

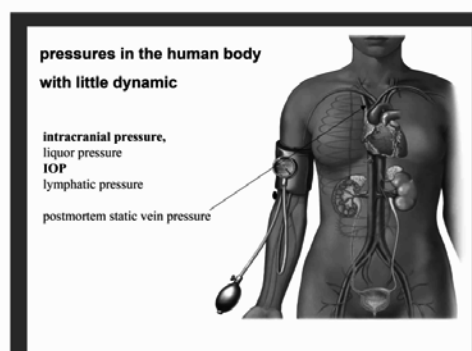
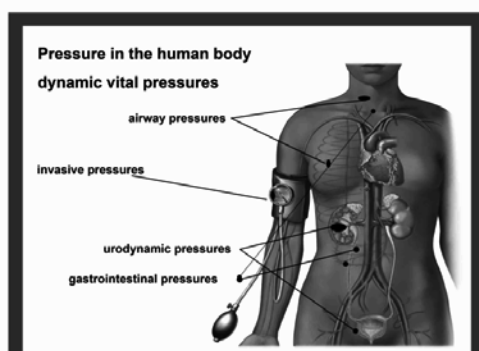
## Pressure Measurement by Medical Devices and within Medical Devices

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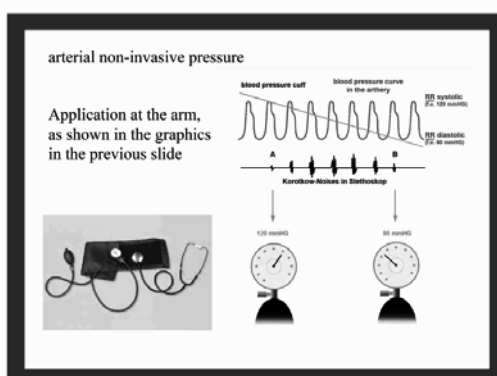
There exist lots of historical pressure units as bar, atm., mmWs, but allowed today in SI = Système International d'unités are only Pascal, Newton/m<sup>2</sup>, exception for medicine: also the pressure unit mm Hg is allowed.

A further difference which will show up in medical applications shall be mentioned: the word "monitoring" means in technical applications: to observe a situation for any changes which may occur over time. In medicine, it also means that, but in addition medical monitoring means: plus alarm. The standard for patient monitors is: ISO 60601-2-49.

Pressures in the human body occur in fast changes and in slow changes:



What everybody knows as it belongs to our normal experience: cuff-measurement of our arterial blood pressure, which is explained by the following graphic:




The real dynamic of the pressure curve in safe and sound conditions between 80 mm Hg (diastolic value) and 120 mm Hg (systolic value) cannot be evaluated by this method, as the acoustic observation of pulse wave sound to start and to end is no recording of the pressure curve. If the patient is hospitalised and there is an arterial access (mostly at the radial artery), then the pressure curve can be recorded in full with a transducer (will be explained later), transferring the mechanical pressure signal to an electrical signal

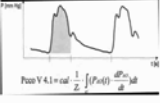
And the same applies to other blood pressures, most common venous pressure (smaller pressure values around 10 mm Hg) and the pulmonary artery pressure.

**arterial invasive pressure**

Invasive measurements by means of a catheter: the distal end of the catheter defines the location where the pressure will be recorded. The extracorporeal monitoring set just is the fluid filled transfer system of the pressure (wave) to the transducer which is pole mounted, for correct zero level at the height of the right atrium.

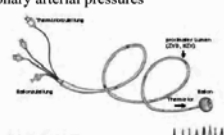


stroke-to-stroke recording  
analysis of hemodynamic effects from arrhythmic distortions  
blood sampling

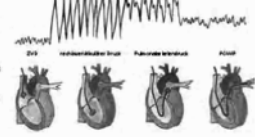


**pulmonary arterial pressures**

**Pulmonalkatheter**

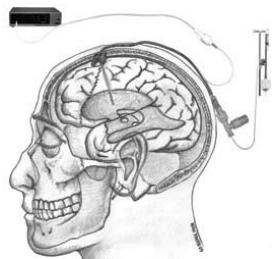


The Swan-Ganz catheter is passing two valves in the right heart to reach the pulmonary artery, finally to measure the wedge pressure



Airway pressure measurements are used in wide variations at these many ventilation procedures (listed alphabetically): APRV (airway pressure release v.), ASB (assisted spontaneous breathing), ASV (adapative support v.), ATC (automatic tube compensation), BIPAP (biphasic positive airway pressure), CMV (continuous mandatory v.), CPAP (continuous positive airway pressure), CPPV (continuous positive pressure v.), EPAP (expiratory positive airway pressure), HFPPV (high frequency positive pressure v.), HFOV (high frequency oscillatory v.), ILV (independent lung v.), IPAP (inspiratory positive airway pressure), IPPV (intermittend positive pressure v.), IRV (inversed ratio v.), LFPPV (low frequency positive pressure v.), MMV (mandatory minute volume), MPAV (proportional assist v.), PCMV 8pressure controlled mandatory v.), PCV (pressure controlled v.), PEEP (positive endexpiratory pressure), PNPV ((positive negative pressure v.), S-CPPV (synchronised continuous positive pressure v.), S-IPPV (as before, intermittend instead of continuous), (S)IMV (synchronisedintermittend mandatory v.), VCMV (volume controlled mandatory v.), VCV (volume controlled v.)


Urodynamic pressures will be measured on special chair equipment, as also the so-called gastro-intestinal manometry. Intracranial pressure (ICP) has nearly no dynamics, therefore even an air filled connection to the transducer is satisfactory, much more important than the pressure sensor is hygienic protection. Normal ICP: 5-15 mmHg, during coughing 50-80 mmHg can b.e achieved



from spiegelberg.de

**IOP, intra ocular pressure**  
main 3 Methods

1. Widely used is the non-contact tonometer (air puff tonometer) invented by Bernard Goldman of American Optical (now Bausch, Inc.) which uses a rapid air pulse to appurate the cornea. The appuration then is detected via an electro-optical system. Today's modern non-contact tonometers show good correlation to the Goldmann tonometry measurements
2. Goldmann tonometer: a special disinfected probe attached to a slit flap biomicroscope is used to flatten the central cornea, eye needs local anaesthesia for this procedure
3. Schiötz tonometry is a type of impression tonometry, makes use of a plunger to indent the cornea. The IOP is determined by correlation of scale reading using a nomogram, with additional small metal weights added for higher levels of IOP



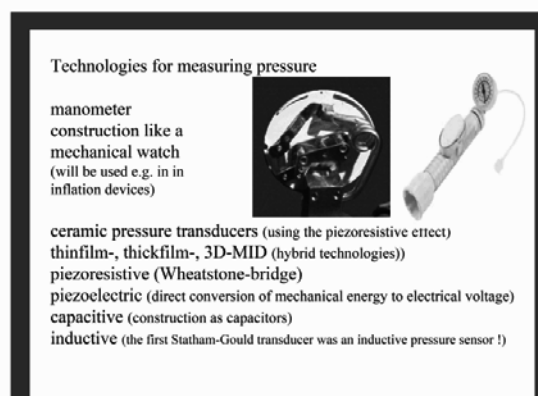
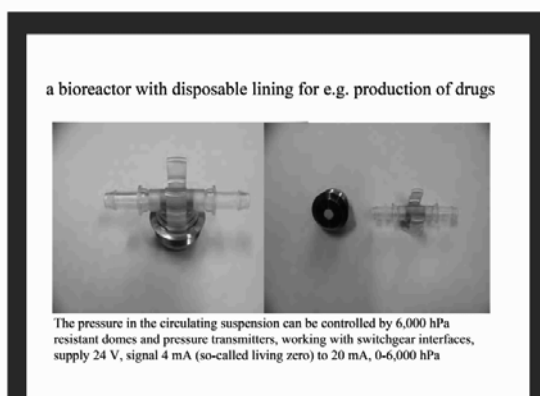
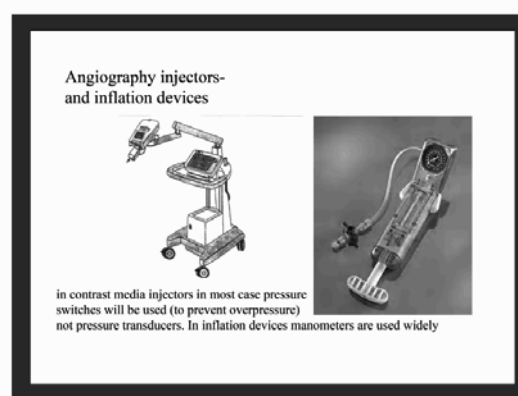
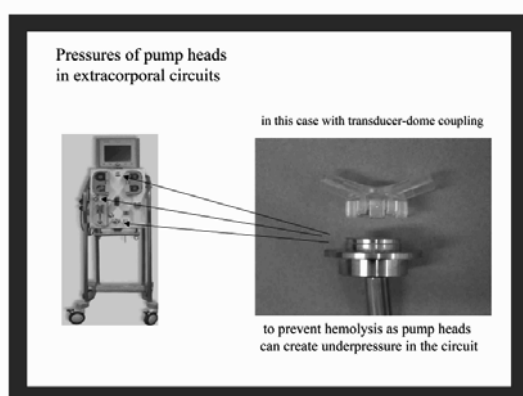
IOP: the details are not so important for the pressure measuring community: basic principle: deflection of the curvature of the cornea by applanation or air puff tonometry.

The lecture will also show a picture of the lymphatic system and the pressures there, just a little bit below the caval vein pressures.

Postmortem static vein pressure is normally around zero, when it has been a slow death. In case it would be around 15-20 mm Hg, then it was a fast death, not necessarily a crime, also an accident could be the reason.

### Pressure in medical devices, treating patients:

Relevant for such pressure monitoring will be respiratory pressures, pump head pressures in extracorporeal circuits, infusion pumps, angiographic injectors, inflation devices.



Even there is in the meantime a way to convert the manometer turn via the Hall effect to an electrical signal (see IntelliGauge from WIKA) the next displayed principles are the ones which really matter

## The piezoresistive sensor structures

measurement principles for pressure transducers

on substrates (as listed in the slide before) “chips” will be mounted to work according measurement principles as

**piezoresistive:**

voltage measurement over the Wheatstone bridge

benefit: signal complies to standard:  $\mu\text{V}/\text{V}/\text{mmHg}$

disadvantage: high power dissipation

**piezoresistive (III): application Si-pressure sensor**

source: S. Büllgenbach Mikromechanik

acc. to the ISO 60601-2-34 standard for blood pressure measurement, the signal output is  $5\mu\text{V}/\text{V}/\text{mmHg}$ , that means, when the patient monitor excites the pressure transducer with the Wheatstone bridge with 5 V, the signal will be  $25\mu\text{V}/\text{mmHg}$ , displayed at the patient monitor.

## The capacitive pressure structure

measurement principles for pressure transducers

**capacitive:** one (or more to improve signal level) several plate capacitors can work as pressure sensor, when one (lower) plate is fixed in the substrate and the other (upper) plate will be deformed by the pressure. The changing capacity  $C = \epsilon_0 \cdot \epsilon_r \cdot A / d$  will be measured in an appropriate circuit, in case of the capacitive pressure sensors of [www.ims.fhg.de](http://www.ims.fhg.de) (view graphic) with the so-called SC-technique (Switched-Capacitor), of an analogue circuitry to measure potential differences

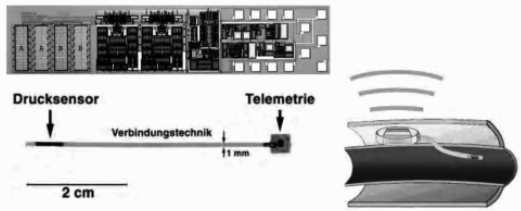
These capacitive structures do not suffer from high power-loss due to heating the Wheatstone bridge, but the signal does not comply to the ISO-60601-2-34 standard, in case it shall, it has to be converted. Or a somehow different interface to the patient monitor is necessary.

In the lecture shortly also the piezoelectric and inductive measurement principles are discussed.

Two demonstrators for the capacitive pressure sensor applications.


a first capacitive pressure system  
which was implanted


ITES was a BMBF funded project around the year 2000 which originally wanted to run a Siemens pressure chip in a telemetric set-up, without battery, but finally ended up in prototypes running with battery.



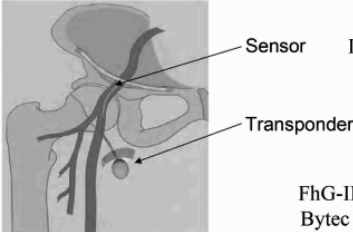
Pictures from the publication of B. Glasbrummel, G. Muhr in MEDRubin 2001,  
<http://www.ruhr-uni-bochum.de/rubin/>, Wissenschaftsmagazin of Ruhr university Bochum

a new project, just in animal tests

GEFÖNDERT VOM  
 Bundesministerium für Bildung und Forschung



Hyper-IMS-Consortium:  
 Dr. Osypka GmbH, Rheinfelden  
 MHM GmbH, Aschaffenburg  
 AME/Helmholtz-Institut  
 Prof. Schmitz-Rode, RWTH-Aachen  
 IWE1, Prof. Mokwa, RWTH-Aachen  
 University Clinics Heidelberg  
 Cardiology Prof. Katus,



Subcontractors:  
 FhG-IMS, Duisburg, chip design, wafer-fab  
 Bytec GmbH, Stolberg, transponder reader

Schematic diagram of the implant in the femoral artery