Two cases showing alterations of the order of tricuspid and mitral valve opening during loading manipulations: a new approach for quick assessment of stress-induced left ventricular filling pressure elevation

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Running head: Quick assessment of elevated LV filling pressure during loading manipulations

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Case 1

A 78-year-old woman was referred to our hospital to diagnose the etiology of left ventricular (LV) systolic dysfunction. Echocardiography showed reduced LV ejection fraction (36%) with diffuse hypertrophy. Precise observation of the motion of atrioventricular valves (AVV) revealed a unique sequence in early-diastolic opening: the tricuspid valve (TV) opened earlier than the mitral valve (MV) (Fig. 1a, Video 1). Pressure recording revealed normal mean pulmonary capillary wedge pressure (PCWP) of 6 mmHg (v-wave: 8 mmHg) at rest, but it dramatically increased to 36 mmHg, with an increase in the v-wave (53 mmHg) during supine bicycle exercise (Fig. 1b). Also, mean right atrial pressure (RAP) increased during exercise (6 to 12 mmHg) but it was less than the change in PCWP (Fig. 1c). Consistently, simultaneous echocardiography with the pressure recording showed increased ratio of early-diastolic transmitral flow velocity to septal mitral annular velocity (E/e′) (17 to 26). Interestingly, the order of early-diastolic AVV opening changed to earlier opening of the MV (Fig. 1d, Video 2).

Case 2

A 79-year-old woman with atrial fibrillation after transcatheter aortic valve implantation underwent invasive hemodynamic and echocardiographic assessment due to exertional dyspnea. Echocardiography demonstrated normal LV ejection fraction (69%) without any transcatheter heart valve dysfunction. At baseline, AVV opened simultaneously (Fig. 1e, Video 3), and PCWP/RAP was 14/7 mmHg, respectively. During passive leg raise, the v-wave of PCWP increased from 19 to

24 mmHg, resulting in increased mean PCWP of 17 mmHg (Fig. 1f) (RAP was somewhat increased to 10 mmHg [Fig. 1g]), whereas slight increase in echocardiographic E velocity (95 to 108 cm/s) and constantly normal septal E/e′ (9 to 8) were observed. In contrast, early-diastolic MV opening became earlier than TV (Fig. 1h, Video 4).

Discussion

Impaired LV diastolic reserve is an occult sign of heart failure and a predictor of its adverse outcomes [1]. While the early-diastolic opening of TV precedes that of MV in normal condition, once left atrial (LA) pressure elevates, the opening of MV becomes early and precedes TV opening resulted from the early crossover of LA and LV pressures [2-4]. In case 1, E/e′ increased along with the elevated PCWP during exercise, and the order of AVV opening was also altered. Meanwhile, in case 2, E/e′ did not track the increase of PCWP during leg lifts, but the order of AVV correctly changed. Because E velocity depends on the early-diastolic LA to LV pressure difference [5], increase in E velocity might have been gentle due to increase of LV minimal pressure despite the increased LA v-wave. These cases underline the potential usefulness of the stress-induced alteration of the order of early-diastolic AVV opening to detect impaired LV diastolic function reserve. However, further studies including a larger sample, ideally using simultaneous catheterization-echocardiographic testing, are needed to confirm our findings.

Declarations

Ethical statements All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1964 and later versions. Informed consent was obtained from all patients for being included in the study.

Conflict of interest Michito Murayama, Hiroyuki Iwano, Ko Motoi, Suguru Ishizaka, Shingo Tsujinaga, Toshiyuki Nagai, and Toshihisa Anzai declare that they have no conflicts of interest.

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FIGURE CAPTION

Figure 1.

Two-dimensional echocardiographic images at echocardiography laboratory **(a, e)**, pulmonary capillary wedge pressure (PCWP) waveforms **(b, f)**, right atrial pressure (RAP) waveforms **(c, g)**, and corresponding echocardiographic images **(d, h)** during loading manipulations in case 1 and case 2. Note that earlier opening of the MV (yellow asterisks) was observed along with the marked elevation of v-wave of PCWP (arrow heads) during the loading manipulation in both cases. LV, left ventricle; RV, right ventricle; MV, mitral valve; TV, tricuspid valve.

Supplemental Video 1. Order of tricuspid and mitral valve opening at rest in case 1

During slow playback, we can appreciate the earlier opening of tricuspid valve.

Supplemental Video 2. Order of tricuspid and mitral valve opening during exercise in case 1

During slow playback, we can appreciate the earlier opening of mitral valve.

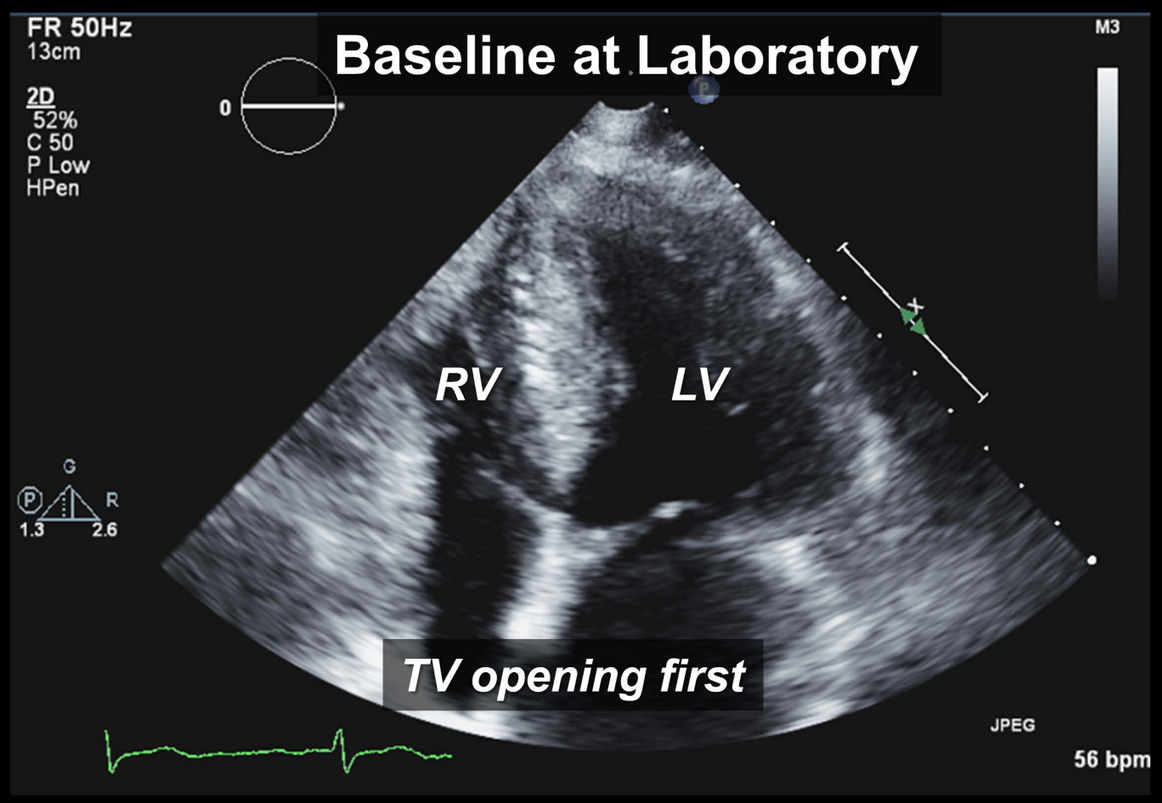
Supplemental Video 3. Order of tricuspid and mitral valve opening at rest in case 2

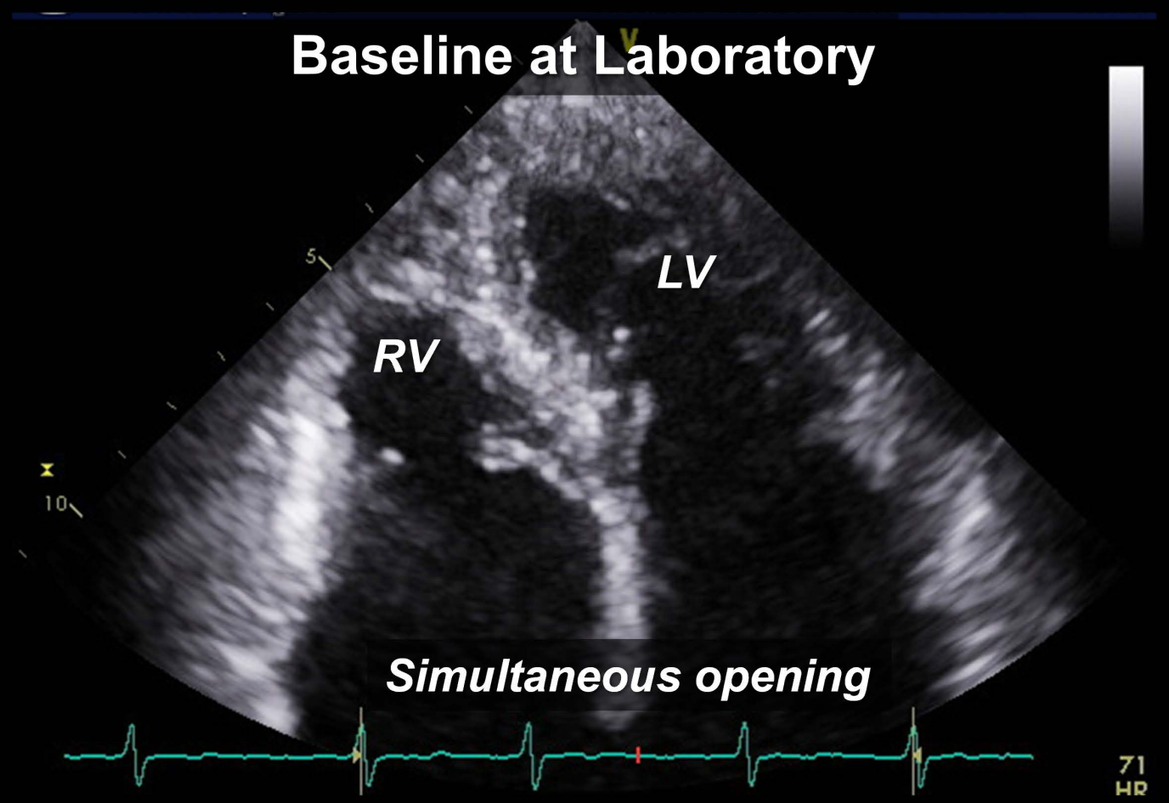
During slow playback, we can notice that both atrioventricular valves open almost simultaneously.

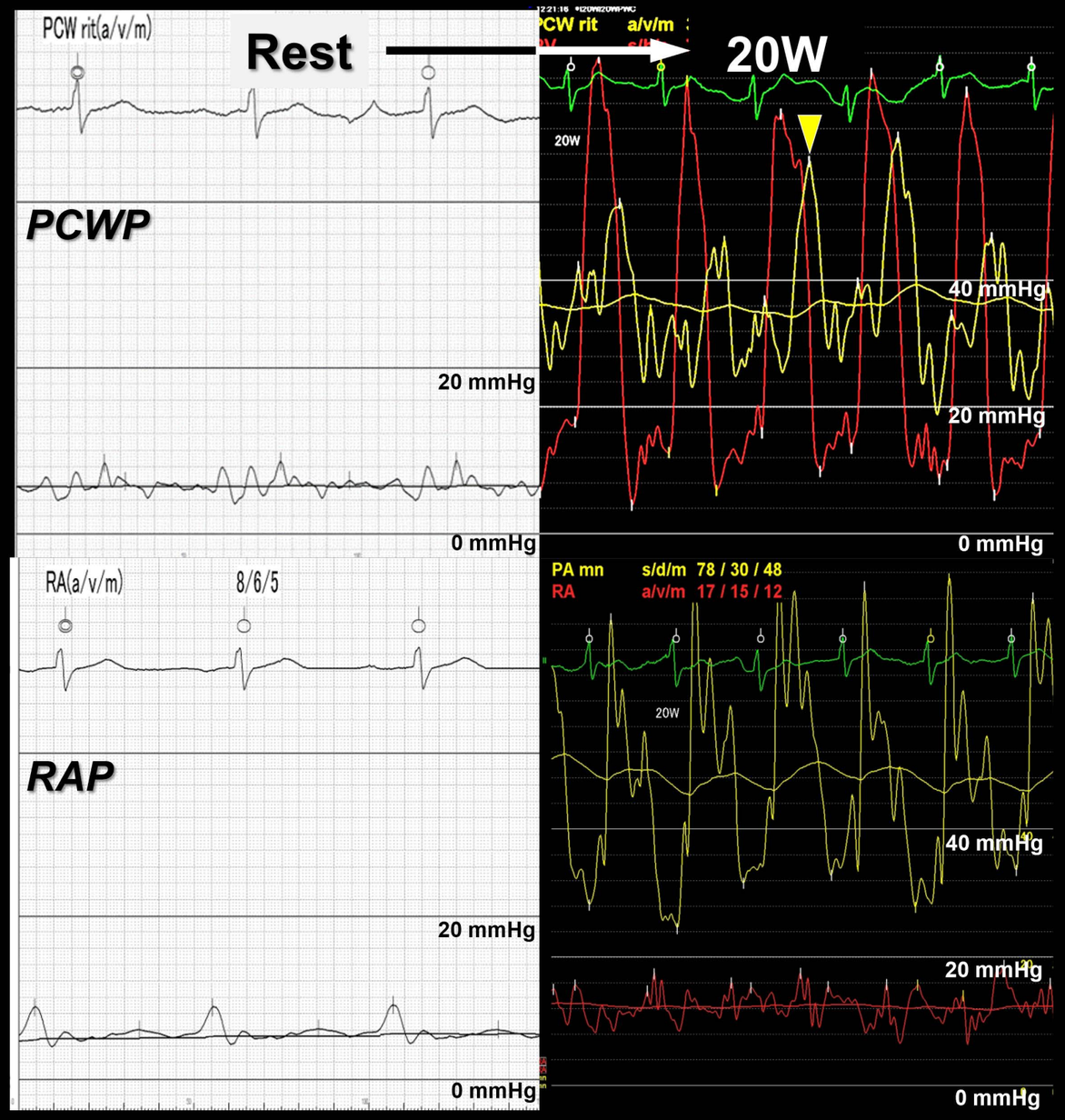
Supplemental Video 4. Order of tricuspid and mitral valve opening during passive leg lifts in

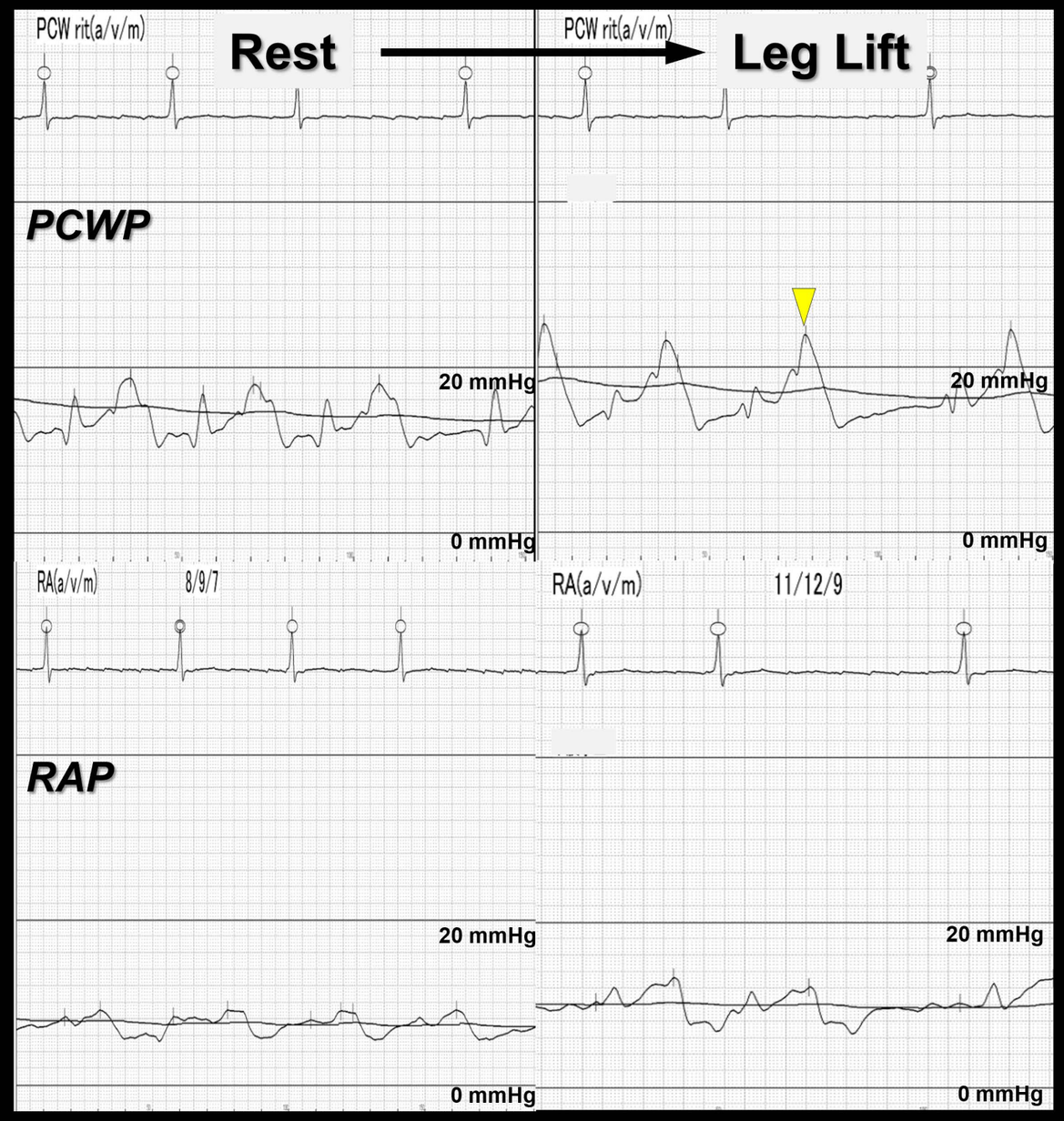
case 2

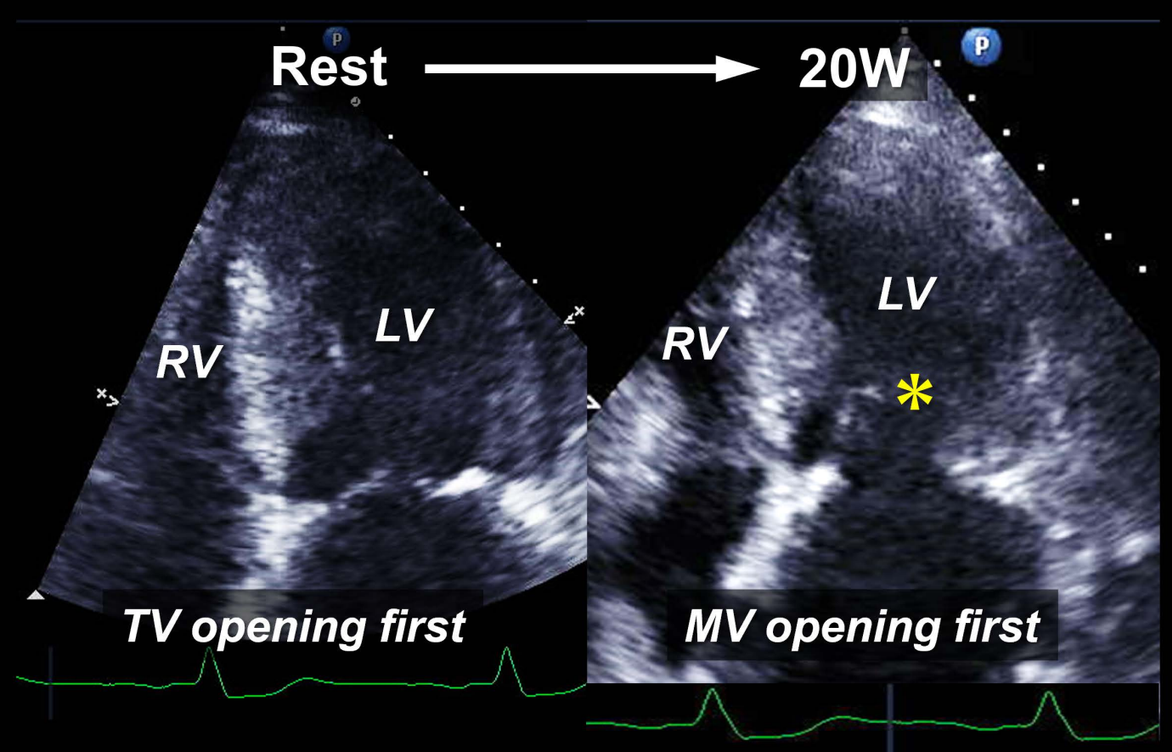
During slow playback, we can appreciate the earlier opening of the mitral valve on the first and third beat whereas both valves open almost simultaneously in the second beat. This image was judged as mitral valve opening first. When beat-to-beat variability was observed, six to nine beats were used, and the majority result was used for the final judgment.

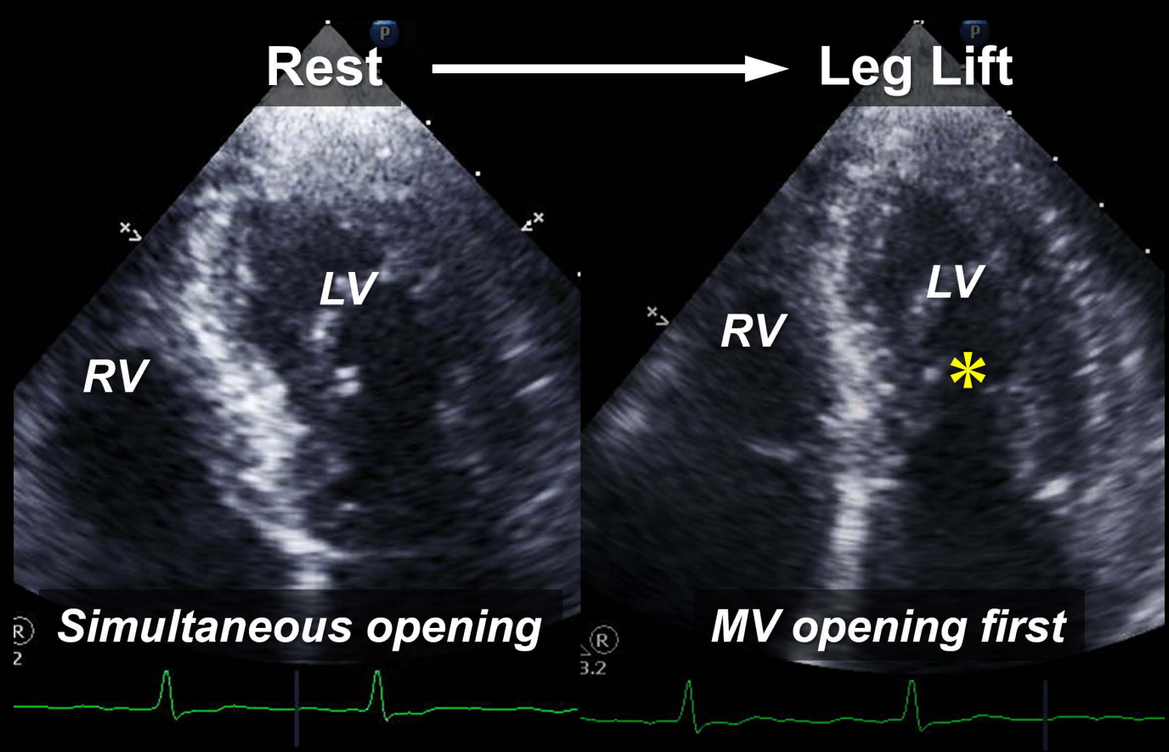

FR 50Hz
13cm
2D
52%
C 50
P Low
HPen
M3
Baseline at Laboratory
RV
LV
TV opening first
JPEG
56 bpm


Baseline at Laboratory
RV
LV
Simultaneous opening
71


PCW rit(a/v/m)
Rest
20W
PCWP
20 mmHg
40 mmHg
20 mmHg
0 mmHg
0 mmHg
RA(a/v/m)
8/6/5
PA mn s/d/m 78 / 30 / 48
RA a/v/m 17 / 15 / 12
RAP
20 mmHg
40 mmHg
20 mmHg
0 mmHg
0 mmHg


PCW rit(a/v/m)
Rest
PCW rit(a/v/m)
Leg Lift
PCWP
20 mmHg
20 mmHg
0 mmHg
0 mmHg
RA(a/v/m)
8/9/7
RA(a/v/m)
11/12/9
RAP
20 mmHg
20 mmHg
0 mmHg
0 mmHg


Rest
20W
RV
LV
TV opening first
RV
LV
*
MV opening first


Rest
Leg Lift
RV
LV
Simultaneous opening
RV
LV
*
MV opening first