Low-Perfusion Resistant Pulse Oximetry.
Weber W., Elfadel I.M., Barker S.J. *J Clin Monit* 1995; 11(40:284.

Introduction
We report on a prototype pule oximeter designed to compute the correct oxygen saturation of arterial hemoglobin at very low blood perfusion in the patient's extremities. In this paper, we explain the fundamental concepts of the advanced signal processing techniques used in this device. We also show actual oxygen saturation results obtained under a variety of clinical situations in which other pulse oximeters fail to give the correct values.

Pulse oximeters have become a standard of care in the operating room, the recovery room and the intensive-care unit. One of their major handicaps is their failure to measure patient's oxygen saturation at extremely low blood flow as is typically the case during critical surgery and critical neonatal care. Extremely low perfusion leads to very weak signals and therefore very low signal-to-noise ratios (SNR). The situation is further aggravated by the presence of motion artifacts induced during operating procedures or caused by the neonate's uncontrolled movements. Low perfusion is a major contributor to the high rate of false alarms in pulse oximetry. Reducing the number of false alarms and giving reliable oximetric readings to the practitioner even in the presence of low blood flow are two major goals that must be attained by any pulse oximeter designed for use in critical care medicine. The main purpose of this paper is to show that these two goals are indeed attainable.

Methods
The SNR can be improved during signal acquisition via the combination of low-noise transducer with signal pre-processing for both red and infrared channels. It can as be improved via the rejection of motion artifacts through adaptive noise cancellation techniques. One novel feature of the Masimo prototype is in the method the noise reference used by the adaptive noise canceler (ANC) is derived. This method consists in a transformation which maps the red and infrared photoplethysmograhic waveforms into a signal correlated with the patient's motion. The output of the ANC is a "clean" signal from which both data acquisition noise and motion artifacts are substantially removed.

Results
Eight healthy volunteers were studied to determine the performance of the Masimo pulse oximeter prototype, a Criticare 504-US, a Nellcor N-200, a Nellcor N-200 (C-lock), an Ohmeda 3740, and a Novametrix Oxypleth in a low-perfusion environment. A mechanical device was utilized to systematically assist each of the subjects in occluding the blood flow in the brachial artery. Saturation values were recorded and compared with those of a reference sensor connected to a non-occluded site. The table below displays the 3% error rate (average number of time the difference between the instrument saturation and the reference saturation was more than 3% in absolute value), failure rate (average number of time the instrument displayed saturation zeroes out), and total error (sum of error rate and failure rate).

Conclusion
By and large, the Masimo prototype performed the best in the simulated low-perfusion environment. Clinical studies are in progress to evaluate the performance of this new technology in neonatal intensive care units.