
Eustachian tube pressure equilibration.

*Quantitative analysis of correlation between
pressure gradient and pressure change rate*

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1.1 Middle ear pressure regulation

6 complementary mechanisms:

1. Gas exchange – continuous bidirectional across mastoid mucosa
2. Eustachian tube openings (ETO's) – intermittent
3. Tympanic membrane deformation – passive and related to elasticity
4. Mastoid buffering – passive and related to volume
5. Mastoid mucosa congestion – active and related to area and volume
6. Eustachian tube valve pumping effects – active

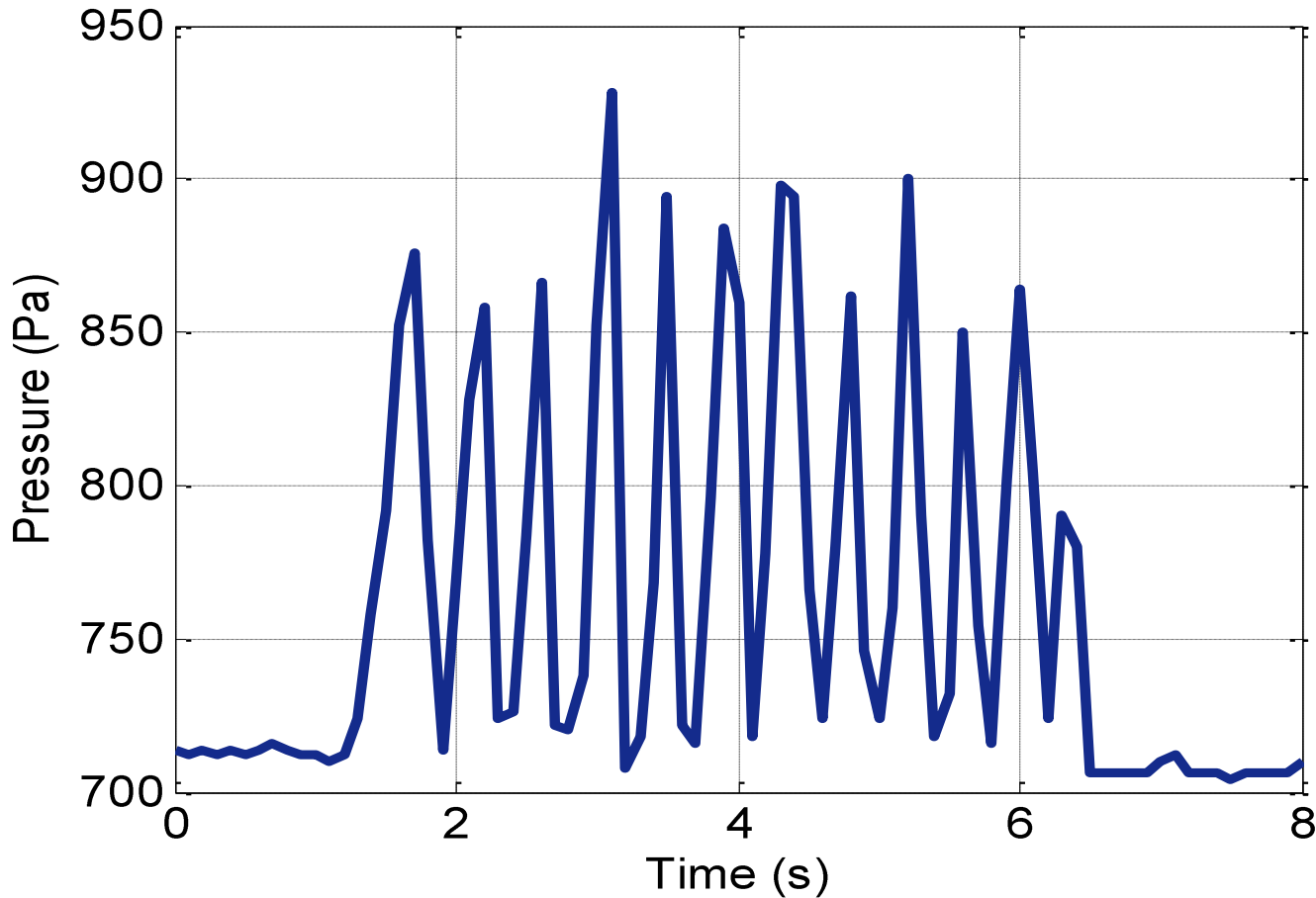
1.2 Measurements of pressure

- Indirect methods – tympanometry
 - inaccurate, impractical for continuous long-term monitoring, low time resolution
- Direct methods – previous
 - ethical problems, impractical for clinical use, TM not intact, leakage
- Our method
 - direct methods with high accuracy (1 Pa)
 - high temporal resolution (0.1 s)
 - agreeable to subjects for long-term monitoring
 - ethical approval in patients for parotid surgery

1.3 Hypotheses – Eustachian tube openings ETO's

- Pressure equilibrations of the ETO's can be described by the pressure change rate, and the pressure change rate correlates to the pressure gradient, and
- these correlations vary individually; ie. correlations may describe individual ET function status

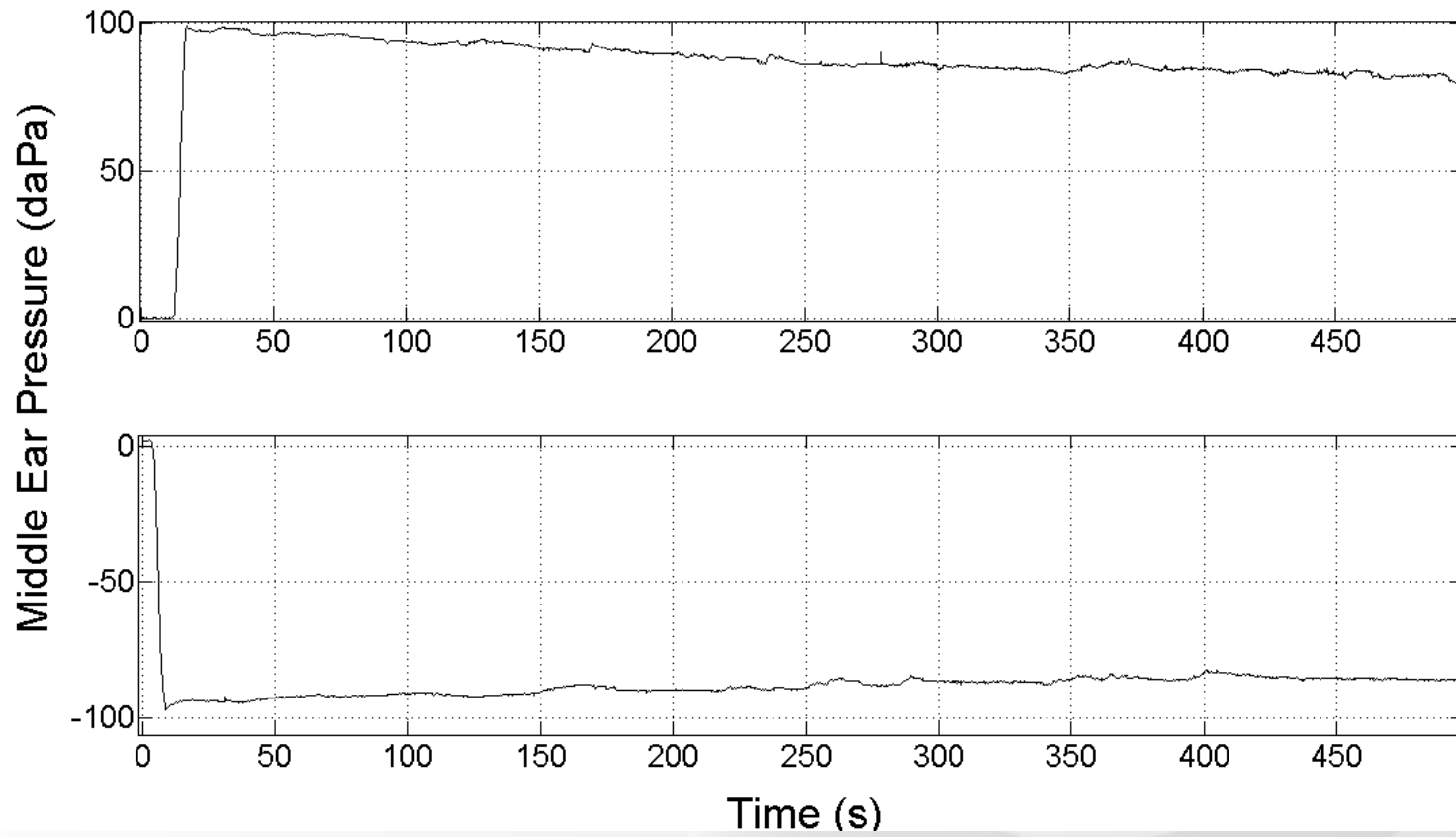
2.1 M&M – diagram and procedure



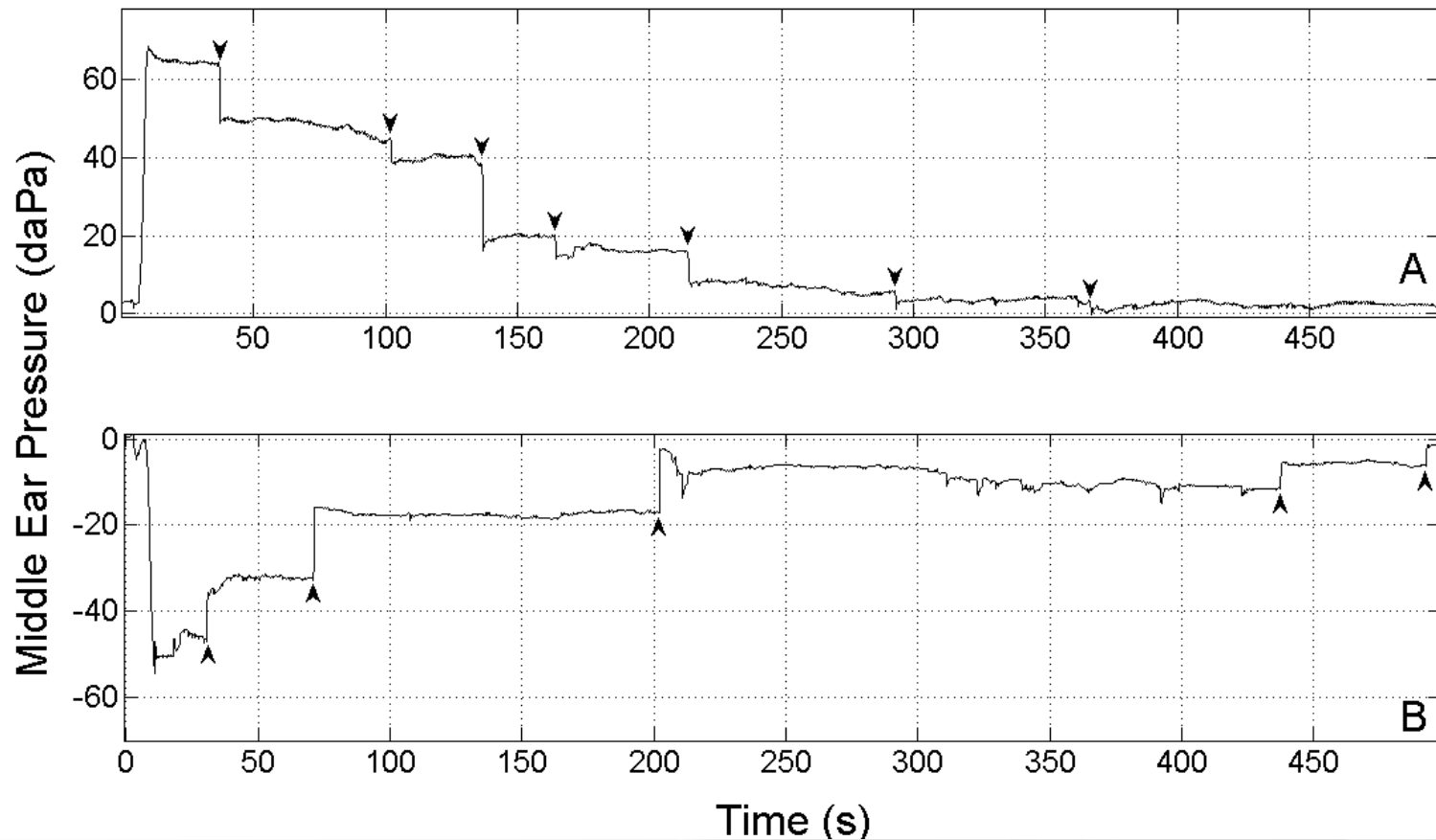
2.2 M&M – participants and experiments

- 12 normal adults patients for parotidectomy
 - normal otomicroscopy, pure tone audiometry, and tympanometry
 - experiments next day after surgery
- Experimental MEP deviations introduced by volumetric changes of:
 - 50, 100 and 200 μ l
 - (3-way-stop-cock and a 500 μ l gas tight syringe)
- Counter-regulation of MEP recorded by on-line exp's
 - 10 min's time frames per experiments
 - 6 experiments minimum per subject

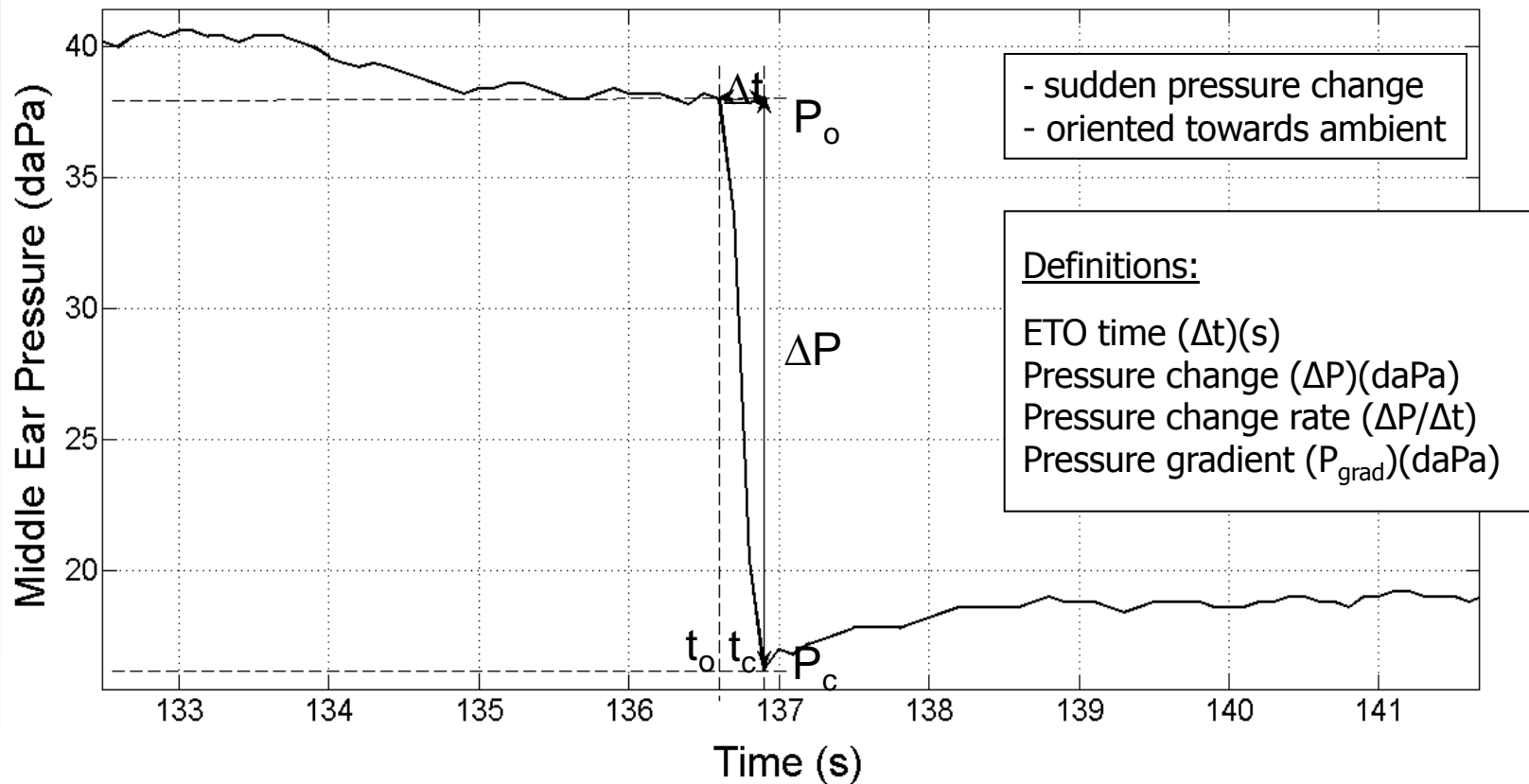
2.3 M&M – gradual responses without ETO's



2.4 M&M – ETO's during inflation and deflation tests



2.5 M&M – description and analysis of ETO's

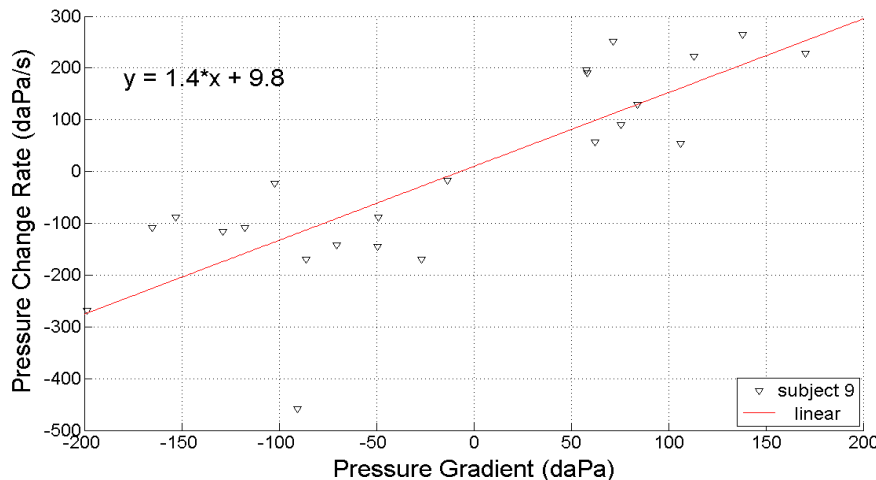
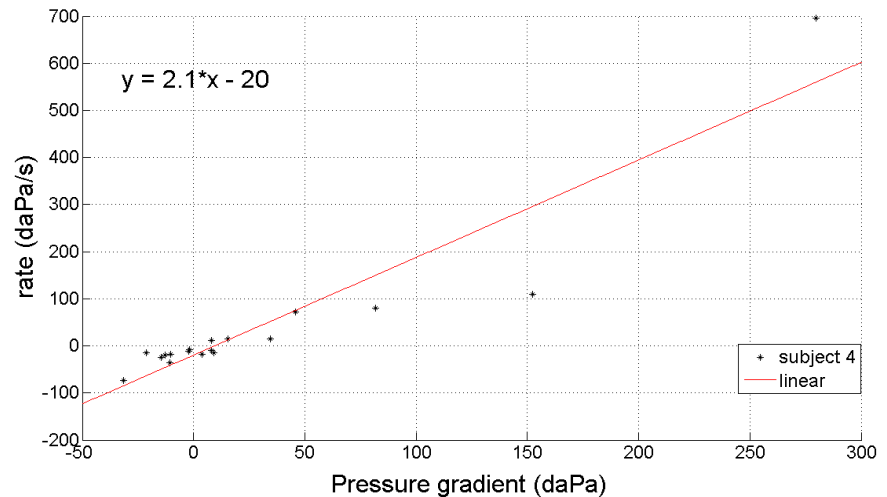


3. Results – equilibration pattern

- Nine subjects successfully completed the experiment
- Gradual response – ie. no ETO's (2/9 subjects)
- Step-wise response – frequent ETO's (7/9 patients)
(three of these showed only few ETO's)

3.1 Results – correlation analysis rate and gradient

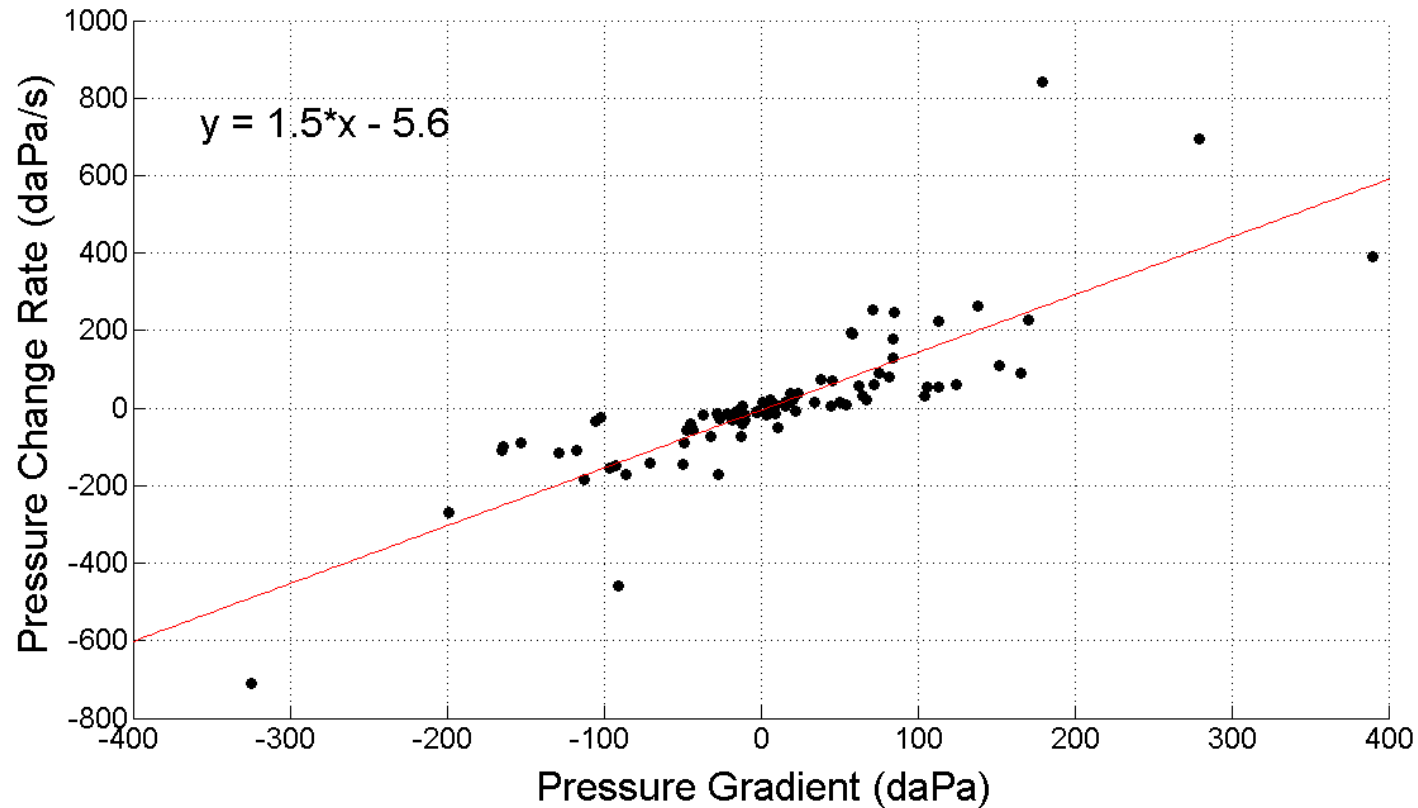
The pressure change rate correlates positively to the pressure gradient, ie. the higher the pressure deviation, the higher the rate of pressure change



3.2 Results – correlation analysis rate and gradient

Subjects	n	slope (daPa/s)	r^2	p -value
2	31	0.86	0.558	<0.001
4	18	2.1	0.867	<0.001
7	10	1.8	0.725	0.002
8	5	0.66	0.594	0.127
9	23	1.4	0.668	<0.001
10	4	0.74	0.977	0.012
11	5	0.66	0.594	0.127
Overall	96	1.5	0.665	<0.001

3.3 Results – overall correlation analysis



4.1 Discussion

- Short term experimental MEP changes in normal awake humans can actively be counter-regulated by both
 - the ETO's
 - gradual responses (both *positive and negative* directions)
- Linear correlations have been found between the pressure change rate by ETO's and the actual pressure in the ME
- Correlations vary individually and may relate to individual ET function

Thank you!



3.4 Results – mean opening times

Subjects	n	Opening time Δt (s)	SD
2	31	0,481	0,3218
4	18	0,500	0,2656
7	10	0,680	0,4541
8	5	0,900	0,3807
9	23	0,230	0,2304
10	4	0,775	0,2217
11	5	0,900	0,3807
Overall	96	0,638	0,087

3.5 Results – mean pressure change rate

Subjects	n	Mean pressure change rate (daPa/s)	SD
2	31	-11,245	40,8541
4	18	41,8132	168,9504
7	10	51,1999	408,1365
8	5	33,4427	25,6763
9	23	-9,5395	187,3849
10	4	34,0381	56,1937
11	5	33,4427	25,6763
Overall	96	12,158	174,327

4.2 Discussion

➤ ETO's

- not the main MEP regulator
- important for large pressure gradients; in full recordings they are not met so often like in pressure alteration tests (< 1 ETO/h)
- They can be passive (when $MEP > 200$ daPa) or active (during swallowing)
- Literature defines them as > 10 daPa, but our recordings at high resolution reveal ETO pattern < 10 daPa → Challenge: where to set the lower limit for definition

➤ Swallowing (deglutition)

- Not always accompanied by ETOs → +/- pressure equilibration
- many times corresponding to spikes of various patterns on full recordings → not interpreted yet

➤ Perspectives: pattern recognition