Pacemaker Risk Analysis

1. Bradycardia

1.1 Slow atrial rate

a. Hazardous situation:

Pacemaker cannot increase heart rate to be normal (60-100bpm)

b. Sequence of events:

Heart or pacemaker generate an atrial event->no atrial event after 1 second

c. Harm:

Bradycardia remains, patient suffers dizziness from insufficient blood supply

d. Risk Control Measures:

Suppose AEI(Atrial Escape Interval) is set to 850ms, If a ventricular event is detected, and 850ms passed without any atrial event happens, pacemaker should be programed to generate an atrial pacing, so that heart rate is controlled within normal range.

1.2 Slow ventricular rate

a. Hazardous situation:

Pacemaker cannot increase heart rate to be normal (60-100bpm)

b. Sequence of events:

Heart or pacemaker generate a ventricular event->no ventricular event after 1 second

c. Harm:

Bradycardia remains, patient suffers dizziness from insufficient blood supply

d. Risk Control Measures:

If a ventricular event is detected, pacemaker should be programed to generate a ventricular pacing within 1 second but no less than 0.6 second if no ventricular event happens during the interval; If an atrial event is detected and 150ms passed without any ventricular event happens, pacemaker should be programed to generate a ventricular pacing, so that heart rate is controlled within normal range (set Atrial-ventricular interval as 150ms).

2. Tachycardia (pacemaker mediated)

2.1 Atrial tachycardia response (DDD)

a. Hazardous situation:

Pacemaker generate ventricular pacing continuously and rapidly while atrial fibrillation, turning supra-ventricular tachycardia to ventricular tachycardia

b. Sequence of events:

Heart generate an atrial sensing->AV node block contraction-> no ventricular event after AVI time->pacemaker generate a ventricular pacing

c. Harm:

cause ventricular tachycardia, patient suffers extreme discomfort, death if not mitigated.

d. Risk Control Measures:

Upon detection of supra-Ventricular tachycardia(SVT), program pacemaker to switch to single chamber pacing mode to detach A-V synchrony, switch back to dual chamber mode after SVT terminates.

2.2 Endless-loop tachycardia (DDD)

a. Hazardous situation:

Random heart event triggers retrograde conduction, causing inappropriately fast ventricular events.

b. Sequence of events:

A premature ventricular contraction happens randomly->an atrial sensing is triggered by retrograde->pacemaker generate a ventricular pacing after AVI time->the VP-AS-VP pattern persists, resulting in endless-loop tachycardia

c. Harm:

Fast ventricular rate no longer reflect physiological need of patient, causing discomfort

d. Risk Control Measures:

When ventricular rate is at Upper Rate Limit and 16 similar consecutive intervals are detected, extend PVARP(Post-Ventricular Atrial Refractory Period) to be longer(e.g. from 100ms to 500ms) for once, thus makes an atrial event unsensed to end the loop.

2.3 Pacemaker Syndrome (VVI)

a. Hazardous situation:

Atrial and ventricular contractions are too close to each other

No A-V synchrony

b. Sequence of events:

Pacemaker generate an ventricular pacing->heart generate an atrial event right after

c. Harm:

cause cardiac arrhythmia, patient suffers discomfort.

d. Risk Control Measures:

Suppose AVI(Atrial-ventricular interval) is set to 150ms, and LRI(Lower Rate Interval) is set to 1s, AEI(Atrial Escape Interval) is set to 850ms.

If an atrial event is detected and 150ms passed without any ventricular event happens, pacemaker should be programed to generate a ventricular pacing. If a ventricular event is detected and 1s passed without any ventricular event happens, pacemaker should also generate a ventricular pacing. If a ventricular event is detected and 850ms passed without any atrial event happens, pacemaker should generate an atrial pacing.

2.4 Pace on T wave (VOO)

a. Hazardous situation:

Pacemaker triggers Ventricular Fibrillation

b. Sequence of events:

A ventricular event happened->pacemaker generates a ventricular pacing within ventricular refractory period->ventricular fibrillation begins

c. Harm:

Patient suffers dizziness. death if not mitigated.

d. Risk Control Measures:

Introduce sensing, filter ventricular electrogram transmitted to the sensing amplifier. Program the pacemaker to generate a ventricular pacing only when LRI (Lower Rate Interval) time passed after a ventricular sensing or AVI (Atrial-Ventricular Interval) time passed after an atrial event.