Strength / Duration

The ability to capture the myocardium can be defined by a strength-duration curve. This is a plot of the pulse amplitude versus pulse duration at threshold. As the pulse duration is progressively decreased, the pulse amplitude increases in order to maintain capture. At extremely narrow pulse durations, the stimulus will be ineffective no matter how high the pulse amplitude. The pulse amplitude required to effectively stimulate the heart decreases as the pulse duration increases. At pulse widths above 1.5 to 2.0 ms, however, further increases in pulse duration usually will not result in a concomitant decrease in pulse amplitude. The voltage level at which a further increase in pulse duration does not result in a continued fall in pulse amplitude is termed the RHEOBASE. The pulse duration threshold at twice the rheobase

Figure 14. Schematic diagram of a capture threshold strength-duration curve. If one were to draw a rectangle corresponding to the amplitude and pulse duration of the pacemaker pulse and it all fell to the left of the curve, the output pulse would not capture. If any portion of it fell to the right of the curve, capture would be present. The percent of the pacemaker pulse to the right of the curve would define the margin of safety to assure continued capture during the normal waxing andwaning of the capture threshold during the course of the day (7).
Strength / Duration

is termed the CHRONAXIE POINT.

A schematic strength-duration curve is shown below. A pacemaker pulse which falls to the left of the curve will be ineffective while one in which a portion of the pulse falls to the right of the curve will be effective.

Capture is as interesting a phenomenon as is the concept of margin of safety. Margin of safety has been reported as multiples of the capture threshold. I prefer to program the output of the pacemaker to obtain a margin of safety in terms of energy.

The formula for energy is:

\[ \text{ENERGY} = \text{Volts} \times \text{Current} \times \text{Pulse Duration} \]

Based upon Ohm’s Law:

\[ \text{Current} = \frac{\text{Volts}}{\text{Resistance}} \]

Substituting the equation for current from Ohm’s Law into the formula for energy:

\[ \text{ENERGY} = \frac{\text{Volts}^2 \times \text{Pulse Duration}}{\text{Resistance}} \]

Hence, based upon this formula:

* Doubling the pulse amplitude will quadruple the delivered energy
* Doubling the pulse duration will only double the delivered energy
* Halving the pulse amplitude reduces the delivered energy by a factor of four
* Halving the pulse duration reduces the delivered energy by a factor of two
If one plots the threshold energy versus the pulse duration, an interesting curve results. At narrow pulse durations, the energy required to pace the heart is extremely high due to the square of the pulse amplitude. The amount of energy necessary to effectively stimulate the heart progressively decreases as the pulse duration approaches the chronaxie point. Once the chronaxie point is passed, there is a progressive rise in energy threshold as the voltage threshold approaches the rheobase. While the voltage does decrease, the rate of decrease is progressively less and no longer compensates for the progressive increase in the pulse duration. Once the rheobase is reached, the effective voltage fails to decrease further, even at greater pulse durations, resulting in a marked rise in “capture threshold,” with continued increases in pulse duration. The most efficient point with respect to energy delivery and providing good margin of safety in all directions is an increase in the voltage threshold at the chronaxie point (18). The chronaxie point in most pacing systems is commonly between 0.4 and 0.6 ms which explains why most manufacturers ship their pacemakers at a nominal pulse duration, between 0.4 and 0.6 ms.
Atrial Based & Ventricular Based

Fig. 6–20. Top, With ventricular-based timing in patients with intact atrioventricular (AV) nodal conduction after atrial (AR) pacing, the sensed R wave resets the ventriculoatrial (VA) interval. The base pacing interval consists of the sum of the AR and the VA intervals; thus, it is shorter than the programmed minimum rate interval. Bottom, With atrial-based timing in patients with intact AV nodal conduction after AR pacing, the sensed R wave inhibits the ventricular output but does not reset the basic timing of the pacemaker. There is AR pacing at the programmed base rate. ARI, interval from paced atrial event to intrinsic QRS; AVI, atrioventricular interval; LRL, lower rate limit. (Reproduced with permission from Siemens-Pacesetter.)