02. INCREASED IMPEDANCE AT RIGHT VENTRICULAR EJECTION

Blood flow in the pulmonary circulation depends on a pressure gradient between the upstream pressure, i.e. the pulmonary arterial pressure, and the downstream pressure, i.e. the pulmonary venous pressure. Insufflation, or the application of a positive end-expiratory pressure (PEEP), generates an increase in transpulmonary pressure (lung distension pressure defined as Palveolar - Ppleural). This increase in transpulmonary pressure leads to an extension of West zone II (Pulmonary arterial pressure > Alveolar pressure > Pulmonary venous pressure) at the expense of West zone III (Pulmonary arterial pressure > Alveolar pressure > Pulmonary venous pressure), which then hinders blood flow in the alveolar vessels. The resulting increase in right ventricular afterload may account for dilatation of the right ventricle. This is particularly true in ARDS where the transpulmonary pressure generated is large because of the drop in pulmonary compliance.

Film no. 11 : Subcostal echocardiography. RV: right ventricle, LV: left ventricle.
Patient mechanically ventilated because of ARDS.
At each inspiration, there is transient dilatation of the right ventricle, reflecting the increase in its afterload.

Film no. 12 : TEE – long-axis view of the left ventricle by the transgastric route. RV: right ventricle, LV: left ventricle.
Patient mechanically ventilated because of ARDS secondary to pneumopathy. PEEP was 5 cmH2O, and plateau pressure was below 30 cmH2O.
At each inspiration, two-dimensional mode coupled to motion mode visualizes dilatation of the right ventricle to the detriment of the left ventricle, which is flattened.

From the pulmonary arterial flow obtained by pulsed Doppler in the trunk of the pulmonary artery, we have developed several indices to evaluate right ventricular afterload during ventilation. These indices can be used to assess tolerance of ventilation, and notably of the PEEP applied.
Thus, the mean acceleration of the flow in the pulmonary artery is an index inversely proportional to right ventricular afterload and is directly proportional to the systolic function of the right ventricle. It is calculated as the ratio of the maximum flow velocity over the acceleration time of this flow (time between the start of ejection and peak ejection).

On insufflation, we have demonstrated a drop in mean acceleration at heart beat 3, reflecting an increase in impedance on right ventricular ejection.
Film no. 13 : TEE – View of the vessels at the base of the heart.
Pulsed Doppler in the trunk of the pulmonary artery.
Inspiration causes a drop in maximum velocity of pulmonary artery flow
Film no. 14
Same recording as the previous film, in the same patient, but at a faster projection speed. This visualizes at heartbeat 3 (end-inspiratory) a lengthening of the acceleration time of the pulmonary artery flow. Coupled with the drop in maximum velocity of the flow, it causes a decrease in the mean acceleration of the right ventricle at heartbeat 3, reflecting the increase in its afterload

From the Doppler flow in the pulmonary artery, we have also used the isovolumetric contraction time of the right ventricle (from the start of the QRS to the start of ejection). It is directly proportional to right ventricular afterload and corresponds to the pressure of isovolumetric contraction measured beforehand using a pulmonary arterial catheter. Insufflation (Figure 6), as well as a high-frequency ventilatory strategy (Figure 7), can lengthen this Doppler time.

Media

figure 5

figure5-interactions05

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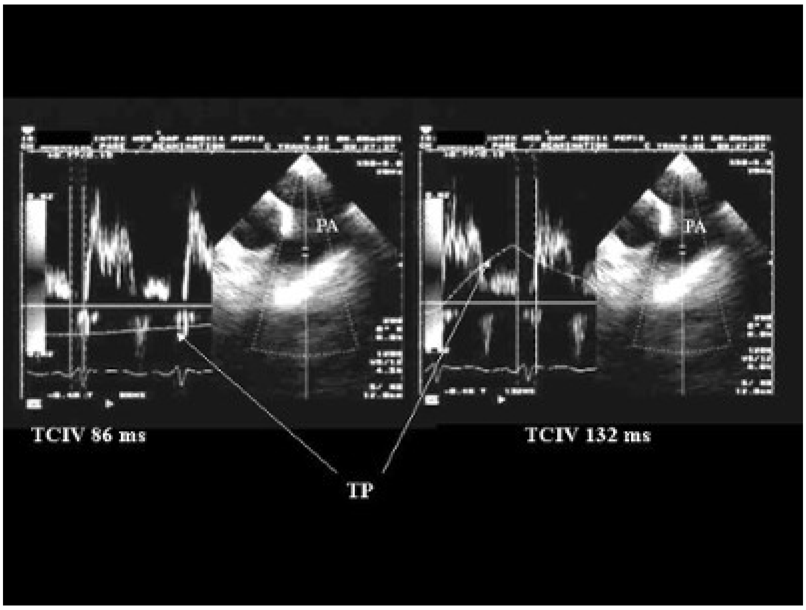

figure 6

figure6-interactions06

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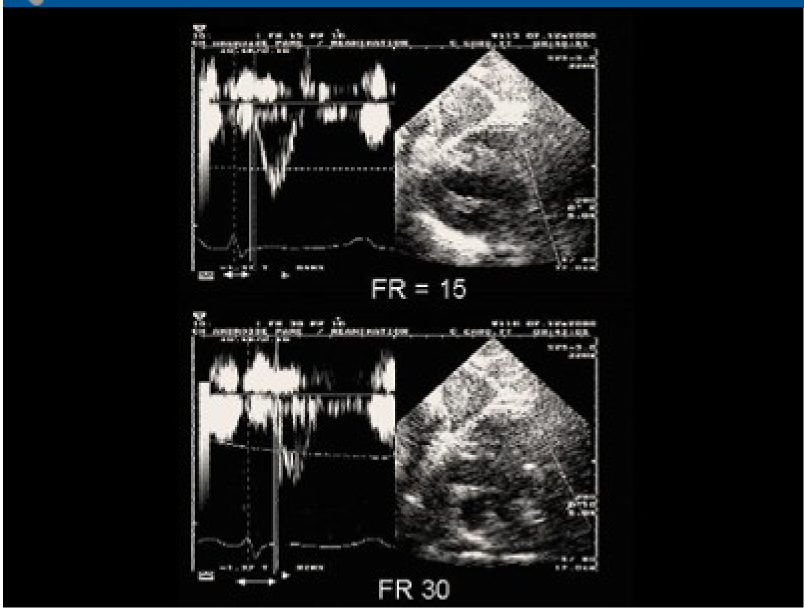

figure 7

Figure 5 : TEE - View of vessels at the base of the heart. Pulsed Doppler recording of flow in the trunk of the pulmonary artery. Vmax: maximum velocity, Tacc: acceleration time. Vmax (m/s or cm/s) is measured at peak flow; Tacc (ms) is measured between the start and the peak of ejection. The mean acceleration of the right ventricle (m/s-2) is calculated as ratio between Vmax and Tacc.

Figure 6 : TEE - View of vessels at the base of the heart. Pulsed Doppler recording of flow in the trunk of the pulmonary artery. IVCT: isovolumetric contraction time (ms). IVCT is measured between the start of the QRS and the start of right ventricular ejection. On the left, measurement of IVCT at the end of expiration. On the right, its measurement in the same patient, at the end of insufflation, reveals a lengthening which results in an increase in right ventricular afterload.

Figure 7 : TTE - View of vessels at the base of the heart by the subcostal route. Recording of pulmonary arterial flow by pulsed Doppler at the pulmonary annulus. IVCT: isovolumetric contraction time (ms). Measurement of IVCT, in end-expiratory phase, in the same patient at a respiratory frequency (RR) of 15 (above) and 30/min (below). Ventilation at high respiratory frequency lengthens IVCT.