ASSESSMENT OF MECHANICAL HEART VALVE INTEGRITY IN PATIENTS USING ACOUSTIC TECHNIQUES REQUIRES ULTRAHIGH FREQUENCY BANDWIDTH HIGH FIDELITY MICROPHONES

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Introduction

Today, more than 200,000 prosthetic heart valves are yearly implanted world wide. Two groups of prosthetic devices are available: the biological and the mechanical heart valves. Most commonly, the mechanical heart valve is chosen for younger patients. The mechanical heart valve devices are thought of as safe and well tested devices with patient life endurance. However, valve dysfunction may still be a potential problem.

The most known failures of valves, which did pass regulatory tests before release, are the Björk-Shiley Convexo-Concave (strut fracture) and the Edwards Duromedics (cavitation deterioration of leaflets). Besides material failures, devices may also be compromised due to panus over growth and thrombus formation (which was a serious problem with the Medtronic parallel valve).

Such complications may be fatal, and it would be desirable to be able to predict valve dysfunction at an early (non-symptomatic) stage. No methods have yet been developed to access valve integrity non-invasively. However, several studies have shown that the acoustic fingerprint of the valve closing sound may hold viable information on valve performance. As a primer in developing an acoustic diagnostic tool, a framework of valve fingerprints and a technical feasible system must be developed.

The aim of this study was therefore to investigate the acoustic signature of mechanical heart valves and to characterize the frequency content of the closing sound.

Materials and Methods

The study material comprised the Omnicarbon valve series (N = 8) with sizes ranging from 19 mm – 33 mm. Closing sounds were recorded in an anechoic chamber. The microphone applied had a bandwidth of approximately 150 kHz. The valves were operated in air avoiding fluid disturbances (such as turbulence and cavitation) to the acoustic signature. The energy spectral density was calculated based on 30 closing sounds for each valve. The bandwidth of the closing sounds was determined as the frequency below which 97.5% of the signal energy was located.

Results

Each valve had the majority of acoustic energy in the ultrasonic range. The closing sounds contained signal component up to and above 40 kHz with distinct resonance frequencies. The bandwidths of the valves were in the range 44.0 kHz – 124.7 kHz but with no relationship to valve size. The spectral presentations were unique for each valve with no common pattern, despite the same geometrical design of different scale.

Conclusions

When mechanical heart valves are examined based on acoustic techniques it is imperative to accommodate the needs for high frequency equipment. The system should have a linear response up to at least 150 kHz. This is also supported by several cavitation studies that indirectly have suggested that closing sounds may contain components near 100 kHz.

Each valve has a unique spectral appearance and for auto reference the patients should have recorded their valve closing sound within one year post operatively. For such recordings, a high bandwidth hydrophone could be used beneficially.

This study provides important information enabling the development of acoustic assessment of mechanical heart valve integrity.

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