# MEASUREMENT OF RAPIDLY CHANGING FLOW RATES AND ASSOCIATED PRESSURES DURING CARDIOPULMONARY BYPASS (CPB)

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**Introduction:** Our initial work, with Automating Data collection from a CPB system, captured pump outlet pressure through use of a conventional pressure transducer connected to our physiologic monitoring system (Intellivue – Philips). This technique permitted direct export of the pump outlet pressure into our AIMS database. Additional flow rate and temperature data from the pump were then obtained by an RS-232 Communication Module (CM) obtained from our Terumo-Sarns rep. Our AIMS cannot interface directly with an RS-232 port and an Asus Eee PC 901 captured the CM output. As we continued our data collection we noted that some bypass cases had frequent, very large excursions, of brief duration, in the pump outlet pressure and arterial flow rate. A review of the literature revealed the potential of these excursions to alter the cognitive outcomes of patients requiring bypass.[1 2 3] Thus we decided to investigate (both in vivo and ex vivo) the measurement of the pressure drop across the CPB Oxygenator (OX) as a means of monitoring the aforementioned flow variations.

**Methods:** IntelliVue pressure transducers were connected to pressure ports upstream and downstream of the OX. These two pressure signals were directly entered into our AIMS every 15 sec. In addition, these pressure waveforms were also recorded by our IntelliVue Information Center (IIC) which can capture and store four waveforms during a case. Typically, EKG, A-line, CO2, and Pulse Oximeter waveforms are selected for capture and storage. These stored waveforms may be viewed at typical EKG scanning rates (6.25, 12.5, 25 and 50 mm/sec. Data were still recorded from the Pump via the RS-232 CM port and the Asus Eee PC. The Pump flows and temperatures are only updated every 66 sec at the CM port. Calibration data were recorded during the time prior to initiating bypass. During this time the CPB circuit contains only Plasmalyte. Changes in Pump flow rate can be made either slowly and deliberately or very abruptly. For calibration purposes we would hold a given flow at a constant value until the CM module reported two or more consecutive, equal values for a flow rate. The upstream and down-stream OX pressures were then averaged over the time interval(s) where consecutive flow values were constant. Rapid (abrupt) changes in flow rate were plotted for all three of the data sampling rates: 66 sec (CM), 15 sec (AIMS), 10 milliseconds (IIC).

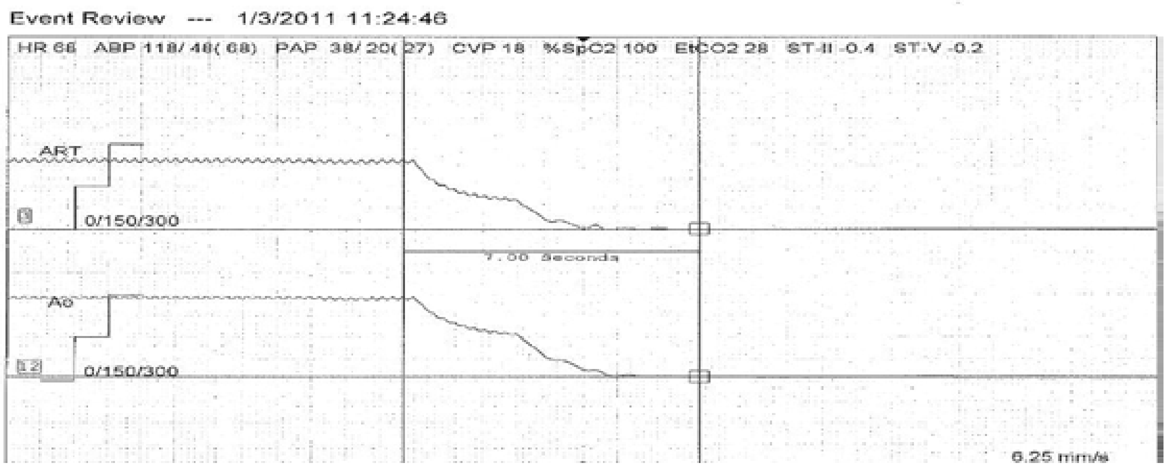
**Results:** Transient flows are shown below with both actual patient bypass in process and during off-line calibration runs. It is clear that the transient waveforms are not adequately represented by 15 sec samples and 66 sec samples may completely miss a pressure excursion (transient) of short duration. (See Figures Below.) The Plasmalyte, off-line calibration curves showed a strongly non-linear relationship between the Arterial pump flow and the pressure drop across the OX.

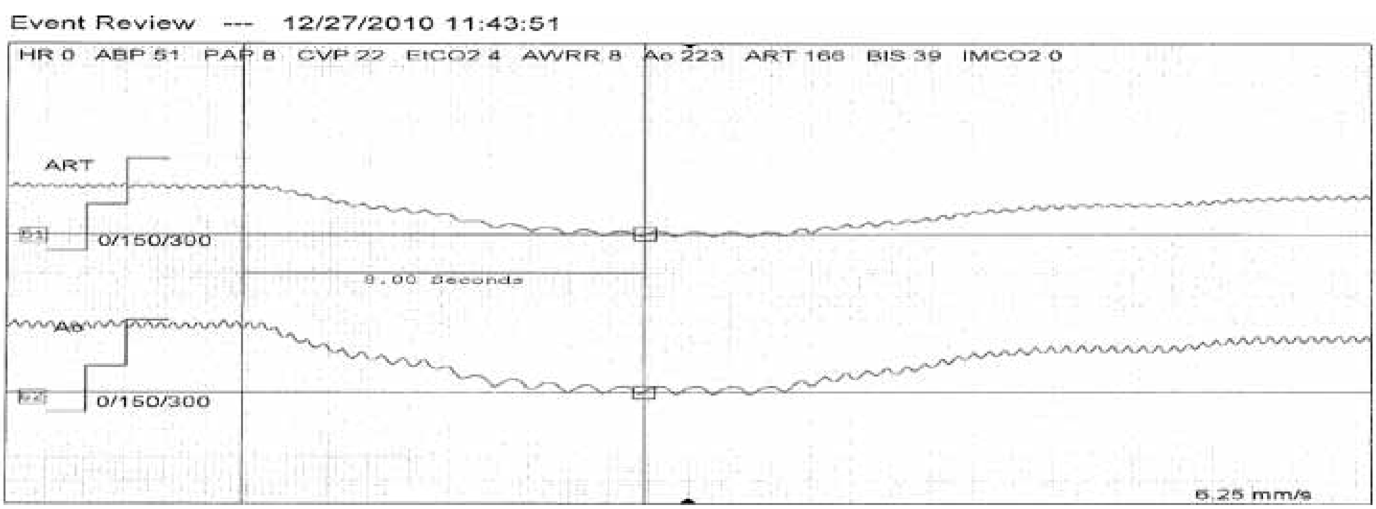
**Summary:** We have been able to collect all pressure transient and calibration data from the three systems noted above. Modification of the sampling rates of both the CM and AIMS systems would be required to obtain clinically useful information regarding the effect of pressure excursions on patient cognitive outcomes.

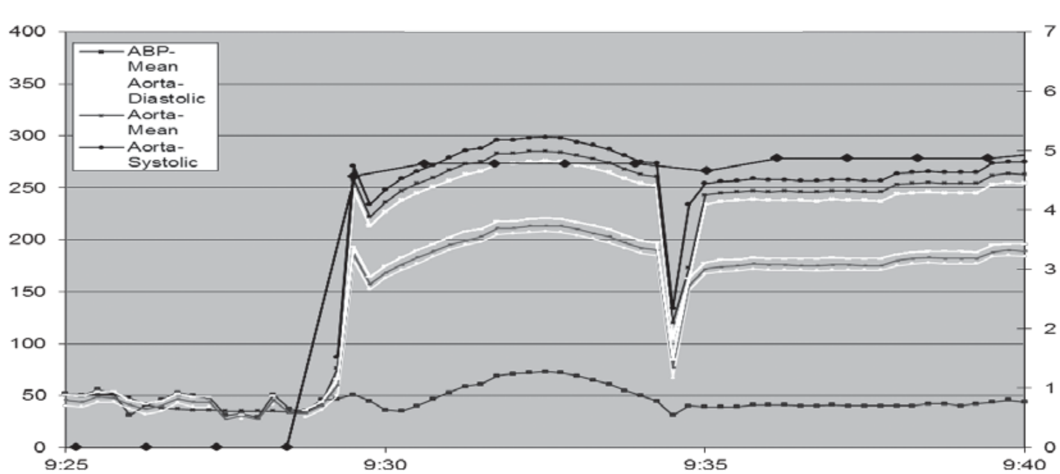
In the Figures shown below Ao refers to the pressure measured just upstream of the OX, ART is the pressure just downstream of the OX. ABP is patient radial artery pressure. These names were required by the IIC so that our pump pressures would have a high priority ranking, and could then be accepted as one of the four waves stored by the IIC. The Pressure transient shown in the first figure below was taken during the calibration tests. The second graph below was recorded near the end of a bypass run. The third figure is the start of a bypass session. The y axis on the right is [Flow – L/min] and left y axis is mmHg.

**Summary:**

1. Ganushchak YM, Fransen EJ, Visser C, de Jong DS, Maessen JG. Neurological complications after coronary artery bypass grafting related to the performance of cardiopulmonary bypass. Chest 2004;125:2196–2205
2. Weerwind PW, Maessen JG. The effect of oxygenator mechanical characteristics on energy transfer during clinical cardiopulmonary bypass. Perfusion 2011 Jan 26 (1) 39-44
3. Centrifugal pump inlet pressure site affects measurement. Simon Augustin1, Alison Horton, Warwick Butt, Martin Bennett, Stephen Horton1. Perfusion 2010 September 25(5) 313–320


Event Review --- 1/3/2011 11:24:46
HR 66 ABP 118/ 48( 68) PAP 38/ 20( 27) CVP 18 %SpO2 100 EtCO2 28 ST-II -0.4 ST-V -0.2
ART
0/150/300
7.00 Seconds
Ao
0/150/300
6.25 mm/s


Event Review --- 12/27/2010 11:43:51
HR 0 ABP 51 PAP 8 CVP 22 EtCO2 4 AWRR 8 Ao 223 ART 166 BIS 39 IMCO2 0
ART
0/150/300
8.00 Seconds
Ao
0/150/300
6.25 mm/s


ABP-Mean
Aorta-Diastolic
Aorta-Mean
Aorta-Systolic
400
350
300
250
200
150
100
50
0
9:25
9:30
9:35
9:40
7
6
5
4
3
2
1
0