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Left Ventricular Contrast Imaging in Echocardiography

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Introduction

Background

Contrast imaging in echocardiography is not a new invention [1]. Several international guidelines are dedicated to this very specific topic. Detailed descriptions about usage, implementation in practice, and safety profile are discussed [2–4]. Overall, in several indications, contrast imaging can be useful and add additional value to comprehensive and emergency echocardiographic evaluations, including stress echocardiography [2–4]. Initially, it is essential to distinguish which type of contrast is required for each indication. This paper will discuss the usage and indications for designated left ventricular (LV) contrast imaging, as well as indications beyond the left ventricle [2, 3, 5, 6].

Materials and Methods

In this white paper, the usability and indications of contrast imaging are discussed. For this purpose, case studies of patients who presented at the state hospital in Steyr in April and May 2025 were evaluated.

System Requirements

For comprehensive evaluation of contrast imaging in echocardiography to detect cardiovascular diseases, high-resolution ultrasound systems like the Samsung cV8, cV7, cV6, or cV5, as shown in Figure 1A, equipped with phased array transducers, are indeed required. These systems offer the necessary features for detailed cardiac assessment.

Figure 1. (A) Samsung cardiovascular cV8 system and (B) recommended probes PA1-5A, PA3-8B, or PA4-12B to perform transthoracic echocardiography for the diagnosis of cardiovascular diseases.

1. Phased array transducers: Samsung PA1-5A, PA3-8B, or PA4-12B for cV8, cV7, cV6 systems, as shown in Figure 1B, are suitable for cardiac imaging, providing a small footprint for intercostal scanning and electronic beam steering capabilities. P1-5AE and PA3-9B are probes for the cV5 ultrasound system.
2. Imaging modes: Following imaging modes are helpful for comprehensive evaluation during contrast imaging for transthoracic echocardiography.
    - B-mode

- M-mode
- Color Doppler
- Pulsed Wave Doppler
- Continuous Wave Doppler
- Tissue Doppler Imaging (TDI)
- Tissue Wave Doppler (TWD)

3. Advanced features:
    - Strain+ LV: For assessing myocardial deformation
    - HeartAssist™: For automatic measurements
    - CEUS+: For adequate visualization of the LV endocardial borders (also known as Left ventricular opacification LVO)
    - StressEcho: For evaluating cardiac performance under stress
    - AutoEF: Measures ejection fraction and left ventricular volumes
    - Cardiac Measurements: For comprehensive quantitative analysis

These systems utilize high-frequency transducers, typically operating between 2-10 MHz, which provide excellent resolution for cardiac structures. The phased array design allows for a sector-shaped image, suitable for cardiac views through limited acoustic windows. The combination of these imaging modes and advanced features enables detailed diagnosis of various cardiovascular diseases, including valvular disorders, myocardial dysfunction, and congenital heart.

How to do LV Contrast

• Before contrast imaging:

Before starting the exam with LV-contrast, it is mandatory first to have the organ in your field of view. You also have to focus on the apical views to have an understanding of which areas you see and which you don't. Focusing on the left ventricle, as seen in the example in Figure 2, the apical regions must be visualized with contrast to achieve opacification and determine if an apical aneurysm is present.

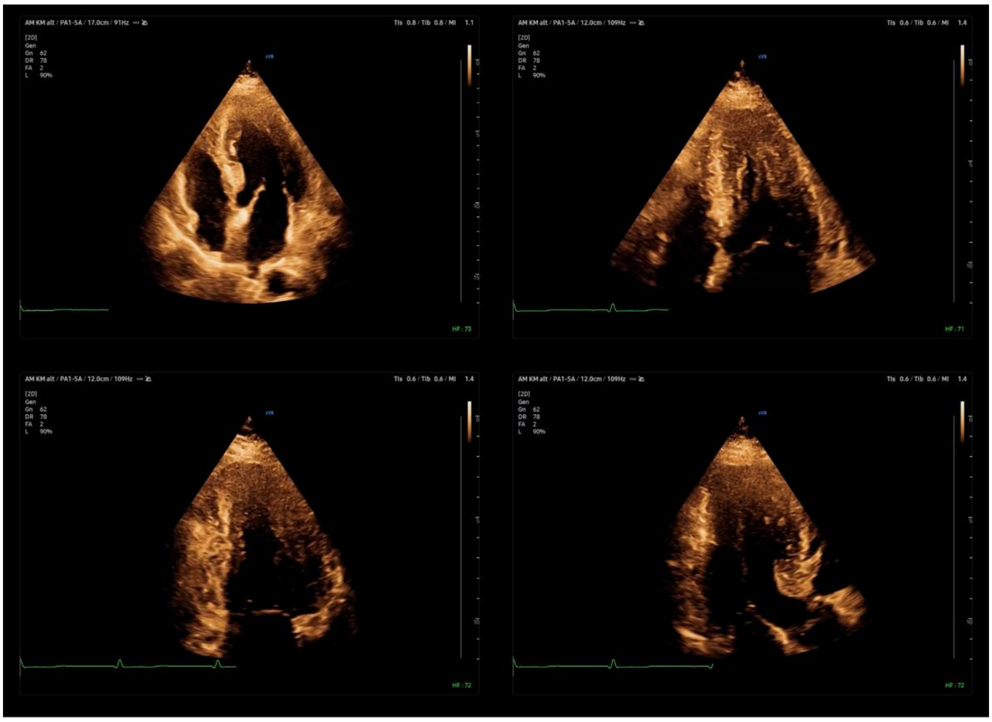

Figure 2: B-Mode Imaging in an apical 4-ChV as an overview, followed by apical focused views – 4-ChV, 2-ChV, and APLAX.

Overall, we perform our comprehensive TTE standard before using contrast (except for the subcostal approach and evaluation of pleural effusions). This helps avoid interference from bubbles, such as in Doppler or Strain measurements [2]. Overall contrast can be used to enhance image quality, not only for suboptimal B-mode images but also for suboptimal Doppler signals, which we cover in a later stage [7].

- ## Preparing the contrast, tips, and tricks for the application:

In our setting, we use ultrasound contrast agent as available in Austria. We prepare one ampulla as seen in Figure 3. Keep in mind that you should not shake the contrast too harshly, as, from our experience, some bubbles might be lost. So, only shake the contrast slightly. Furthermore, please note that if you use the syringe provided in the package for a patient other than the intended recipient, a new syringe is required. Once used, the syringe should not be reattached to the ampulla. Be aware that, you do not apply contrast through a hindrance or a filter. That can also lead to the destruction of the bubbles.

We use only 1 mL, so from one ampulla, we can perform five to six contrast studies. Sometimes, especially in severely obese patients, it may be necessary to apply a second dosage of contrast. We use 0.5 to 1 mL again. In our setting, the application of 0.5 mL was too little and led to inefficient opacification of the LV; however, it can be achieved by following the current guidelines [2, 3]. Mostly, we rely on a bolus method; for continuous application, a special device is required that can be used for perfusion stress echocardiography [1, 2].

Figure 3: Preparation of LV-contrast – how it is done in the state hospital of Steyr, department of Cardiology, Nephrology and Intensive Care Medicine.

- ## Settings:

In our setting, we use a preset specified by the respective vendor and adjust the color maps and individual settings according to the patient. The most important setting (besides the color maps) is the mechanical index (MI). We use an MI that is mostly in the range of 0.18 to 0.22. If you choose an MI that is too high (in normal B-Mode imaging, the MI typically ranges from 0.8 to 1.1, depending on the vendor), the bubbles will disappear quickly. If it is too low, the image quality can be suboptimal. Overall, an MI of 0.1 should be possible with only 0.5 mL of contrast agent. In our setting, we do not achieve this scenario to a degree where every user feels comfortable with the settings. In general, all features that smooth the image should be turned off initially.

Moving on to the actual application, in our setting, we gather informed consent and ask the patient for any allergies from contrast agents, specifically including sulfonamides.

- ## Application:

One milliliter is applied through the venous access, and it takes some heartbeats (normally 2-4 heartbeats) to observe opacification in the right atrium (RA). If the cardiac output is reduced, it can take significantly longer (>10 heartbeats). For central lines, port-a-caths, or other central venous catheters, opacification can be achieved immediately.

Initially, a rapid flush of contrast agent will occur into the right atrium (RA) and right ventricle (RV), resulting in a hyperechoic appearance in the apical regions that obstructs the basal regions. Next, the left atrium fills with contrast, and the left ventricle (LV) follows. The same process occurs with the LV; initially, the apical regions are very bright, while the basal ones are less well visible as shown in Figure 4.

Figure 4: Contrast agent application with initial opacification of the RA, the RV, followed by the LA & LV, with attenuation of the apical regions.

This timeframe can already be used to see the apical regions and diagnose aneurysms or thrombi. Afterwards, the LV will be filled with contrast agent, and an optimal visualization of the LV will be achieved. In this timeframe, you should acquire the views for LV volume and ejection fraction measurements. Also, the wall thickness of specific regions can be optimally visualized in Figure 5.

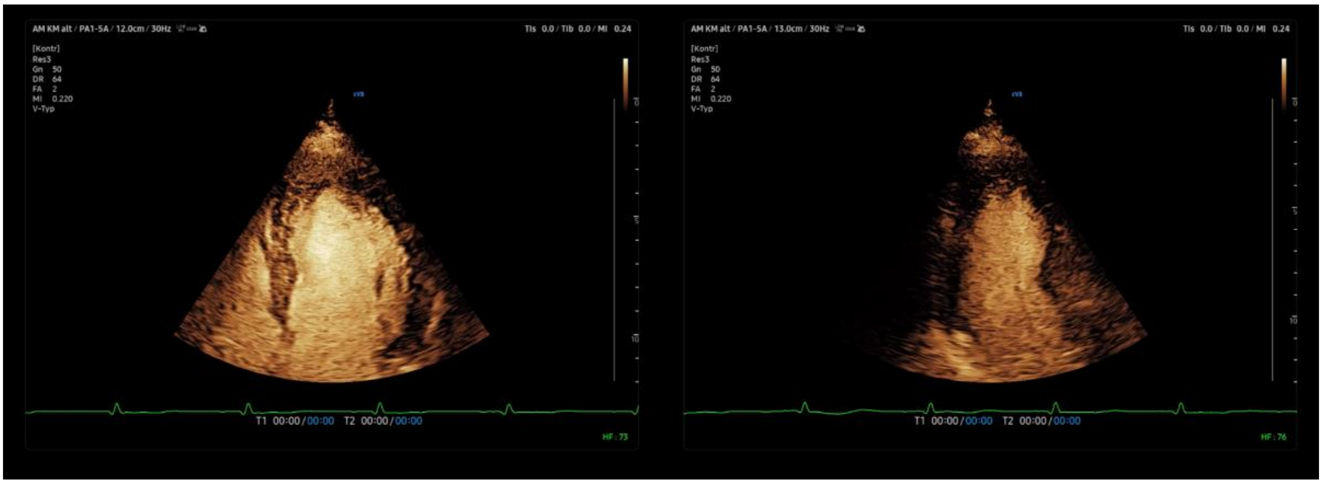

Figure 5: Full opacification of the left ventricle, where measurements such as volumes and LVEF should be executed.

For measuring the wall thickness, a measurement in the parasternal long or short axis is also possible (PLAX, PSAX). To some degree, contrast can also make sense in scanning the subcostal area as illustrated in Figure 6.

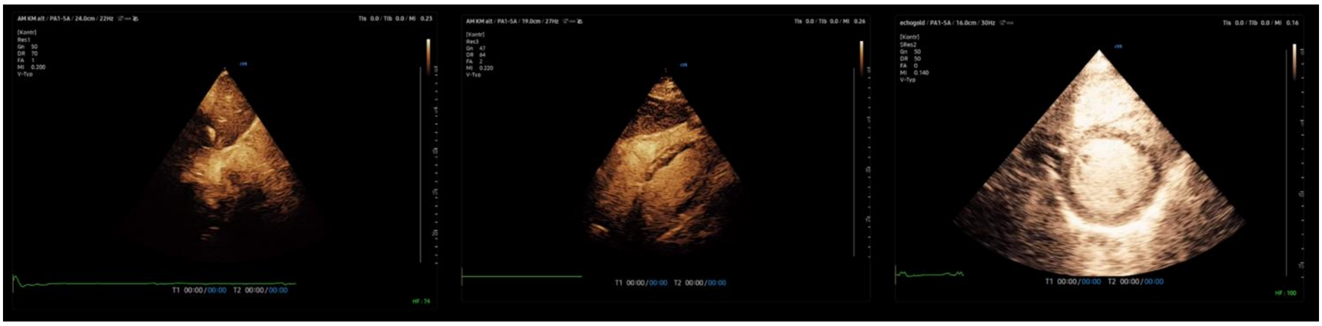

Figure 6: Loop 1 contrast opacification is seen in the SVC filling the RA, loop 2 showing a subcostal 4-ChV in a patient with atrial flutter and HFpEF visualizing the cardiac chambers, loop three shows a patient with group 3 pulmonary hypertension and a subcostal short axis to visualize the interventricular septum (IVS) and RV dilatation and prominent trabeculation.

The one indication where contrast is used most extensively is in patients with reduced image quality and a lack of visibility of two or more myocardial segments in a 17-segment model [2, 3, 8]. However, more indications are described in the literature [5, 7, 9, 10]. For example, volumetric measurements of the left ventricle, thrombus detection in both the left and right ventricles, evaluation for cardiac tumors, assessment of other tumors, and, especially important, aneurysm detection [1, 2, 5, 7, 10].

Case Study 1 – a case of hypertrophy

A female patient, 68 years of age, presents with dyspnea, a reduction in exercise capacity, and intermediate, not atypical chest pain. Coronary artery disease was excluded in an outpatient setting, and she was referred to our echo laboratory for a specialized evaluation for LV-thrombus in the apical regions, which lacked proper image quality. In Figure 2, you can see how B-mode imaging displays the apical four-chamber. In the focused views, it is already possible to visualize that the left ventricle is thickened, especially in the apical regions. For this specific case, two questions remain for contrast. Firstly, how thick is the myocardium, especially in the apical regions, as this may be an apical form of hypertrophic cardiomyopathy (aHCM) [2, 11]. Secondly, is there an apical aneurysm and LV-thrombus to be found there? With B-mode imaging, it is often overlooked that the supra-apical regions are truly aneurysmatic in patients with HCMP [2, 11, 12].

In Figure 3, you can review again how the contrast agent is prepared. In Figure 4, you can see that the contrast is applied and initially fills the right atrium, then the right ventricle, continues with the left atrium, and finally the left ventricle. Continuing in the left ventricle, there is a short period of time when the contrast is very bright in the apex and less bright in the basal regions. That is always visible in the ventricles, and you simply have to wait until the LV is entirely opacified to a similar degree. This effect is called Attenuation. When the entire LV is opacified, you can report and save the imaging of the LV, including a four-, two-, and three-chamber-view (apical long axis) as shown in Figure 5 [2].

In this specific case, the diagnosis was aHCM, which was verified with MRI, no apical aneurysm, and no thrombus was present [2].

Case Study 2 – wall motion abnormalities and systolic LV dysfunction

A 72-year-old patient with a known history of coronary artery disease and normal ejection fraction (regular follow-ups without contrast imaging were performed) decompensated and is in a stationary setting on our ward. The patient has no heart failure medication established, his progressive dyspnea was treated with oral diuretics for some time, but at the time of presentation in our hospital, he was not able to be included in an outpatient care (severe symptoms, moderate pleural effusion). He was decongested and then presented in our echo laboratory. In Figure 7, the B-mode imaging of this patient shows severe foreshortening and suboptimal imaging of the heart [7, 13].

In this case, contrast was used to evaluate for wall motion abnormalities and to verify if a truly normal ejection fraction was evident. In Figure 8, apical and anterior wall motion abnormalities are visible [13].

In this specific case, due to still a suboptimal image quality, the contrast settings were changed to create a "rougher" image – MI was increased to a very small degree, gain was increased, the dynamic range was significantly decreased and a specific setting to smoothen the image, which we use in a low intensity in our normal contrast setting, was switched off entirely, creating a more optimal delineation of the endocardial walls and better delineation of the endocardial borders over all. In the 4-ChV, the mid- and basal segments are hypercontractile while the apical segments show WMA as a compensatory mechanism. In the 2-ChV and the APLAX, the apical WMA looks even more prominent, and the patient was diagnosed with HFrEF (ejection fraction we graded as 35-40%) in ischemic heart disease, needing a different kind of therapy compared to HFpEF, seen in Figure 9 [2, 13].

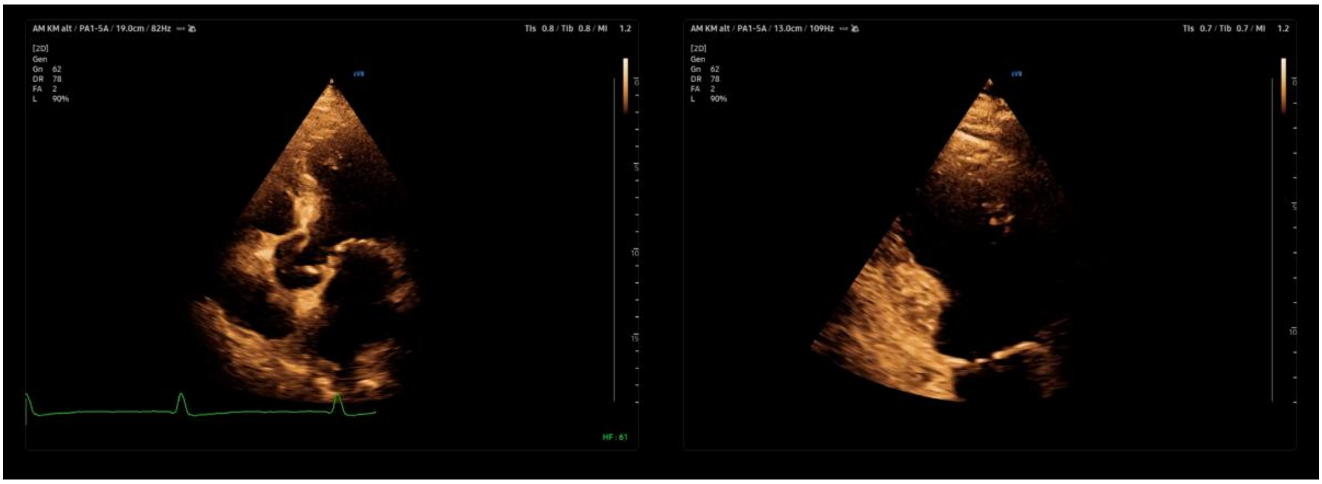

Figure 7: B-mode imaging showing severe foreshortening and suboptimal imaging of the heart, WMA depiction is significantly limited.

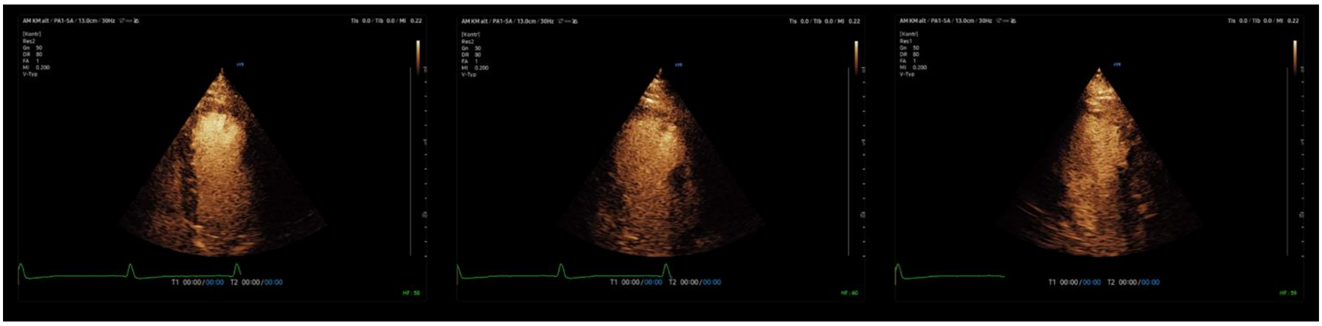

Figure 8: WMA apical and anterior are visible in contrast imaging.

Figure 9: Diagnosis of HFrEF due to contrast usage in a patient with CAD.

Case Study 3 – hypertrabeculation with heart failure

In a follow-up, a patient with known heart failure with hypertrabeculation presented mildly symptomatic [5, 7, 11]. The patient was diagnosed with an ejection fraction of 25-30%, having been in HFimpEF at the last visit, with an EF in the range of 40-45% [13]. In this specific case, the LV volumes, EF, and the evaluation of the trabecula for excluding apical thrombi were important, and contrast was used. In Figure 10, a 4-ChV without and with contrast is displayed, showing the true left ventricular (LV) delineation with contrast, which misses some volume due to the hypertrabeculation of the apex. There were no thrombi present, and the ejection fraction and left ventricular volumes remained stable.

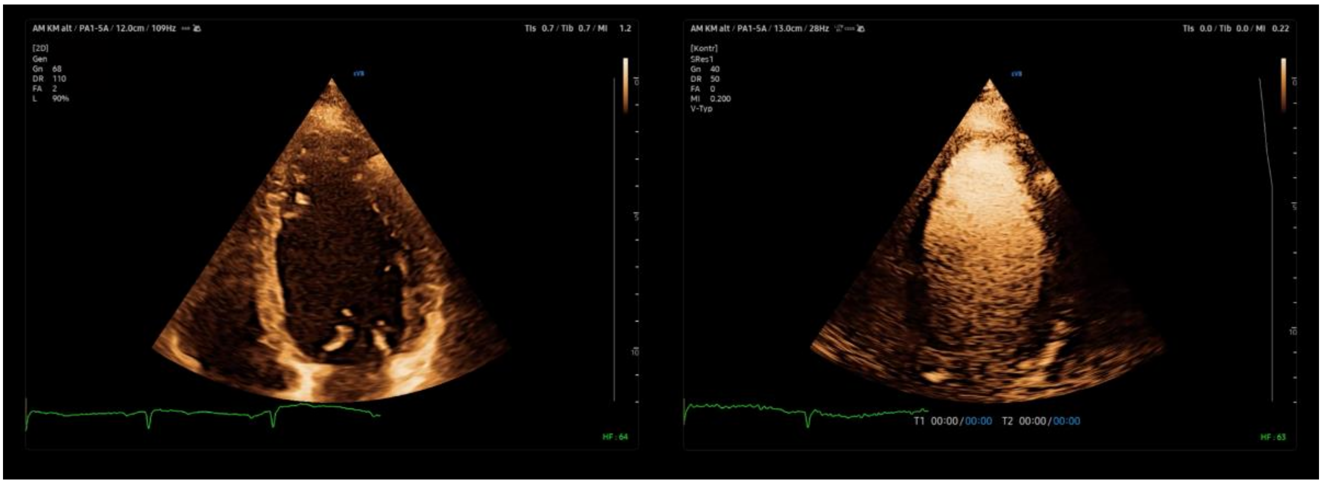

Figure 10: Hypertrabeculation with heart failure – without and with contrast imaging of the LV to visualize the true LV volumes & EF, no thrombus is visible in the apical hypertrabeculated regions.

Future directions

In many countries worldwide, contrast imaging is still underutilized [14]. This can be a result of a lack of contrast, as well as a lack of specific presets in certain machines [2].
That holds true not only for the left ventricle, but also for other indications that have to be mentioned. In specific situations, contrast can be used to visualize other cardiac chambers or enhance Doppler signals. In Figure 11, two pulsed-wave Doppler signals of the pulmonic valve from a subcostal short-axis view are shown to evaluate for pulmonary hypertension. The first signal still shows artifacts; in the second example, the gain is reduced to achieve optimal visualization of the PW-Doppler curve [2, 7].

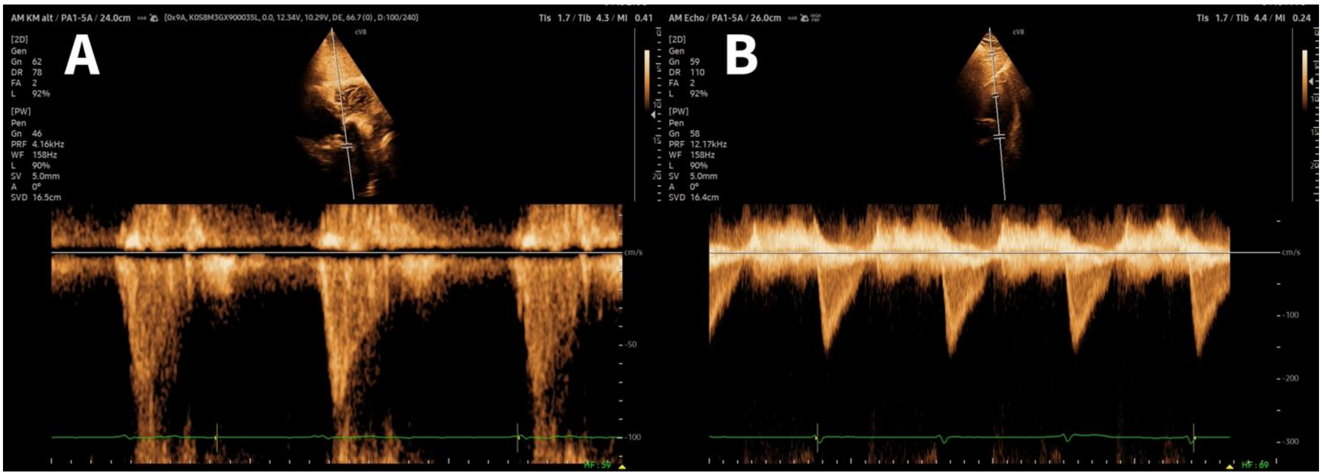

Figure 11: PW-Doppler signals to enhance the quality of the Doppler, a) still over-gained signal, b) optimally adjusted signal. Those are just some examples of the wide possibilities for contrast imaging.

Conclusion

In conclusion, contrast imaging in several settings contrast imaging shows that it can improve image quality, being affordable, and more widely available compared to cardiac MRI you would need as an alternative imaging method if LV-volumes are not properly measurable, thrombi not safely excludable or simply structures visible which cannot be interpreted or understood otherwise.

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