Results with the SO₂-Controlled Pacemaker

E. Alt, A. Wirtzfeld, and R. Heinze

Summary: Currently available physiological pacing systems do not fully restore rate regulation, especially with respect to little or no atrial response to activity. Other biological parameters, detected by sensors, may provide the physiological responsiveness necessary for rate-regulating pacemakers. An optical sensor using mixed venous oxygen saturation may be the ideal parameter for such a pacing system. At present, further research is necessary to elaborate a suitable algorithm for optimal rate control.

As described elsewhere, a variety of biological parameters have been proposed and are suitable for a rate-responsive pacing system.

For different reasons, we believe that mixed venous oxygen saturation, measured as HbO₂ saturation, represents a very good physiological parameter for pacing regulation. Unlike the pH value or, to some extent, the blood temperature, the body has no marked O₂ pools, and venous O₂ saturation is exclusively determined by the cardiac output and the peripheral O₂ demand. By raising oxygen consumption any increase in physical activity results in an increment of the O₂ transporting capacity, which is accomplished by two mechanisms:

- an increase in cardiac output, and
- an enhancement of oxygen extraction from arterial blood.

This latter change leads to an increase in arteriovenous oxygen difference which is a consequence of a drop in mixed venous oxygen saturation as arterial saturation remains unchanged. With raised oxygen consumption the mixed venous HbO₂ saturation falls promptly and quickly reaches a new plateau.

The extent of the drop in HbO₂ saturation depends on the level of exercise as well as on cardiac performance and thus on cardiac output (Fig. 1).

*Fig. 1.* Mixed venous oxygen saturation (SO₂) in a healthy volunteer during increasing physical work. 1 to 2 minutes after the beginning a new plateau is attained with a distinct relation between the level of exercise and the fall in SO₂. There is a rapid increase in SO₂ after the test is finished.
Figure 2 shows the different hemodynamic results and the respective mixed venous oxygen saturation (SO₂). The data were measured on 10 pacemaker patients at rest and during two exercise tests with 25 and 50 watts, each performed either with a rate VVI 70 or with atrial triggered VDD pacing. One can see that during VVI ventricular stimulation the cardiac output (CO) rises only slightly compared with the increase during VDD stimulation. Compensatorily the equal oxygen uptake by physical work is brought about by enhanced oxygen extraction from the blood, according to the formula oxygen uptake (VO₂) = cardiac output (CO) x arteriovenous oxygen difference (AVDO₂).

**Fig. 2.** SO₂ and cardiac output (CO) at rest and during exercise with 25, 50 and 75 watts. Ventricular stimulation with a rate of 70 (VVI 70) results in a smaller increase in CO, and thus in enhanced oxygen extraction and reduced SO₂ at a given level of exercise, whereas a VDD stimulation causes reduced oxygen extraction due to the enhanced CO.

**Fig. 3.** Cross-section of the sensor. One can see the light emitting diode (LED) and the phototransistor that measures the reflected light. Two elements are shown, situated around the longitudinal axis of the lead.