

Abstract

The baroreceptor is a stretch receptor which detects changes in pressure in arterial blood vessels. Baroreceptor nerves inform the brainstem of changes in blood pressure, which then influences sympathetic and parasympathetic nervous activity to counteract that change. Due to the relationship between essential hypertension, sympathetic nervous activity and the baroreflex, there is some debate in the literature about whether the baroreflex can act as a long-term controller of blood pressure. This debate has increased in recent years, due to the high prevalence of essential hypertension in all societies and the introduction of new technologies to counteract drug-resistance hypertension. The baroreflex has become a source of debate due to the complex physiological feedback control that regulates blood pressure and due to new stimulating electrical devices, which have shown promising results in reducing drug-resistant essential hypertension.

This investigation studies the baroreceptor's role as a sensor in a physiological feedback control system. This is done through a literature survey extending through experimental and modelling research, where selected mathematical models of the baroreceptor are then analysed and simulated to find the best performing model, so that they may be simulated for an extended frequency response than what would be experimentally possible. The purpose of this investigation is to determine, through simulation, what the sensor's static and dynamic characteristics are. Through this characterisation of the sensor behaviour of the baroreceptor in the baroreflex control loop, it is then possible to infer whether the baroreflex can act as a long-term controller of blood pressure.

An overview of experimental and analytical investigations on the baroreceptor over the last 70 years is summarised. This overview includes mathematical models, which predict experimental results. A subset of four models from Srinivasen et al., Bugenhagen et al., Beard et al. and Mahdi et al. are selected. These models are implemented in MATLAB and Simulink. The parameters and experimental conditions are integrated into the Simulink models, and the simulated results are compared to the reported experimental data. In this way, each mathematical model is evaluated using secondary data for its ability to simulate the expected behaviour. Thereafter, all simulated models are compared under the same input conditions (a 0-230 mmHg step input over 12 s). These results are used to select the best performing models, based on how well they were parameterised and validated for experimental tests. The best performing models are those of Beard et al. and Bugenhagen et al. They are tested for a wide range of artificial inputs at different frequencies, with sinusoidal inputs which have periods that range from 0.1 s to 10 days and have a 100 mmHg operating point with a 1 mmHg peak amplitude.

All modelling techniques studied show that the baroreceptor firing response resets due to the rate of change in strain in the visco-elastic arterial wall. Both tested model frequency responses, although parameterised for different species and for different major vessels, show high sensitivity to inputs in

the range from 1 s to 1 min 36 s (0.01 Hz – 1Hz), and very low sensitivity for changes that are longer than 16 min 36s (0.001 Hz). This extrapolated simulation suggests a zero gain near DC.

The simulated frequency response of the best performing baroreceptor models, which were validated against short-term experimental data, indicate that the baroreceptor is only able to sense changes that happen in less than 1 min 16s. The critical analysis of all the simulated baroreceptor models show that this characteristic of the baroreceptor is caused by the visco-elastic layers of the arterial wall, and is likely in all baroreceptors regardless of type or species. It also indicates that under electrical stimulation of the baroreceptor, the input signal from the electrical device bypasses the baroreceptor nerve ending (which is embedded in the arterial wall) and that the electrical signal of the baroreceptor is bypassed by the new stimulated electrical signal of the device. Furthermore, if the sensor can only detect short-term changes, then it is unlikely that the baroreceptor can inform the brainstem on long-term changes to mean arterial blood pressure. Therefore, based on the models examined in this study, this suggests that the baroreceptor is unlikely to be involved in long-term blood pressure control. This analysis of the best performing model is presented to show the limitations of the baroreflex in long term control of blood pressure. It serves as a simulated experiment to rationalise the contentious debate around the role of the baroreflex in long term blood pressure control, and to allow for future improvements that can be made on the baroreceptor model to allow for more extended modelling on the baroreceptor's sensor characteristics. An improvement that could be applied to the best performing baroreceptor models, implemented in this study, is to examine the effects of ageing and inter-species variability on carotid sinus dimensions and visco-elastic wall properties.