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Refining Auscultation of Left Ventricular Assist Devices: Insights From Phonocardiography

Faris Araj*, Alpesh Amin, Julie Cox, and Pradeep Mammen

University of Texas Southwestern Medical Center

*Corresponding author: *faris.araj@utsouthwestern.edu*

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There have been over 15,000 continuous flow left ventricular assist devices (LVADs) implanted in the United States[1]. As the care of these patients expands into the general community, it is important for providers at all levels to be familiar with the sound of a normal LVAD. The sound generated is normally described as an “LVAD hum”. That non-descriptive term may be misunderstood as all LVADs or “hums” are the same, when in fact the sound produced is unique to each device. Another common misconception held by some providers, is the absence of heart sounds in a normally functioning LVAD. Using apex phonocardiography we were able to better visualize these unique characteristics (Figures 1-4, phonocardiograms of three United States Food and Drug Administration approved durable LVADs), and suggest a refined description of each device sound. The recordings were made on normal functioning LVADs using the EKO Core stethoscope attachment (EKO, Berkeley, CA).

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Abbreviation	Meaning
M	Monotone
Blue arrows	Native heart sound
Green arrows	Abrupt decrease in speed
Red arrows	Abrupt increase in speed
CT	Crescendo tone
DT	Decrescendo tone
CD	Crescendo-decrescendo
AP	Artificial pulse

Figure 1: HeartMate II

The HearMate II (Abbott, Inc. Abbott Park, IL) device is a continuous flow LVAD that uses axial flow technology.[2] Normally the pitch is medium to high in intensity. The phonocardiogram shows a predominantly uniform or monotone (M) sound without fluctuations in sound amplitude, irrespective of native heart sounds (arrows).

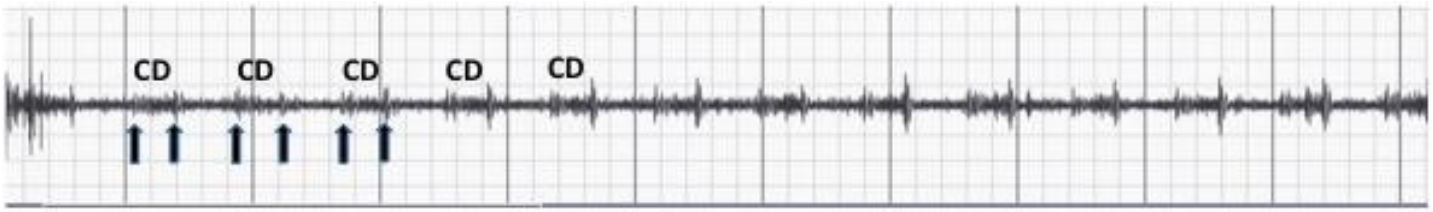

Figure 2: HeartWare- Lavare Cycle off

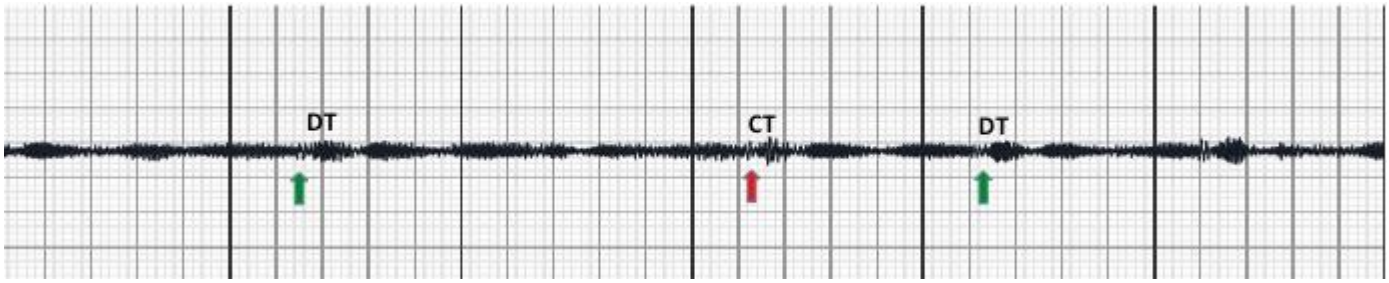

Figure 3: HeartWare- Lavare Cycle on

The HeartWare (Medtronic, Minneapolis, MN) is a continuous flow LVAD that uses centrifugal flow technology.2 Normally, the pitch is medium to high in intensity. The phonocardiogram shows a baseline monotone sound interspersed with repetitive crescendo-decrescendo (CD) within the confines of the native first and second heart sound (either aortic, pulmonic, or a combination). The sound is louder during systole.

The HeartWare operation can be set to increase washing of the left ventricle and pump, termed the Lavare Cycle. This cycle consists of abrupt speed decrease (arrow and decrescendo tone (DT) for 2 seconds, followed by speed increase (arrow and crescendo tone (CT) for 1 second, followed by the return to baseline speed settings (arrow and decrescendo tone (DT) . The cycle is repeated every 60 seconds.

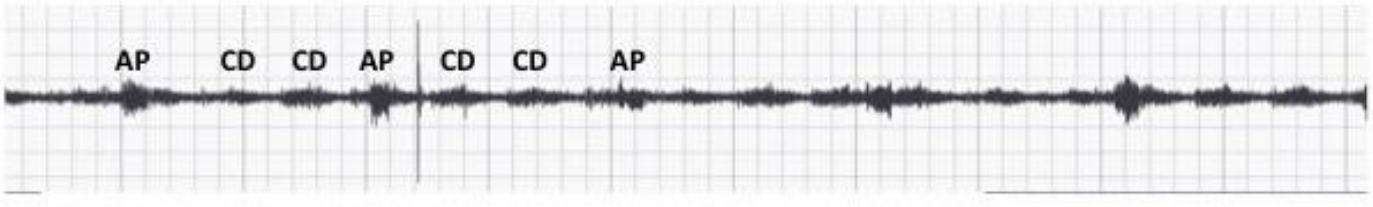

Figure 4: HeartMate III

The HeartMate III (Abbott, Inc. Abbott Park, IL) is a continuous flow LVAD that uses centrifugal technology.[3] Unique to this device is the presence of an artificial pulse that occurs every 2 sec. Normally the pitch is medium in intensity. The phonocardiogram shows a baseline of crescendo decrescendo sound (approximately 2-3 cycles), which is then interrupted by a higher amplitude sound

with components above and below the baseline. This latter sound is generated by the artificial pulse cycle.

Discussion

It is well known that the use of cardiac auscultation skills to identify cardiac pathology among trainees is poor, and that the emphasis on this skill set has diminished.[4,5] Data suggest that incorporating digital stethoscopes in the learning process, can improve trainee auscultatory performance. [6,7] Since auscultation of the pump is an important part of the physical examination of a patient with a durable LVAD, an audio-visual learning experience (e.g. phonocardiography) may be a better tool for teaching. Additionally, the sounds can be saved and played back to increase familiarity with normal device sound.

It is the authors' belief that a more refined understanding of an LVADs unique sound profile may help clinicians identify changes in sound that may reflect underlying device pathology, immediately at the bedside. Slaughter et al used an aquatic hydrophone system to detect 1st generation pulsatile LVAD device failure.[8]

More recently Kaufmann et al, and Yost et al used analysis to evaluate to study current generation continuous flow LVADs. The former analyzed the HeartWare in vivo, and the latter the Heartmate II both in vitro and in vivo. The presence of a third harmonic sound was suggestive of pump thrombosis in the HeartWare device, and a reduction of spectral energy over a sound frequency range in the HeartMate II.[9,10] Although both groups used more complex and sophisticated sound analysis than simple phonocardiography, the concept was simple: a thrombus on the rotor leads to imbalance, and that can lead to a change in device sound.

The main findings from our data:

1. Not all LVAD hums are the same- each device has its own unique sound characteristic.

2. The emitted sound can be recorded using a modern-day stethoscope, or stethoscope attachment.

3. The sound generated can be reviewed and analyzed.

4. To our knowledge no other publication has comprehensively displayed the phonocardiograms of the three main FDA approved durable LVADs.

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