmonary Arterial Circulations

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ABSTRACT

Introduction: Systolic pressure variation has previously been used to detect the presence of hypovolemia in mechanically ventilated patients but remains difficult to measure.

Methods: We describe the application of a commercially available physiological data acquisition system, PowerLab[®] (ADI Instruments Castle Hill, New South Wales, Australia), to acquire and graphically display simultaneous recordings of the airway pressure, as well as systemic and pulmonary arterial pressures. The technique involves the use of standard pressure transducers to record each pressure reading and has been used to obtain measurements in patients undergoing elective cardiac surgery.

Results: The technique permits calculation of systolic pressure variation of both the systemic and pulmonary arterial pressure waveforms. In addition it is possible to estimate plateau airway pressure and perform expiratory hold maneuvers to determine its constitutive components δ -up and δ -down. Waveforms can be exported into MS-windows Paint[®] and saved in JPEG or bitmap format.

Conclusions: The technique described will permit future analysis of the factors affecting the systolic pressure variation for the systemic and pulmonary arterial pressure waveforms in the clinical context. (*Critical Care and Resuscitation* 2004; 6: 204-208)

Key words: Systolic pressure variation, pulmonary artery pressure variation, plateau pressure

The changes in intrathoracic pressure induced by mechanical ventilation produce cyclical fluctuations of the systemic arterial pressure. The increase in blood pressure that results from insufflation is thought to result from emptying of alveolar capillaries and an increased left ventricular preload.^{1,2} At the same time, the increase in intrathoracic pressure results in reduced venous return and a reduction in the right ventricular preload.^{3,4} This results in a decrease in the arterial blood pressure over the subsequent cardiac cycles. A number of studies have demonstrated that systolic pressure variation (SPV) is more pronounced in the presence of hypovolemia.⁵⁻⁸ Indeed, this dynamic measurement of filling status is

reported to be a sensitive indicator of preload.⁹

Despite this, the simultaneous acquisition of the arterial and airway pressure waveforms to allow determination of systolic pressure variation has remained more difficult than other readily available but flawed variables such as central venous pressure and pulmonary artery occlusion pressure. The majority of studies on systolic pressure variation have required the creation of purpose written computer programs and the use of an analogue-to-digital interface board. To our knowledge, none have allowed the simultaneous recording and graphical display of the systemic arterial, pulmonary arterial, and airway pressures. Automated systems have

been developed for the determination of SPV as well as its components δ -up and δ -down,^{10,11} but are not commercially available. We describe here a technique for the simultaneous acquisition of the waveforms for airway pressure, systemic arterial pressure, and pulmonary arterial pressure, and present the concept of pulmonary arterial pressure variation. The technique permits simultaneous recording and archiving of digital information of the pressure measurements, as well as the capacity to graphically display the data in jpeg or bitmap format for purpose of publication.

MATERIALS and METHODS

Approval for the study was obtained from the Medical Centre Ethics Committee, and signed consent was obtained from each patient studied.

All patients studied were intubated and mechanically ventilated following elective cardiac surgery and had arterial lines and pulmonary artery catheters inserted as part of routine care.

Data was acquired using a PowerLab800® (ADI Instruments Castle Hill, New South Wales, Australia) connected to a lap-top computer using a SCSI card and the provided *Chart 4 for Windows*® software. Hewlett Packard transducers were inserted proximally into 3 separate ML117 BP amplifiers (ADI Instruments), and the distal end of the transducer line was inserted into a 3 way tap contained within transducer tubing of the arterial and pulmonary arterial catheter (figure 1). Airway pressure was obtained by using non-compliant airway tubing attached to a Y-Piece on the ventilator

tubing incorporating an in-line bacterial filter.

All transducers were zeroed and leveled at the phlebostatic axis and digital input into each channel was at 400 Hz.

RESULTS

The technique described allows acquisition of simultaneous waveforms from the systemic arterial, pulmonary arterial, and airway pressure traces. A movable cursor allows determination of the pressure at each time coordinate to permit determination of the highest and lowest systolic and diastolic pressures. Hence, it is possible to calculate systolic pressure variation as previously described¹² (figure 2). Furthermore, this technique permits calculation of the pulmonary arterial systolic pressure variation (PA-SPV) (figure 3). In addition, the cursor permits identification of the time course of the changes in these pressure readings.

The introduction of an inspiratory hold on the ventilator permits determination of the plateau airway pressure (figure 4). Finally, an expiratory hold on the ventilator will permit determination of δ -up and δ -down (figure 5) which have been implicated as important indicators of hypovolemia.⁵

DISCUSSION

We have described here a technique which permits the simultaneous measurement of the systolic pressure variation of both the systemic and pulmonary arterial pressure waveforms, in relation to the airway pressure.

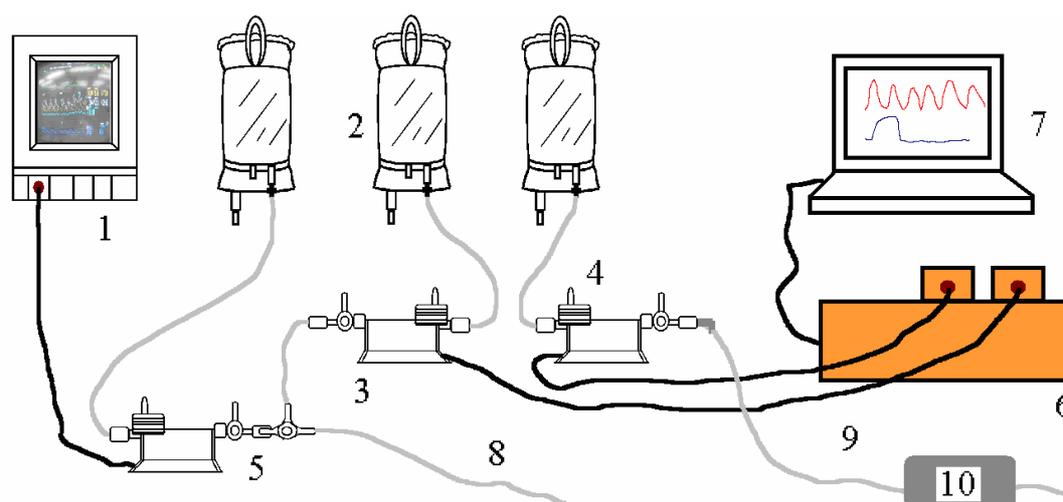


Figure 1. Schematic representation of set-up for simultaneous assessment of systemic arterial pressure and airway pressure for determination of systolic pressure- and pulse pressure – variation. **1:** bedside monitor, **2:** pressure bags for transducer kits, **3:** transducer for arterial pressure or pulmonary arterial pressure slaving to ML117 BP amplifiers of the Power Lab 800, **4:** transducer for airway pressure slaving to Power Lab 800, **5:** transducer with 3-way tap to permit monitoring of pulmonary and systemic arterial pressure waveform, **6:** Power Lab 800 slaving to lap-top computer using SCSI card, **7:** lap-top PC with Chart 4 software installed, **8:** tubing connected to pulmonary or systemic arterial line in patient, **9:** disposable ventilator tubing with nipple to attach directly to pressure transducer and **10:** bacteriostatic filter between transducer tubing and ventilator tubing.

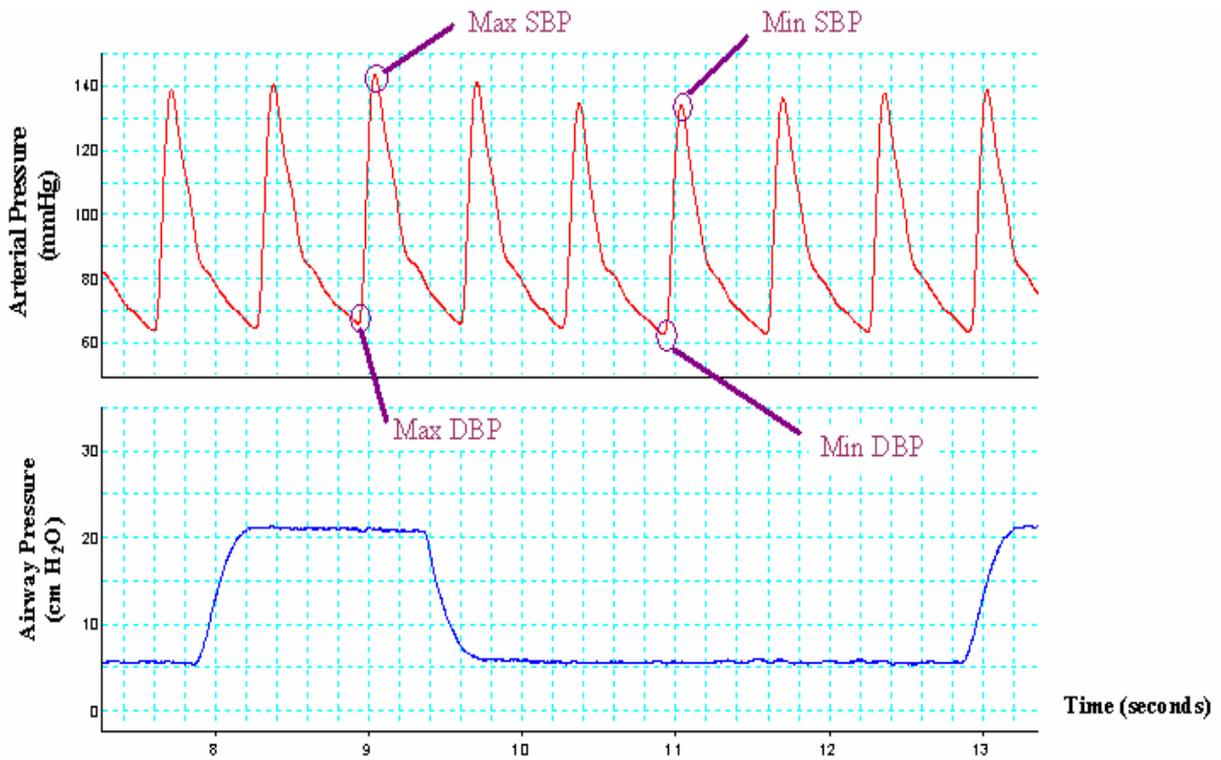


Figure 2. Determination of systolic pressure variation

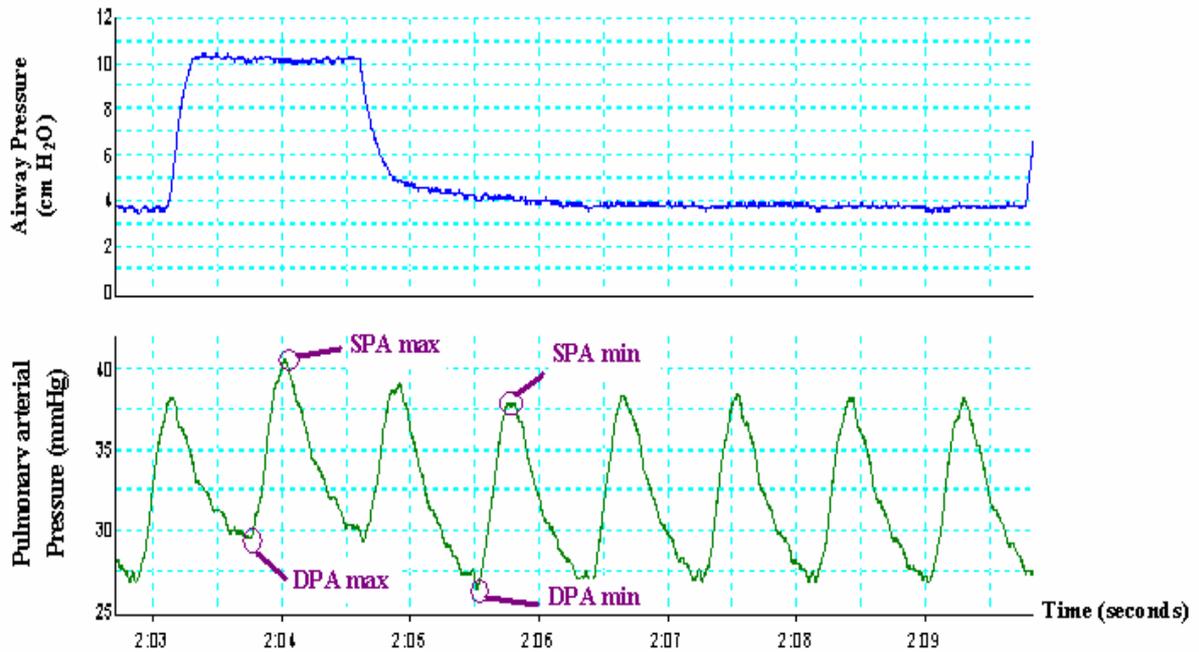


Figure 3. Determination of pulmonary artery systolic pressure variation

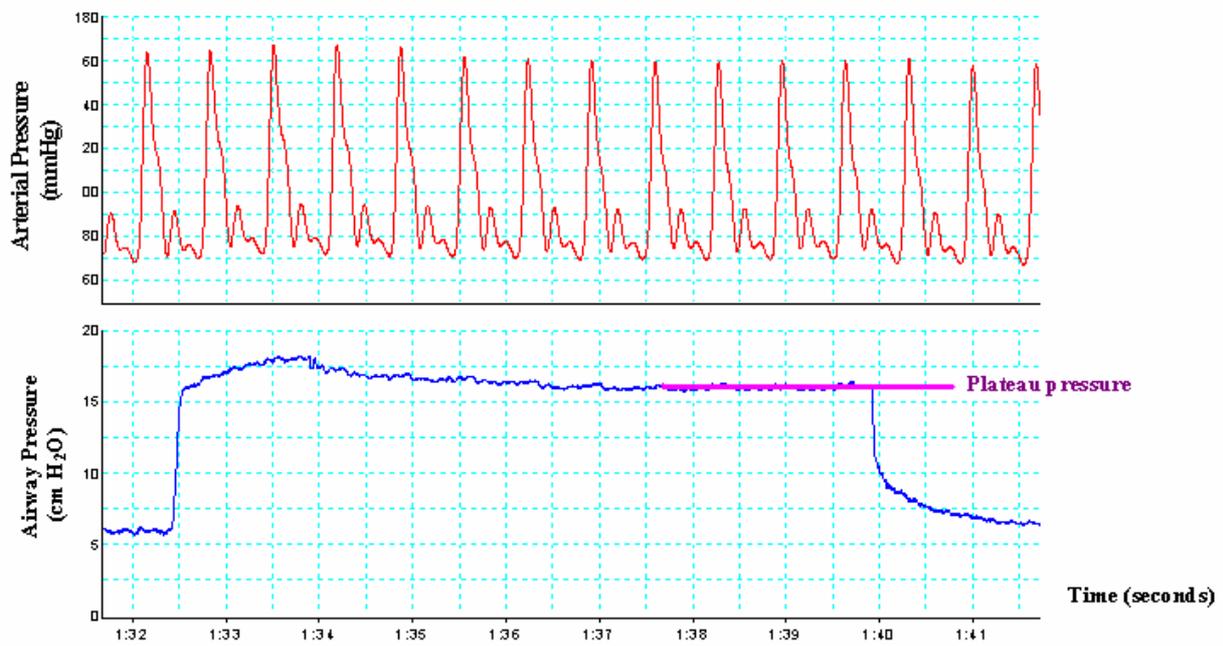


Figure 4. use of inspiratory hold on the ventilator for estimation of plateau airway pressure

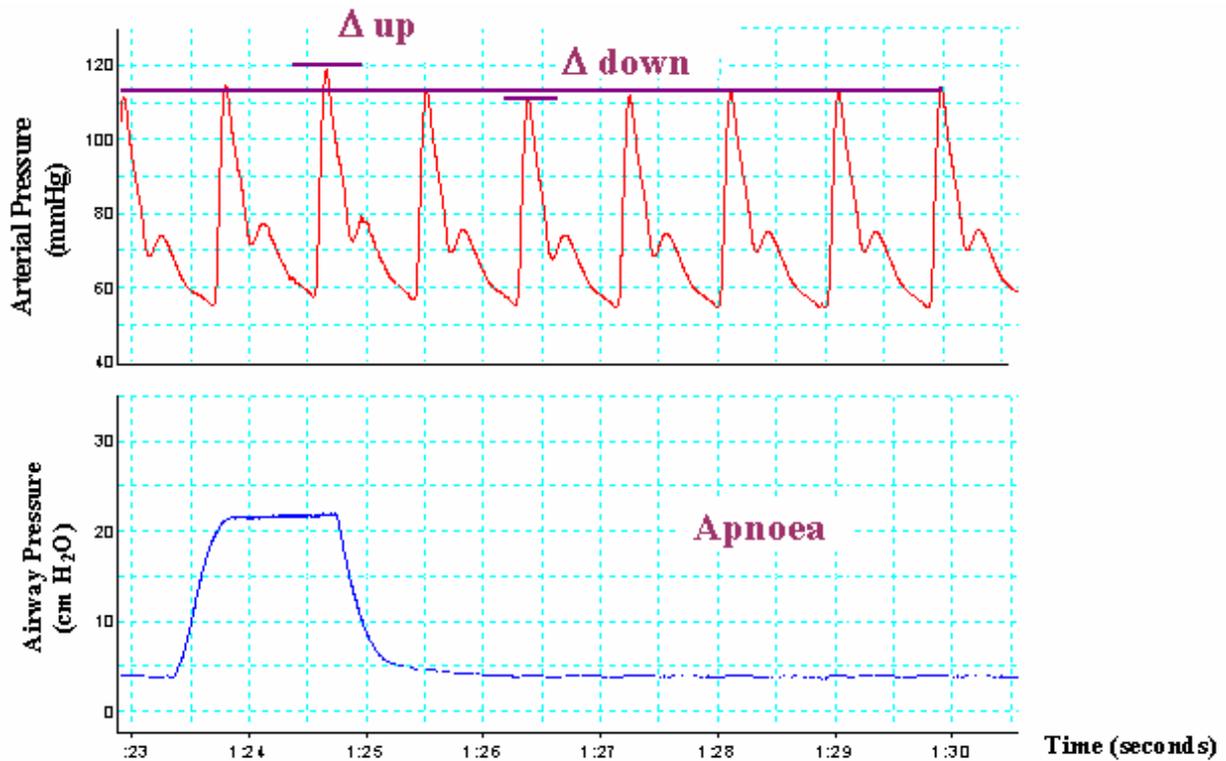


Figure 5. Use of apnoea (expiratory hold) on the ventilator for the determination of δ -up and δ -down.

The major advantage of the technique compared to previous approaches is the ability to obtain large amounts of continuous data which can be archived to the hard disc of the computer and subsequently analysed. The Chart 4[®] program is MS Windows based. It is user-friendly and eliminates the need for purpose written software and the use of a digital-to-analogue interface cards. It is possible to export data from the Windows based Chart 4[®] program to MS Windows Paint[®] to be archived in jpeg or bitmap format for use in publications.

The technique has been used to assess systolic pressure variation in patients undergoing elective cardiac surgery. In another report in this journal we also present the results of a pilot study investigating the effects of varying airway pressure on systolic pressure variation of the systemic and pulmonary arterial waveforms.¹³ In addition, we are currently using the technique to investigate the correlation between systemic systolic pressure variation and stroke volume variation as assessed by pulse contour analysis. Finally, the technique will permit future analysis of the impact of various modes of ventilation on the pulmonary and arterial circulations in patients with various cardiac and respiratory conditions, as well as those with spinal cord injuries.

In conclusion, the technique described here permits acquisition and archiving of simultaneous recordings of systemic arterial, pulmonary arterial, and airway pressures. Analysis of the data provided by the method permits estimation of plateau airway pressure as well as systolic pressure variation for both the systemic and pulmonary arterial waveforms. The technique will allow future analysis of heart-lung interactions in intensive care patients on mechanical ventilation.

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