

L. Y. D. i Marco, D. Raine, J. P. Bourke and P. Langley, "Atrial fibrillation type characterization and catheter ablation acute outcome prediction: Comparative analysis of spectral and nonlinear indices from right atrium electrograms," *Computing in Cardiology 2014*, Cambridge, MA, 2014, pp. 817-820.

Abstract: Atrial fibrillation (AF) is the most common arrhythmia in clinical practice. As catheter ablation (CA) is increasingly becoming the preferred treatment, identifying predictors of CA outcome is important to assist clinical decision making. Previous studies have explored spectral and nonlinear indices. However, a comparative analysis of indices from preprocedural intracardiac recordings is lacking. The aim of this study was to present a comparative analysis of spectral and nonlinear indices derived from a simple threshold-based segmentation of intracardiac electrograms (EGM) to characterize AF type (paroxysmal vs. persistent) and predict AF termination by CA. Preprocedural 1 minute recordings of right atrium EGM from 54 AF patients (age 58 ± 9 years, 37 male; 27 paroxysmal AF, 27 persistent) were used. EGMs were band-pass filtered (F-EGM). f-wave activation fiducial points were identified using a threshold-based segmentation. The AF cycle length (AFCL) time series was built calculating the distance between consecutive fiducial points. The instantaneous fibrillatory rate (IFR) time series was calculated as AFCL inverse. Nonlinear indices were calculated: i) median AFCL (MAFCL); ii) localization index (LI) (concentration of IFR histogram around the mode); iii) sample entropy (SampEn); iv) root mean square error (RAISE) of IFR vs. Gaussian distribution fit. Standard methods were used to calculate spectral indices: i) dominant frequency (f_{dom}); ii) organization index (OI) (ratio of area under f_{dom} and its harmonics to total power) of F-EGM. Persistent AF was associated with higher f_{dom} ($p < 0.005$), lower MAFCL ($p < 0.01$) and LI ($p < 0.05$), higher SampEn ($p < 0.05$) and RAISE ($p < 0.01$). OI was not associated with AF type. Nonlinear indices: MAFCL

keywords: {Gaussian distribution;band-pass filters;bioelectric potentials;catheters;diseases;electrocardiography;entropy;mean square error methods;medical signal processing;patient treatment;spectral analysis;time series;AF cycle length time series;Gaussian distribution fit;arrhythmia;atrial fibrillation type characterization;band-pass filter;catheter ablation acute outcome prediction;clinical decision making;f-wave activation fiducial points;instantaneous fibrillatory rate time series;intracardiac electrograms;median AFCL;nonlinear index analysis;right atrium EGM recordings;right atrium electrograms;root mean square error;sample entropy;spectral index analysis;threshold-based segmentation;time 1 min;Abstracts;Catheters},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7043168&isnumber=7042955>

M. Frischholz, L. Sarmiento, M. Wenzel, K. Aquilina, R. Edwards and H. B. Coakham, "Telemetric Implantable Pressure Sensor for Short- and Long-Term Monitoring of Intracranial Pressure," *2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Lyon, 2007, pp. 514-514.

doi: 10.1109/IEMBS.2007.4352337

Abstract: Patients with hydrocephalus, idiopathic intracranial hypertension and head injury frequently require monitoring of intracranial pressure (ICP) and may need repeated episodes of monitoring months or years apart. The gold standard for measurement of ICP remains the external ventricular catheter. This is a fluid-filled catheter transducer system that allows regular recalibration and correction of zero drift by its position relative to a fixed anatomical reference. It also allows drainage of cerebrospinal fluid (CSF), providing a means of lowering the ICP. Several catheter tip transducer systems are currently in clinical use, including using strain gauges or fiber-optical pressure sensing techniques. In these devices, zero drift and calibration cannot be checked in vivo. All the ICP monitoring devices in current clinical use require a physical connection between the brain and the external environment. This is a source of infection and limits the duration of monitoring. A number of telemetric monitoring devices, in which data is in some way transmitted transcutaneously, have been developed over the last twenty years, but significant technical problems have precluded their use in routine clinical practice. All current ICP monitors are temporary percutaneous implanted devices. Placement of these devices carries significant morbidity, particularly infection. Patients undergoing repeated monitoring require multiple surgical procedures. Apart from decreasing the risk of infection in patients with severe head injury, the clinical value of an accurate telemetric ICP monitoring system which maintains its reliability over a long period of implantation is high. Several neurosurgical conditions require close control of ICP over several years to ensure a satisfactory outcome, such as hydrocephalus treated by a VP shunt or endoscopic third ventriculostomy as well as idiopathic intracranial hypertension. Currently, in these situations, ICP is measured by tapping a ventricular access - evic or by lumbar puncture; these invasive procedures, often necessary in children, carry a risk of infection. Current ICP monitors show a significant zero drift of the sensor over time which excludes them from being used in long-term implants where recalibration of the sensor is not possible. An implantable telemetric device would overcome many of the problems currently associated with ICP monitoring. Telemetry would allow the ICP to be measured non-invasively at home; symptoms could then be easily evaluated and the necessary adjustments to a programmable shunt, when present, could be performed and confirmed. Utilizing micro- and nanotechnologies as well as advanced packaging technologies, we have developed a fully implantable ICP sensor for long-term use. The sensor implant comprises an absolute capacitive pressure sensor and readout integrated circuit with ultra low power consumption and hence does not require an implanted battery as a power supply, which would otherwise limit the implant's lifetime. The sensor transmits pressure data via inductive coupling to an external device transcutaneously while being powered from outside via radio frequency. The external reader device compensates the absolute pressure data by measuring and subtracting the barometric pressure and displays data representative of intracranial fluid pressure. The implant is encapsulated by several functional layers, ensuring a hermetic sealing while at the same time providing high flexibility. A final biomaterial nano-layer to reduce cell growth and impairment of the mechanical functionality of the sensor is in development. The use of capacitive sensors and the encapsulation scheme guarantees a drift-free performance over time. The implant is designed in a manner so that it can be inserted according to the proven minimally invasive procedures known from current ICP monitors. The measurement tip can be placed either in the ventricle or brain parenchyma while the telemetry unit is located o

keywords: {biomedical telemetry;bone;brain;capacitive sensors;diseases;encapsulation;nanobiotechnology;neurophysiology;packaging;patient monitoring;pressure sensors;prosthetics;skin;ICP monitoring devices;biomaterial nanolayer;brain;brain parenchyma;capacitive sensors;catheter tip transducer systems;cerebrospinal fluid;cranial bone;encapsulation;external ventricular catheter;fiber-optical pressure sensing;fluid-filled catheter transducer;head injury;hermetic sealing;hydrocephalus;idiopathic intracranial hypertension;implantable pressure sensor;inductive coupling;infection;intracranial pressure;long-term monitoring;lumbar puncture;microtechnology;morbidity;nanotechnology;neurosurgical conditions;packaging;readout integrated circuit;recalibration;reliability;short-term monitoring;skin;strain gauges;telemetric monitoring devices;ventricle;ventriculostomy;zero drift correction;Brain injuries;Catheters;Cranial pressure;Gold;Hypertension;Intracranial pressure sensors;Measurement standards;Patient monitoring;Telemetry;Transducers;0},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4352337&isnumber=4352185>

P. D. Goodyer, J. C. Fothergill, N. B. Jones and C. D. Hanning, "The design of an optical fiber pressure transducer for use in the upper

airways," in *IEEE Transactions on Biomedical Engineering*, vol. 43, no. 6, pp. 600-606, June 1996.

doi: 10.1109/10.495279

Abstract: The development of an optical fiber transducer for use in biomedical applications has been presented. The design was targeted for use in the upper airways of patients with sleep disorders stemming from partial or total occlusion of the airway. The transducer's preliminary specification was suited for that of upper airway manometry: a resolution of 10 Pa over the range /spl plusmn/5 kPa, a single transducer being less than 0.94 mm in diameter. Amplitude modulated optical fiber sensors are susceptible to loss due to bending of the fiber core and cladding. The design of the transducer uses a series of three optical fibers, one emitting and two receiving, the combination of the two receiving optical fibers is used to reduce effects of light loss: a bend radius of 50 mm is typical for the insertion into the naso-pharynx. The transducer transduction element is a silicone gel coated with reflective titanium dioxide, the meniscus deforms under pressure and modulates the intensity of light reflected back into the receiving optical fibers. The main disadvantage of optical fiber pressure transducers is their susceptibility to temperature drift. Temperature in the airway rarely changes more than 17/spl deg/C. The frequency of breathing and the high thermal mass of the catheter means that temperature drift in this application is not significant, and will cause an insignificant error of 12 Pa. The transducer is inexpensive to produce, and may be deemed disposable: approximately \$20 in material costs (using current manufacturing techniques this can be halved). The system has the added advantage of being electrically, magnetically, and chemically passive. The potential for miniaturization is limited only by the mechanical strength of the optical fibers as mechanical problems associated with fragile elastic membranes do not apply.

keywords: {fibre optic sensors;pneumodynamics;pressure transducers;-5 to 5 kPa;0.94 mm;17 C;50 mm;TiO/sub 2;/biomedical device;meniscus deformation;naso-pharynx;optical fiber mechanical strength;optical fiber pressure transducer design;reflective titanium dioxide;silicone gel;sleep disorder patients;temperature drift;transducer transduction element;upper airway manometry;upper airways;Amplitude modulation;Biomedical transducers;Optical design;Optical fiber losses;Optical fiber sensors;Optical fibers;Optical modulation;Sleep;Temperature;Titanium;Airway Obstruction;Calibration;Equipment Design;Fiber Optics;Fourier Analysis;Humans;Manometry;Models, Biological;Sleep Apnea Syndromes;Temperature;Transducers},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=495279&isnumber=10802>

N. Ozana, R. Califa, A. Schwarz, N. Lipschitz-Tayar, M. Wolf and Z. Zalevsky, "Remote optical sensor for detection of middle ear effusion," *2017 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC)*, Munich, 2017, pp. 1-1.

doi: 10.1109/CLEOE-EQEC.2017.8087198

Abstract: Summary form only given. Middle ear effusion (MEE) is related to a group of inflammatory diseases of the middle ear. There are two main groups of otitis media (OM): The first group refers to acute OM (AOM), typically expressed by pain and elevated temperature of an acute onset, related to an infection of the middle ear that is caused by known pathogens (viruses and bacteriae). The second group, refers to OM with effusion (OME), has a rather benign course and is mainly presented with hearing loss. These two disorders share a significant impact upon public health and both demand appropriate diagnosis and specific treatment [1].The need for improving diagnosis of middle ear infections is attributed to the fact that symptoms are neither sensitive nor specific. The hallmark sign for middle ear infection is the presentation of fluids, instead of air, in the middle ear cavity, leading to changes in the physical characteristics of the TM. Diagnosis is determined by handpiece otoscopy (pediatricians) or microscopic otoscopy (ENT specialists) with inaccuracies related to both. This paper presents a very simple, inexpensive photonic devise, which can be used easily by every primarycare physicians and even for home use. The technique is based on temporal tracking of back-reflected secondary speckle patterns generated while illuminating the eardrum with a laser, while applying external remote periodic acoustic pressure to the eardrum via a controlled vibration source [2,3]. The application of a series of different vibration frequencies to the eardrum and analyzing the 2-D time varying speckle patterns in response to the applied periodic pressure, creates a different frequency response for otitis with respect to healthy eardrum. Analyzing these spectral responses is the first step toward a simple detection of middle ear effusion.

keywords: {diseases;ear;laser applications in medicine;microorganisms;optical sensors;patient diagnosis;remote sensing by laser beam;speckle;2-D time varying speckle patterns;ENT specialists;acute OM;back-reflected secondary speckle patterns;bacteriae;controlled vibration source;elevated temperature;external remote periodic acoustic pressure;frequency response;handpiece otoscopy;healthy eardrum;hearing loss;inflammatory diseases;laser;microscopic otoscopy;middle ear cavity;middle ear effusion;middle ear infections;otitis media;pain;pathogens;pediatricians;periodic pressure;photonic devise;public health;remote optical sensor;spectral responses;temporal tracking;vibration frequencies;viruses;Blood;Ear;Frequency response;Media;Optical sensors;Speckle;Vibrations},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8087198&isnumber=8086161>

G. C. Gutiérrez-Tobal *et al.*, "A Bayesian neural network approach to compare the spectral information from nasal pressure and thermistor airflow in the automatic sleep apnea severity estimation," *2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Seogwipo, 2017, pp. 3741-3744.

doi: 10.1109/EMBC.2017.8037670

Abstract: In the sleep apnea-hypopnea syndrome (SAHS) context, airflow signal plays a key role for the simplification of the diagnostic process. It is measured during the standard diagnostic test by the acquisition of two simultaneous sensors: a nasal prong pressure (NPP) and a thermistor (TH). The current study focuses on the comparison of their spectral content to help in the automatic SAHS-severity estimation. The spectral analysis of 315 NPP and corresponding TH recordings is firstly proposed to characterize the conventional band of interest for SAHS (0.025-0.050 Hz.). A magnitude squared coherence analysis is also conducted to quantify possible differences in the frequency components of airflow from both sensors. Then, a feature selection stage is implemented to assess the relevance and redundancy of the information extracted from the spectrum of NPP and TH airflow. Finally, a multiclass Bayesian multi-layer perceptron (BY-MLP) was used to perform an automatic estimation of SAHS severity (no-SAHS, mild, moderate, and severe), by the use of the selected spectral features from: airflow NPP alone, airflow TH alone, and both sensors jointly. The highest diagnostic performance was reached by BY-MLP only trained with NPP spectral features, reaching Cohen's $\kappa = 0.498$ in the overall four-class classification task. It also achieved 91.3%, 84.9%, and 83.3% of accuracy in the binary evaluation of the 3 apnea-hypopnea index cut-offs (5, 15, and 30 events/hour) that define the four SAHS degrees. Our results suggest that TH sensor might be not necessary for SAHS severity estimation if an automatic comprehensive characterization approach is adopted to simplify the diagnostic process.

keywords: {air;feature selection;medical disorders;multilayer perceptrons;neural nets;patient diagnosis;pneumodynamics;sleep;spectral analysis;thermistors;Bayesian neural network approach;NPP spectral feature selection;automatic sleep apnea severity estimation;magnitude squared coherence analysis;multiclass Bayesian multilayer perceptron;nasal prong pressure;sensor acquisition;sleep apnea-hypopnea syndrome context;thermistor airflow;Correlation;Estimation;Feature extraction;Sensor phenomena and

characterization;Sleep apnea;Training},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8037670&isnumber=8036736>

M. Trawka, J. Smulko and T. Chludziński, "Portable measurement system for breath analysis by real-time fluctuation enhanced sensing method," *2017 International Conference on Noise and Fluctuations (ICNF)*, Vilnius, 2017, pp. 1-3.

doi: 10.1109/ICNF.2017.7985948

Abstract: Resistance flicker noise of gas sensors gives a new opportunity to improve gas detection by enhancing selectivity and sensitivity of cheap and popular gas sensors. The improvement at low gas concentrations can be even increased further by UV light irradiating the gas sensing layers exhibiting photocatalytic effect (e.g., WO_3 or TiO_2 gas sensing layers). A new system has been developed recently to utilize low frequency noise measurement method but controlling a set of sensors applied for breath analysis and medical check-up. The system measures DC resistance and resistance noise in an array of four prototype resistive gas sensors. An operating temperature of each sensor can be set independently by the software controlling the system. Some sensors can be irradiated by the UV light as well. Humidity, temperature and pressure within a miniature gas chamber, of a volume about 40 ml, is monitored to secure repeatable conditions during the measurements and to avoid humidity condensation in the exhaled breath. The setup is controlled by an FPGA circuit performing necessary computations (power spectrum density estimation) and data transmission. Further processing by applying selected detection or gas concentration estimation methods can be done by a smartphone or a PC controlling the measurement setup. The system was prepared for fast and non-invasive medical diagnosis of patients suffering from tropical diseases.

keywords: {catalysis;diseases;field programmable gate arrays;flicker noise;gas sensors;patient diagnosis;photochemistry;pneumodynamics;portable instruments;smart phones;DC resistance;FPGA circuit;PC;UV light;breath analysis;data transmission;exhaled breath;gas concentration estimation methods;gas detection;gas sensing layers;humidity condensation;low frequency noise measurement method;measurement setup;medical check-up;miniature gas chamber;noninvasive medical diagnosis;operating temperature;photocatalytic effect;portable measurement system;power spectrum density estimation;prototype resistive gas sensors;real-time fluctuation enhanced sensing method;resistance flicker noise;resistance noise;smartphone;tropical diseases;Electrical resistance measurement;Fluctuations;Gas detectors;Immune system;Temperature measurement;Temperature sensors;breath analysis;flicker noise;gas sensor;measurement set-up;power spectral density},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7985948&isnumber=7985924>

M. H. Behfar *et al.*, "Inductive passive sensor for intraparenchymal and intraventricular monitoring of intracranial pressure," *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Orlando, FL, 2016, pp. 1950-1954.

doi: 10.1109/EMBC.2016.7591105

Abstract: Accurate measurement of intracranial hypertension is crucial for the management of elevated intracranial pressure (ICP). Catheter-based intraventricular ICP measurement is regarded as the gold standard for accurate ICP monitoring. However, this method is invasive, time-limited, and associated with complications. In this paper, we propose an implantable passive sensor that could be used for continuous intraparenchymal and intraventricular ICP monitoring. Moreover, the sensor can be placed simultaneously along with a cerebrospinal fluid shunt system in order to monitor its function. The sensor consists of a flexible coil which is connected to a miniature pressure sensor via an 8-cm long, ultra-thin coaxial cable. An external orthogonal-coil RF probe communicates with the sensor to detect pressure variation. The performance of the sensor was evaluated in an in vitro model for intraparenchymal and intraventricular ICP monitoring. The findings from this study demonstrate proof-of-concept of intraparenchymal and intraventricular ICP measurement using inductive passive pressure sensors.

keywords: {cardiology;catheters;coils;neurophysiology;patient monitoring;pressure measurement;pressure sensors;ICP monitoring;catheter-based intraventricular ICP measurement;cerebrospinal fluid shunt system;external orthogonal-coil RF probe;inductive passive sensor;intracranial hypertension;intracranial pressure;intraparenchymal monitoring;intraventricular monitoring;miniature pressure sensor;ultrathin coaxial cable;Frequency measurement;Iterative closest point algorithm;Monitoring;Pressure measurement;Probes;Radio frequency;Resonant frequency;Implantable ICP sensors;intraventricular ICP monitoring;passive sensors;wireless telemetry;Cerebrospinal Fluid Shunts;Equipment and Supplies;Humans;Intracranial Hypertension;Intracranial Pressure;Monitoring, Physiologic},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7591105&isnumber=7590615>

R. Kosaka, M. Nishida, O. Maruyama and T. Yamane, "Noninvasive miniaturized mass-flow meter using a curved cannula for implantable axial flow blood pump," *2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, Boston, MA, 2011, pp. 1343-1346.

doi: 10.1109/IEMBS.2011.6090316

Abstract: Blood flow should be measured to monitor conditions of patients with implantable artificial hearts continuously and noninvasively. We have developed a noninvasive miniaturized mass-flow meter using a curved cannula for an axial flow blood pump. The mass-flow meter utilized centrifugal force generated by the mass-flow rate in the curved cannula. Two strain gauges served as sensors. Based on the numerical analysis, the first gauge, attached to the curved area, measured static pressure and centrifugal force, and the second, attached to the straight area, measured static pressure for static pressure compensation. The mass-flow rate was determined by the differences in output from the two gauges. To compensate for the inertia force under the pulsatile flow, a 0.75-Hz low-pass filter was added to the electrical circuit. In the evaluation tests, numerical analysis and an actual measurement test using bovine blood were performed to evaluate the measurement performances. As a result, in the numerical analysis, the relationship between the differential pressure caused by centrifugal force and the flow rate was verified. In the actual measurement test, measurement error was less than ± 0.5 L/min, and the time delay was 0.12 s. We confirmed that the developed mass-flow meter was able to measure mass-flow rate continuously and noninvasively.

keywords: {blood flow measurement;haemodynamics;haemorheology;low-pass filters;prosthetics;blood flow;bovine blood;centrifugal force;curved cannula;electrical circuit;frequency 0.75 Hz;implantable artificial hearts;implantable axial flow blood pump;low-pass filter;noninvasive miniaturized mass-flow meter;numerical analysis;pulsatile flow;sensors;static pressure compensation;time 0.12 s;Blood;Bovine;Calibration;Computational fluid dynamics;Fluid flow measurement;Force;Pressure measurement;Catheters;Computer-Aided Design;Equipment Design;Equipment Failure Analysis;Heart-Assist Devices;Infusion Pumps, Implantable;Miniaturization;Reproducibility of Results;Rheology;Sensitivity and Specificity},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6090316&isnumber=6089866>

A. Rosen and H. D. Rosen, "The role of engineering principles in the medical utilization of electromagnetic energies: Examples," *2008*

33rd International Conference on Infrared, Millimeter and Terahertz Waves, Pasadena, CA, 2008, pp. 1-1.

doi: 10.1109/ICIMW.2008.4665832

Abstract: The use of RF/microwaves in medicine has increased dramatically over the last ten years. RF and microwave therapies for the treatment of cancer in humans are well documented, and are presently used in many cancer centers. RF treatments for supra ventricular arrhythmias, and more recently for the treatment of ventricular tachycardia, are currently employed by major hospitals. RF/microwaves are also used in human subjects for the treatment of benign prostatic hyperplasia (BPH). In the last few years, several otolaryngological centers have been utilizing RF to treat upper airway obstruction and to alleviate sleep apnea. Many centers also utilize RF for the treatment of gastro-esophageal disease (GERD), for pain management, and for endometrial ablation. Balloon microwave catheters for ablating solid tumors, then forming cavities in those tumors for the local delivery of therapeutic agents, are currently being investigated. New modalities are being studied, such as RF/microwave for the enhancement of drug absorption and microwave septic wound treatment, microwave imaging for the detection of breast cancer, epidemiological studies on the effects of ratspsila exposure to microwave, as well as tissue regeneration using electromagnetic fields. In addition, technology is presently being developed that allows for permanent implantation of microwave wireless sensors in humans. A permanently implantable intra-cranial pressure monitor is one such application of the latter technology. Many more areas of research are currently being investigated, a partial list of which is summarized in the introduction.

keywords: {bio-optics;biological effects of microwaves;cancer;drug delivery systems;lung;mammography;microwave imaging;patient diagnosis;patient monitoring;prosthetics;tissue engineering;tumours;RF therapy;balloon microwave catheters;benign prostatic hyperplasia;breast cancer;drug absorption;endometrial ablation;epidemiological studies;gastroesophageal disease;implantable intra-cranial pressure monitor;medical electromagnetic energy;microwave biological effects;microwave imaging;microwave septic wound treatment;microwave therapy;pain management;sleep apnea;supraventricular arrhythmia;tissue regeneration;tumors;upper airway obstruction;ventricular tachycardia;Biomedical engineering;Biomedical imaging;Breast

neoplasms;Cancer;Diseases;Hospitals;Humans;Medical treatment;Radio frequency;Sleep apnea},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4665832&isnumber=4665395>

P. F. Meagher, R. E. Jensen, M. H. Weil and H. Shubin, "Measurement of Respiration Rate from Central Venous Pressure in the Critically Ill Patient," in *IEEE Transactions on Biomedical Engineering*, vol. BME-13, no. 2, pp. 54-57, April 1966.

doi: 10.1109/TBME.1966.4502406

Abstract: Central venous pressure is measured in critically ill patients. The venous pressure is transmitted to a strain gauge transducer through a catheter inserted into the right atrium or superior vena cava. Through a signal conditioning technique using a low-pass filter with a cutoff at 0.8 c/s, the pulsatile variations related to heart action that are superimposed on the low-frequency respiratory changes are removed. The output of the respirometer is sampled every five minutes by art IBM 1710 control system computer and printed on an output typewriter, together with a number of variables, in a comprehensive patient monitoring system.

keywords: {Capacitive sensors;Catheters;Control systems;Electric shock;Heart;Low pass filters;Pressure measurement;Radiation detectors;Testing;Transducers;Blood Pressure Determination;Humans;Monitoring, Physiologic;Respiration},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4502406&isnumber=4502402>

D. Gurkan, D. Starodubov and Xiaojing Yuan, "Monitoring of the heartbeat sounds using an optical fiber Bragg grating sensor," *IEEE Sensors*, 2005., Irvine, CA, 2005, pp. 4 pp.-.

doi: 10.1109/ICSENS.2005.1597697

Abstract: Heartbeat is intuitively examined via a stethoscope that amplifies the sound. Diagnosis may be broadened by extracting more information: strength, frequency components, and sound pressure. This paper is on the demonstration of an optical fiber Bragg grating sensor to monitor the heartbeat using sound pressure and possibly extending to application of ballistocardiography (BCG: the heartbeat-associated movements imparted by recoil and impact). To our knowledge, cardiac examination with BCG and sound sensing using FBG technology has not been explored. In this setup, heartbeat sounds are translated into an electrical signal using a strain-sensitive reflective FBG sensor that provides differential changes in the reflection spectrum. For a proof-of-concept demonstration, FBG sensor is glued to the vibrating membrane of a subwoofer of a speaker set. Using recordings of various heartbeat sounds, spectral changes are recorded at a 250-Hz sampling rate. The results show increased sensitivity to: strength of the heartbeat, frequency and temporal content of the oscillatory wave pattern

keywords: {acoustic variables measurement;cardiovascular system;fibre optic sensors;patient diagnosis;250 Hz;Bragg grating sensor;ballistocardiography;cardiac examination;heartbeat sounds monitoring;optical fiber sensor;sound sensing;Acoustic sensors;Bragg gratings;Data mining;Fiber gratings;Frequency;Heart beat;Optical fiber sensors;Optical fibers;Optical reflection;Stethoscope},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1597697&isnumber=33608>

H. Sorvoja, V. M. Kokko, R. Myllyla and J. Miettinen, "Use of EMFi as a blood pressure pulse transducer," in *IEEE Transactions on Instrumentation and Measurement*, vol. 54, no. 6, pp. 2505-2512, Dec. 2005.

doi: 10.1109/TIM.2005.853345

Abstract: This paper describes and tests two prototype series of pressure transducer arrays based on electromechanical film (EMFi). By offering high ($\sim T\Omega$) resistance, EMFi is an excellent material for low-current long-term measurement applications. About 50 transducer arrays were designed and tested using different configurations and electrode materials to sense low-frequency pressure pulsations on the radial artery in the wrist. Essential requirements included an adequate linear response in the desired temperature range and uniform quality. Transducer sensitivity was tested as a function of temperature in the range of 25°C-45°C at varying dc and ac pressures. The average sensitivity of the EMFi used in the transducers proved adequate ($\sim 2.2\text{mV/mmHg}$ and $\sim 7\text{mV/mmHg}$ for normal and high-sensitive films) for the intended purpose. Moreover, EMFi's spectral response covered the required range for biomedical applications, but it was unable to measure static pressure ($f_3\text{ dB}\approx 38\text{ }\mu\text{Hz}$). The sensitivity of the EMFi material was sufficiently constant for measuring blood pressure pulses in the desired range (0-300 mmHg), and the best achieved deviation in sensitivity was $\pm 5.1\%$. It was also established that in addition to sensitivity and its standard deviation, crosstalk between electrode elements also depends strongly on electrode thickness.

keywords: {biomedical transducers;blood pressure measurement;electrochemical electrodes;patient monitoring;pressure transducers;25 to 45 C;EMFi material;EMFi spectral response;biomedical application;blood pressure monitoring;blood pressure pulse transducer;electrode element;electrode material;electrode thickness;electromechanical film;linear response;low-frequency pressure pulsation;pressure transducer array;pulse transit time;pulse wave velocity;radial artery pulsation;static pressure;Biomedical measurements;Blood pressure;Electrodes;Pressure measurement;Prototypes;Pulse measurements;Temperature distribution;Temperature

sensors;Testing;Transducers;Blood pressure monitoring;noninvasive;pressure transducer array;pulse transit time;pulse wave velocity;radial artery pulsation},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1542559&isnumber=32946>

J. L. Gonzalez, O. Yadid-Pecht, D. Sadowski, K. V. I. S. Kaler and M. P. Mintchev, "Integrated esophageal pressure, pH and bolus transit sensor," *Proceedings of IEEE Sensors, 2004.*, 2004, pp. 1369-1372 vol.3.

doi: 10.1109/ICSENS.2004.1426438

Abstract: Pressure, pH and bolus transit measurements are commonly used for diagnosing esophageal motility disorders. In the present study, a probe that integrates novel techniques for monitoring all variables of interest for esophageal testing is proposed. Innovative catheter design offers proper selection of frequencies and electrode arrangement for enhanced impedance-based pH and bolus transit monitoring. In addition, a novel optical method for contraction detection is proposed. A model of the esophagus was used to test the multi-sensor probe. Repeatability of the obtained impedance measurements related to pH was tested. The obtained results satisfied the requirements of DeMeester and Johnson scoring system for pH measurements. Bolus transit and reflux periods were simulated in the test model and were successfully identified. Optical detection of intraluminal pressure and subsequent reconstruction of esophageal wall dynamics were also explored. Experimental results showed the feasibility of the suggested integrated sensor approach for esophageal testing.

keywords: {CMOS image sensors;force sensors;optical sensors;pH measurement;patient diagnosis;patient monitoring;pressure sensors;CMOS imager;bolus reflux periods;bolus transit sensor;catheter;contact force measurement;esophageal motility disorder diagnosis;esophageal pressure sensor;esophageal testing;esophageal wall dynamics;esophagus;impedance-based pH monitoring;intraluminal pressure optical detection;multisensor probe;optical contraction detection method;pH sensor;solid-state pressure transducer;Catheters;Electrodes;Esophagus;Frequency;Impedance;Monitoring;Optical sensors;Pressure measurement;Probes;Testing},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1426438&isnumber=30805>

E. Siwapornsathain, A. Lal and J. Binard, "A telemetry and sensor platform for ambulatory urodynamics," *2nd Annual International IEEE-EMBS Special Topic Conference on Microtechnologies in Medicine and Biology. Proceedings (Cat. No.02EX578)*, Madison, WI, 2002, pp. 283-287.

doi: 10.1109/MMB.2002.1002331

Abstract: This paper reports the use of pressure sensitive telemetry device to access the pressure state of the bladder for ambulatory urodynamics. The device consisted of pressure sensor, amplifier, VCO, and oscillator. The integrated circuit was fabricated using MOSIS AMI 1.5 micron technology. The device was able to transmit pulses of radio waves whose pulsing rate is a function of the pressure. A small balloon technology was also developed to help the device float in the water

keywords: {biomedical electronics;biomedical telemetry;micromachining;microsensors;patient monitoring;piezoresistive devices;pressure sensors;radio transmitters;voltage-controlled oscillators;MOSIS technology;SPICE simulation;VCO;ambulatory urodynamics;bladder diagnosis;bladder pressure state;bulk micromachining;catheter procedure;in vitro testing;integrated piezoresistors;integrated system;membrane sensor;pressure sensitive telemetry device;pressure sensor;small RF transmitter;small balloon technology;Biomedical measurements;Bladder;Catheters;Consumer electronics;Frequency;Integrated circuit technology;Oscillators;Pressure measurement;Radio transmitters;Telemetry},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1002331&isnumber=21629>

C. L. de Korte *et al.*, "Intracoronary elastography in the catheterisation laboratory: preliminary patient results," *1999 IEEE Ultrasonics Symposium. Proceedings. International Symposium (Cat. No.99CH37027)*, Caesars Tahoe, NV, 1999, pp. 1649-1652 vol.2.

doi: 10.1109/ULTSYM.1999.849312

Abstract: Intravascular ultrasound (IVUS) elastography is a new imaging technique that reveals regional mechanical properties of the vascular wall by measuring the local strain. In this study, the Feasibility and potential of the technique during cardiac catheterization are investigated. Presently, nine patients scheduled for percutaneous transluminal coronary angioplasty (PTCA) have been investigated. The intracoronary pressure was used as a mechanical stimulus. Local strain was estimated by cross-correlation analysis of the radio-frequency IVUS signals, obtained from two frames acquired at different pressures. Since errors are incurred with catheter motion, the phase in the heart cycle with minimal catheter motion was determined. The relation between mean strain (average strain value over the full cross-sectional circumference) and the systolo-diastolic change in lumen area was also investigated. Reliable elastographic results were obtained on sequential echo-frames near end-diastole. The elastograms reveal that regions with calcified material (as identified from the echogram) have low strain values: 0 to 0.1%. Normal vessel wall and other plaques demonstrated strain ranging from 0.1 to 1%.

A high correlation was found between the mean strain at end diastole and the change in lumen over the cardiac cycle ($r^2=0.81$, $p=0.005$). The results of this preliminary clinical experience suggest that it is feasible to produce clinically useful elastograms

keywords: {biomechanics;biomedical ultrasonics;elasticity;laboratory techniques;cardiac cycle;catheterisation laboratory;clinically useful elastograms;cross-correlation analysis;end-diastole;full cross-sectional circumference;imaging technique;intracoronary elastography;intracoronary pressure;intravascular ultrasound elastography;local strain;lumen area;mechanical stimulus;medical diagnostic imaging;radio-frequency IVUS signals;systolo-diastolic change;vascular wall regional mechanical properties;Angioplasty;Capacitive sensors;Catheterization;Catheters;Laboratories;Mechanical factors;Mechanical variables measurement;Strain measurement;Ultrasonic imaging;Ultrasonic variables measurement},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=849312&isnumber=18457>

O. Barnea and V. Shusterman, "Analysis of skin-temperature variability compared to variability of blood pressure and heart rate," *Proceedings of 17th International Conference of the Engineering in Medicine and Biology Society*, Montreal, Que., 1995, pp. 1027-1028 vol.2.

doi: 10.1109/IEMBS.1995.579449

Abstract: High resolution skin-temperature measurement performed in normal human subjects and in patients with coronary artery disease revealed low-amplitude temperature oscillations ($40 \times 10^{-3}^\circ\text{C}$) designated as 'Temperature Variability' (TV). Spectral analysis of the filtered signal showed that most of the energy was in the range 0.015-0.04 Hz. Power spectra of temperature variability and pulse pressure amplitude were compared. Both of the signals exhibited similar peak frequency and similar stress-related response. Stress-related changes of TV power spectrum were similar to-changes of power in the spectrum of heart rate variability in the same frequency range. The TV signal showed greater sensitivity to stress than mean temperature. The TV phenomenon was attributed to vasomotor activity primarily mediated by sympathetic tone. In patients with coronary artery disease TV magnitude during baseline and stress was

significantly lower than in normal subjects

keywords: {blood pressure measurement;cardiology;medical signal processing;skin;spectral analysis;temperature measurement;0.015 to 0.04 Hz;blood pressure variability;coronary artery disease patients;filtered signal spectral analysis;heart rate variability;low-amplitude temperature oscillations;normal human subjects;peak frequency;skin-temperature variability analysis;stress-related response;sympathetic tone;Coronary arteriosclerosis;Energy resolution;Frequency;Humans;Performance evaluation;Signal resolution;Spectral analysis;Stress;TV;Temperature sensors},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=579449&isnumber=12476>

B. B. Flick *et al.*, "New analysis techniques and waveform displaying for intracranial pressure data," *Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. Vol.20 Biomedical Engineering Towards the Year 2000 and Beyond (Cat. No.98CH36286)*, Hong Kong, 1998, pp. 1509-1512 vol.3.

doi: 10.1109/IEMBS.1998.747173

Abstract: This paper describes a new data analysis technique for the computation of important brain parameters from intracranial pressure (ICP) data. In contrast to conventional methods, our method does not need the additional infusion of liquor into the brain. Our new technique is able to achieve the requested parameters only from natural fluctuations within the intracranial pressure signal. The advantage of our method is the minimisation of the risk for the patient. Furthermore, the proposed technique is much more comfortable for patients than the conventional methods. For the data acquisition a portable telemetric measurement unit will be used. Plausible Results from real data show that our method is highly efficient. Due to its simplicity our method is suitable for on-line monitoring applications. This new measuring system could also be implemented in other fields where telemetric sensors are needed and biological signals up to the 50 Hz-range are measured

keywords: {biomedical telemetry;biomedical transducers;brain;computerised monitoring;data acquisition;medical signal processing;patient monitoring;pressure sensors;spectral analysis;time-frequency analysis;automatic event recording;brain parameters;cerebrospinal fluid;compliance;data acquisition;data analysis technique;intracranial pressure data;natural fluctuations;on-line monitoring;patient risk minimisation;plateau waves;portable telemetric measurement unit;resorption;time frequency analysis;waveform display;Biosensors;Cranial pressure;Data acquisition;Data analysis;Fluctuations;Measurement units;Minimization methods;Patient monitoring;Sensor systems;Telemetry},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=747173&isnumber=16077>

J. Ji, S. T. Cho, Y. Zhang, K. Najafi and K. D. Wise, "An ultraminiature CMOS pressure sensor for a multiplexed cardiovascular catheter," in *IEEE Transactions on Electron Devices*, vol. 39, no. 10, pp. 2260-2267, Oct 1992.

doi: 10.1109/16.158797

Abstract: A multiplexed ultraminiature pressure sensor designed for use in a cardiovascular catheter is described. The sensor operates from only two loads, which are shared by two sensors per catheter. The sensing chip is 350 μm wide by 1.4 mm long by 100 μm thick. CMOS readout circuitry at the sensing site converts applied pressure to a frequency variation in the supply current, which is detected at the end of the catheter by a microprocessor-controlled interface. The nominal pressure sensitivity is 2 kHz/ff about a zero-pressure output frequency of 2.7 MHz. This on-site circuitry contains two reference capacitors which allow external compensation for nonlinearity and temperature sensitivity and has an idle-state power dissipation of less than 50 μW . With the transducer sealed at ambient pressure, the device can resolve pressure variations of about 3 mmHg, while vacuum-sealed devices do considerably better and should permit <2 mmHg resolution in practical systems

keywords: {CMOS integrated circuits;biomedical electronics;biomedical equipment;cardiology;haemodynamics;patient monitoring;pressure sensors;2.7 MHz;50 μW ;CMOS pressure sensor;CMOS readout circuitry;external compensation;frequency variation;idle-state power dissipation;microprocessor-controlled interface;multiplexed cardiovascular catheter;sensing chip;temperature sensitivity;ultraminiature type;vacuum-sealed devices;Capacitors;Cardiology;Catheters;Circuits;Current supplies;Frequency conversion;Power dissipation;Sensor phenomena and characterization;Temperature sensors;Transducers},

URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=158797&isnumber=4087>