

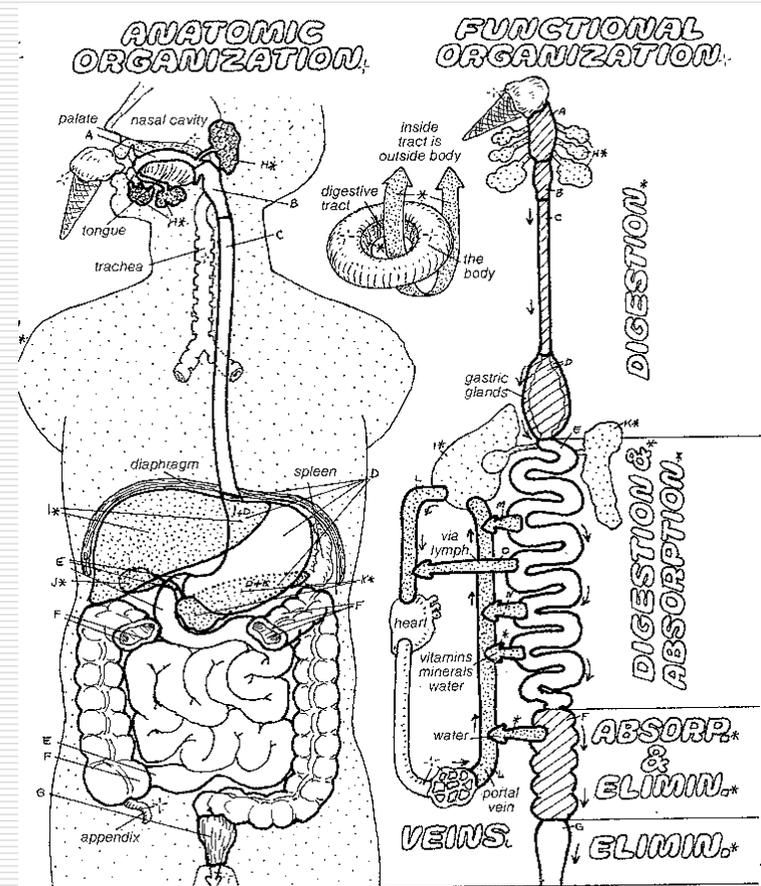
# Introdução ao Biomagnetismo

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Oswaldo Baffa Filho  
Departamento de Física-FFCLRP  
Universidade São Paulo  
Aula #5-Aplicações em  
Gastroenterologia

# Motivação

- ❑ Para que o processo de digestão se realize o alimento tem que transitar por diferentes segmentos do tubo digestivo com uma velocidade apropriada.
- ❑ Enzimas
- ❑ Motilidade
- ❑ Irrigação
- ❑ Sinais elétricos



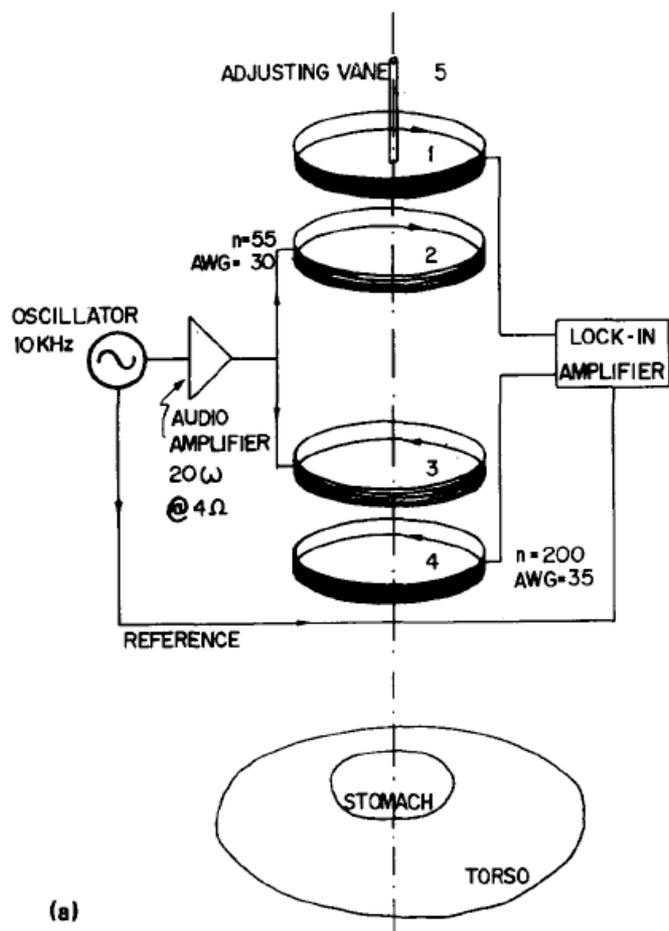
# Métodos em Uso para o Estudo do Trato GI

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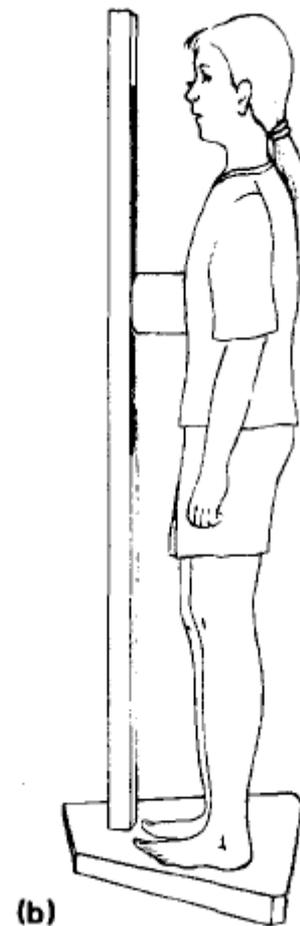
- Sondas e Cateteres
    - Medidas de pressão, pH, conteúdo gástrico
  - Raios X
    - Fluoroscopia com agente de contraste
  - Radioisótopos
    - Alimento teste com marcador radiativo
- Estes métodos são invasivos ou utilizam radiação ionizante



# Esvaziamento Gástrico sensor (a) e posicionamento (b)



(a)



(b)

# Esvaziamento Gástrico

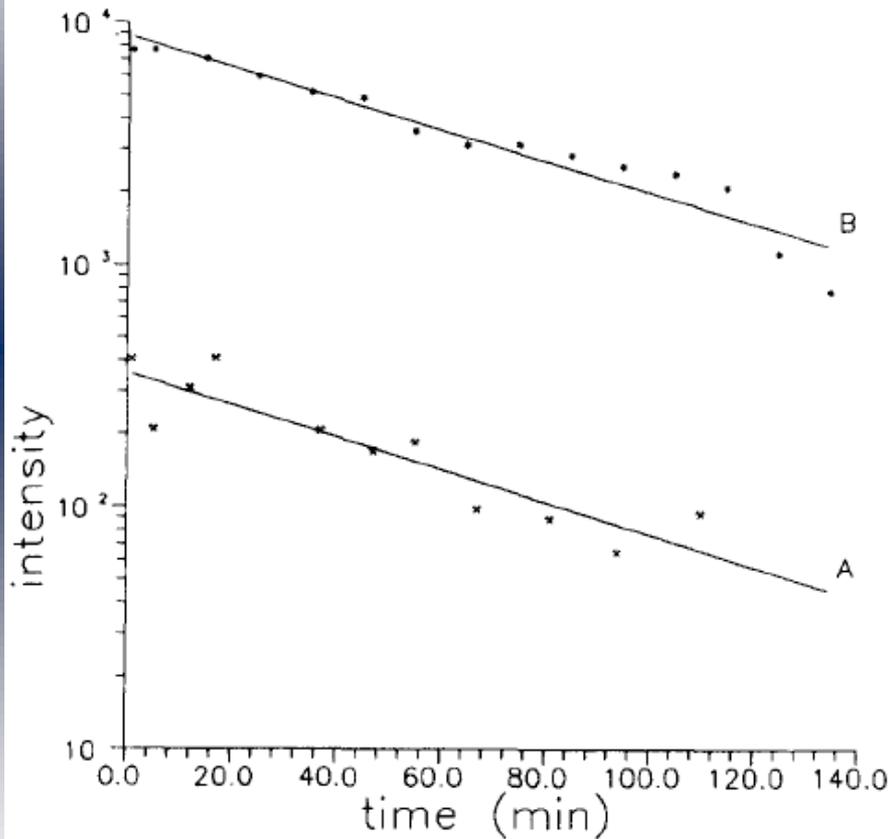


TABLE I. Gastric emptying times (minutes) with standard deviations.

Subject	Susceptometry	Gamma camera
JRM	61 ± 19	61 ± 17
MA	45 ± 18	47 ± 12
JVS	80 ± 20	70 ± 21

MIRANDA, J. R., BAFFA, O., OLIVEIRA, R. B., MATSUDA, N. M. An AC Biosusceptometer to Study Gastric Emptying. Medical Physics. , v.19, n.2, p.445 - 448, 1992.

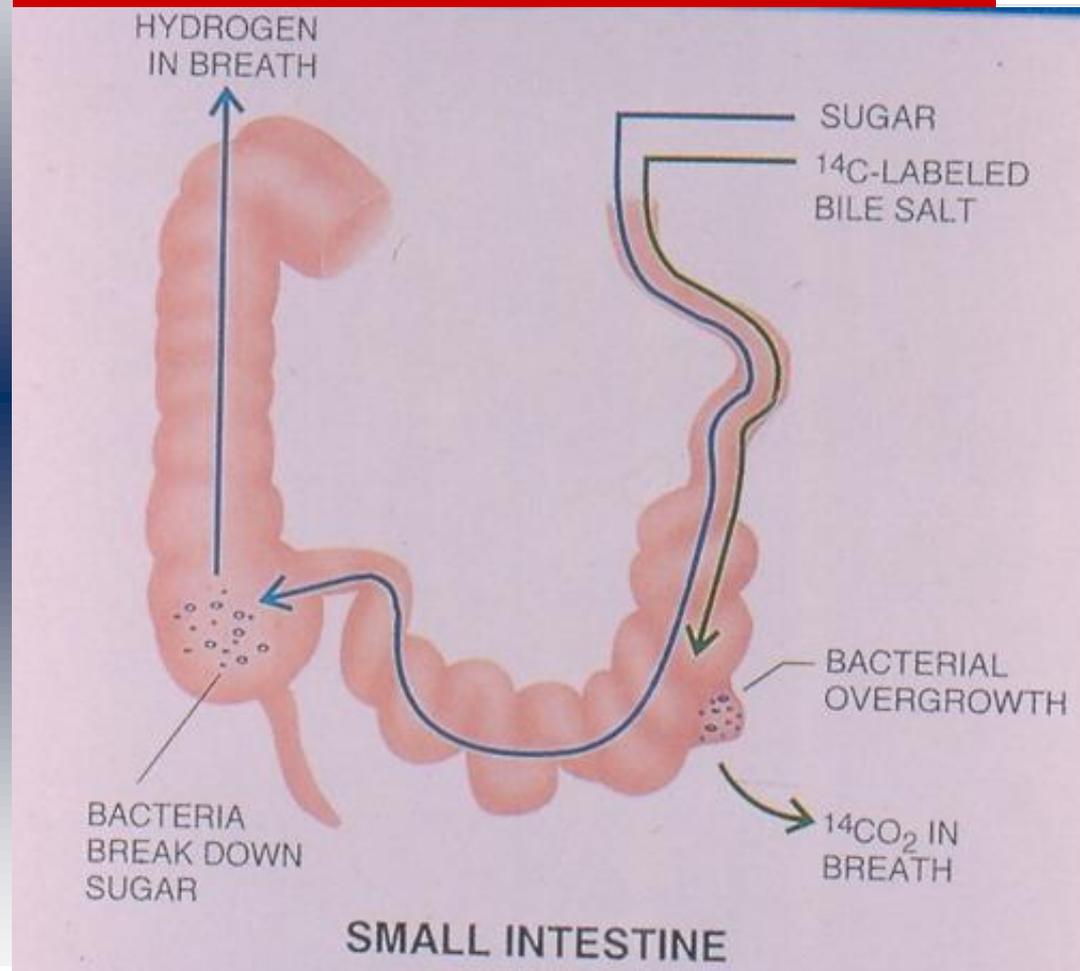
# Medidas de Tempo de Trânsito Orocecal

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- ❑ OCTT foi medido por métodos biomagnéticos e os resultados foram comparados aos teste do hidrogênio expirado.
- ❑ Uma refeição de prova magnética contendo lactulose foi ingerida pelo sujeito e o hidrogênio expirado foi analisado por cromatografia gasosa.

OLIVEIRA, R. B., BAFFA, O., TRONCON, L. E. A., MIRANDA, J. R. A., CAMBREA, C. R. Evaluation of a Biomagnetic Technique for Measurement of Orocaecal Transit Time. *European Journal Of Gastroenterology Hepatology.* , v.8, p.491 - 496, 1996.

# Tempo de Trânsito Orocecal-Teste do Ar Expirado



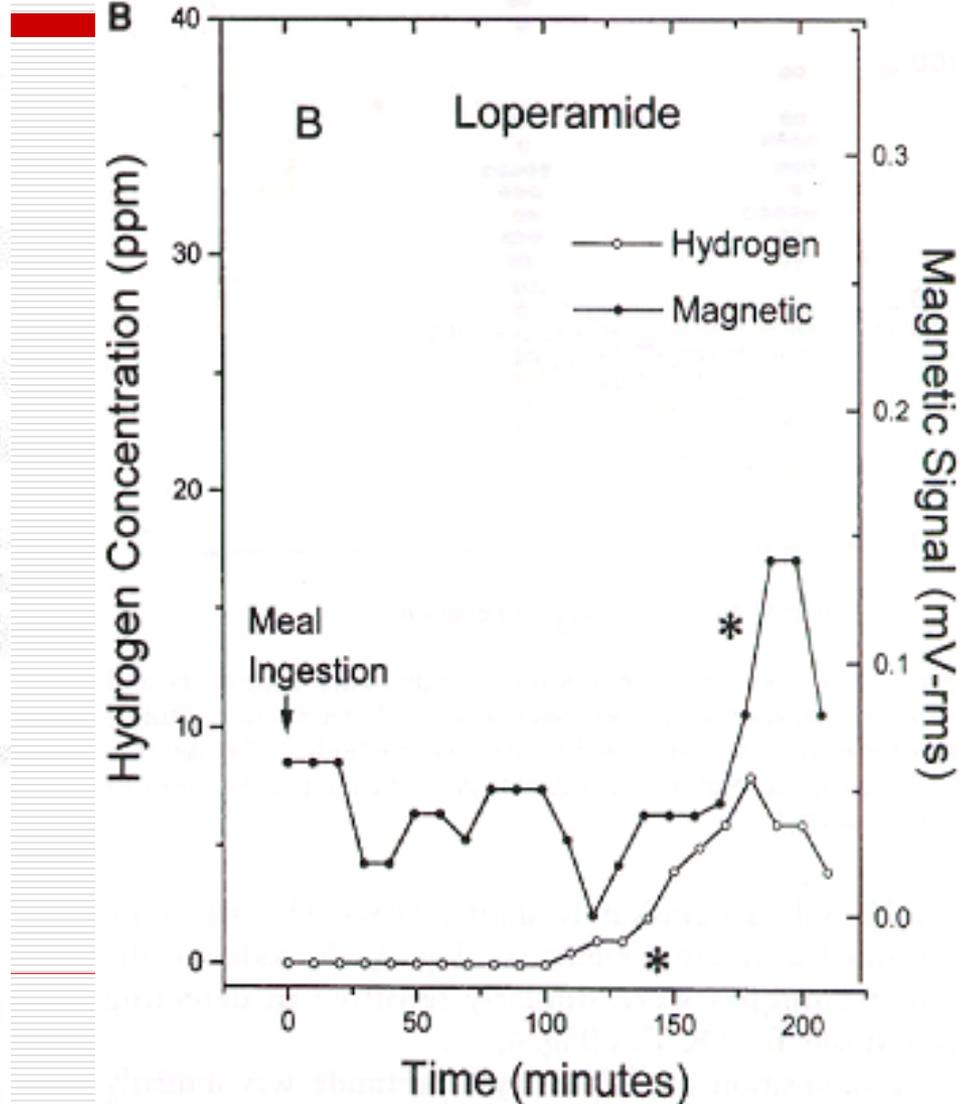
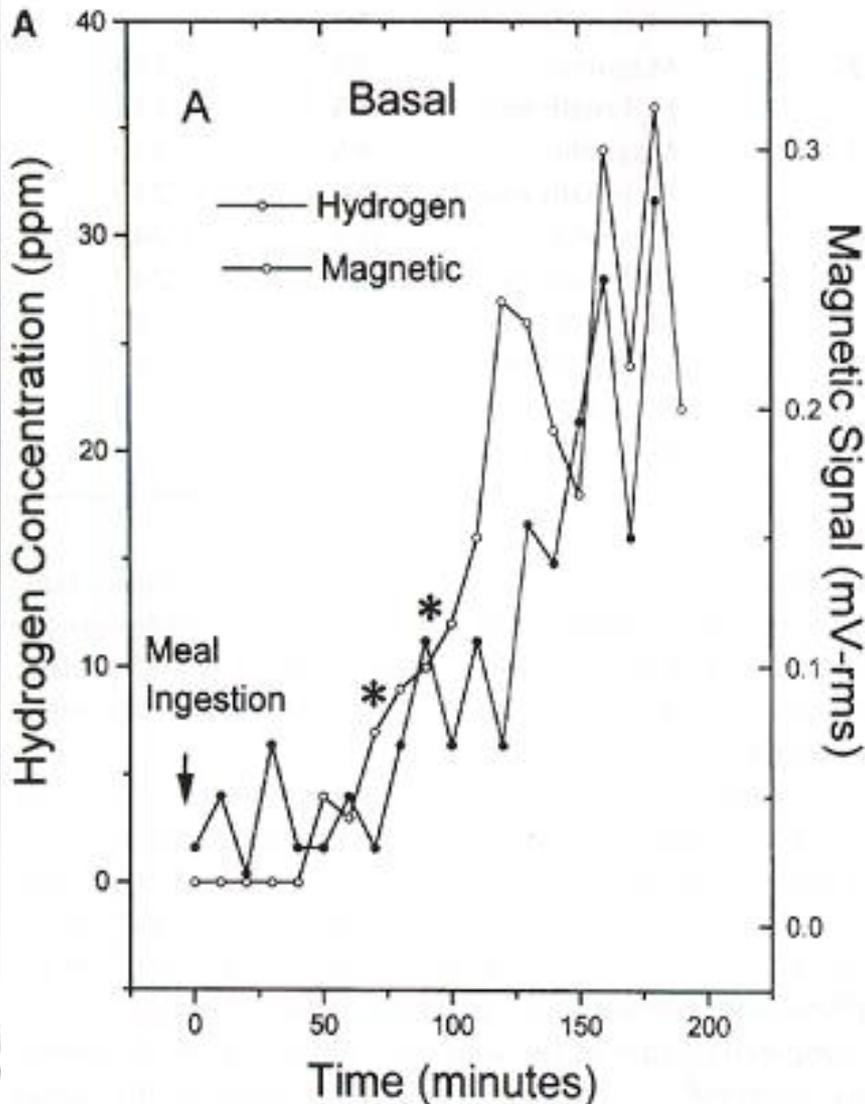
- Uma refeição de prova contendo lactulose chega ao ceco onde o açúcar é digerido por bactérias produzindo hidrogênio

# Coleta of Hidrogênio Expirado

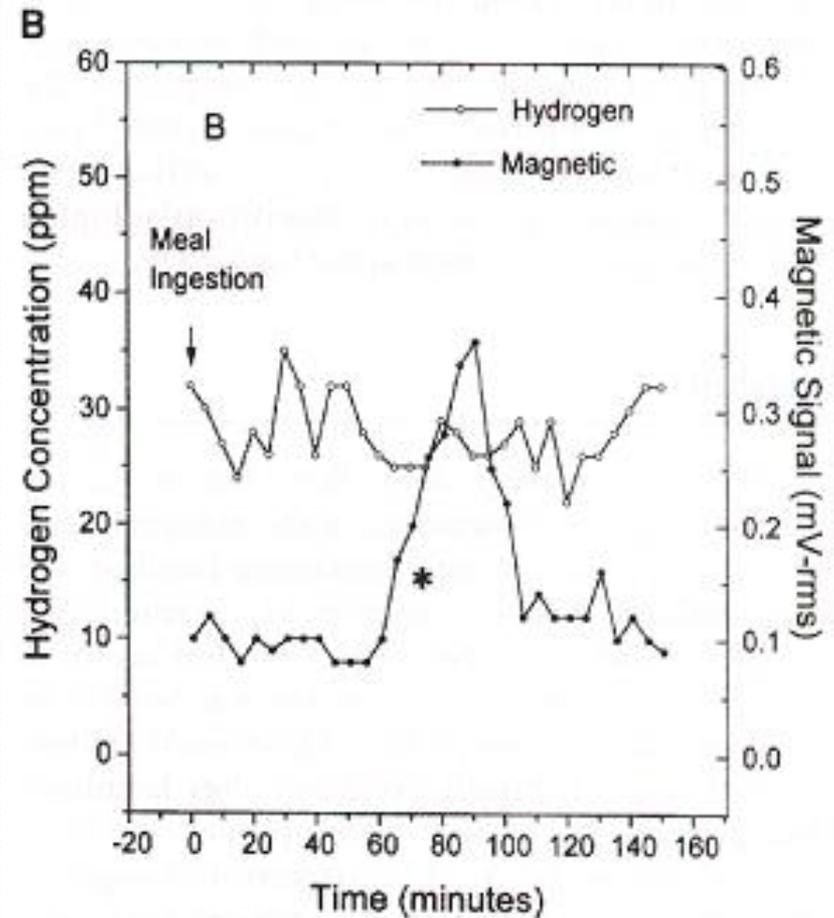
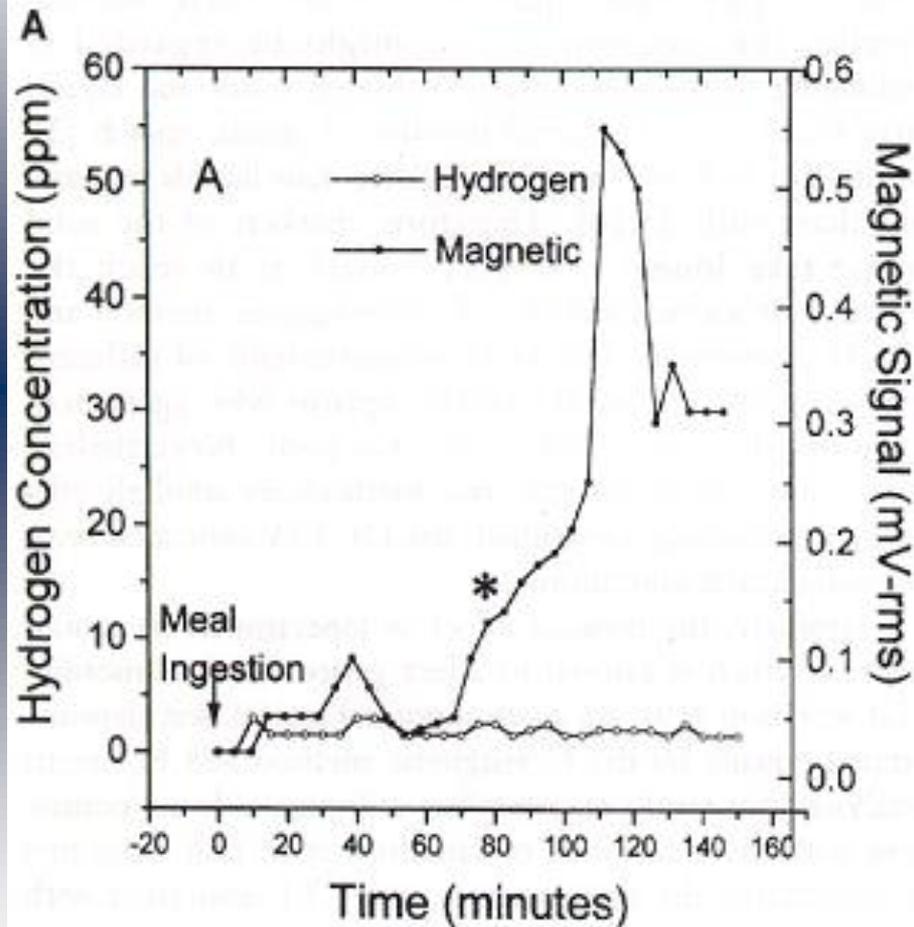
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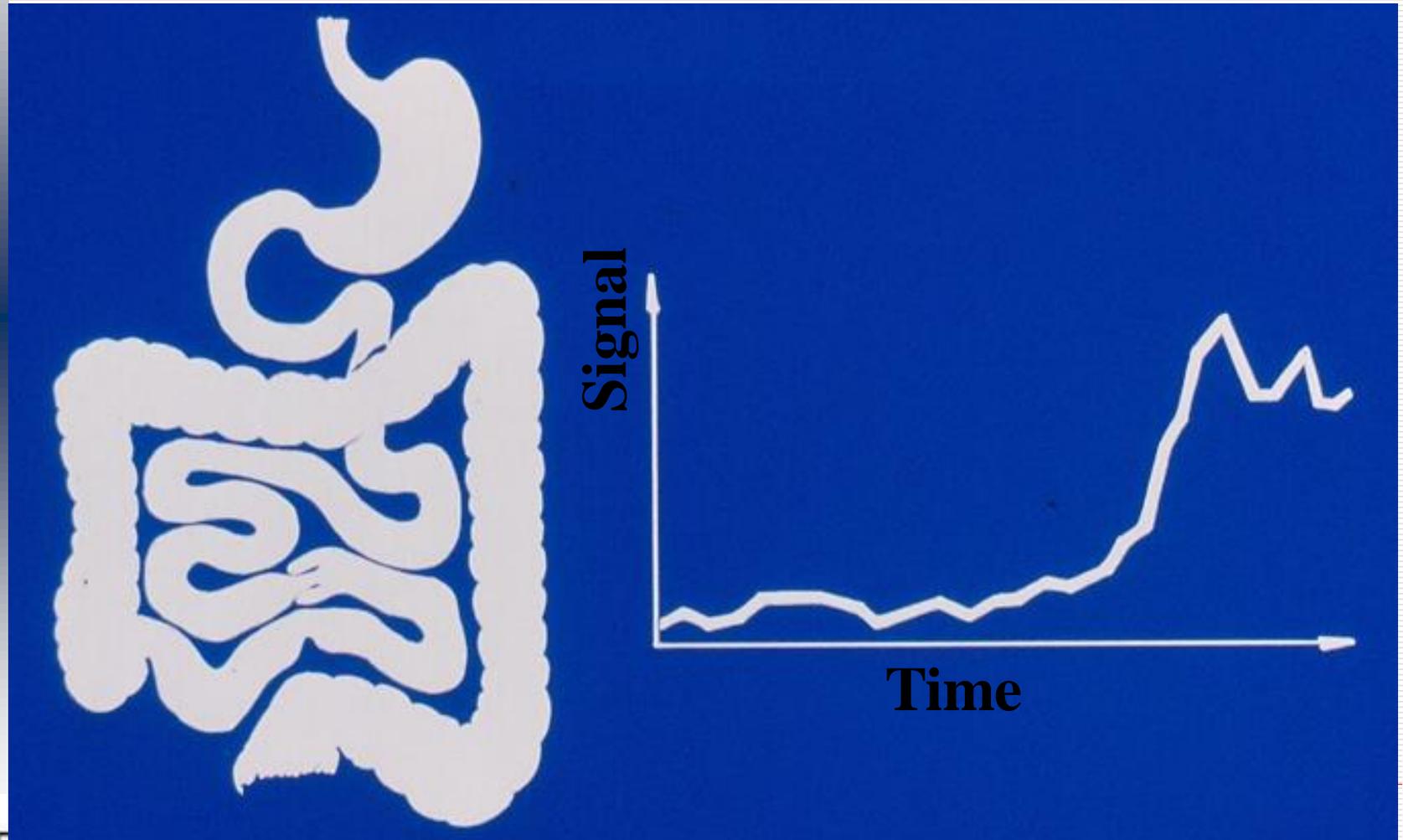
# OCTT do Mesmo Sujeito Antes e Depois da Administração de Loperamida



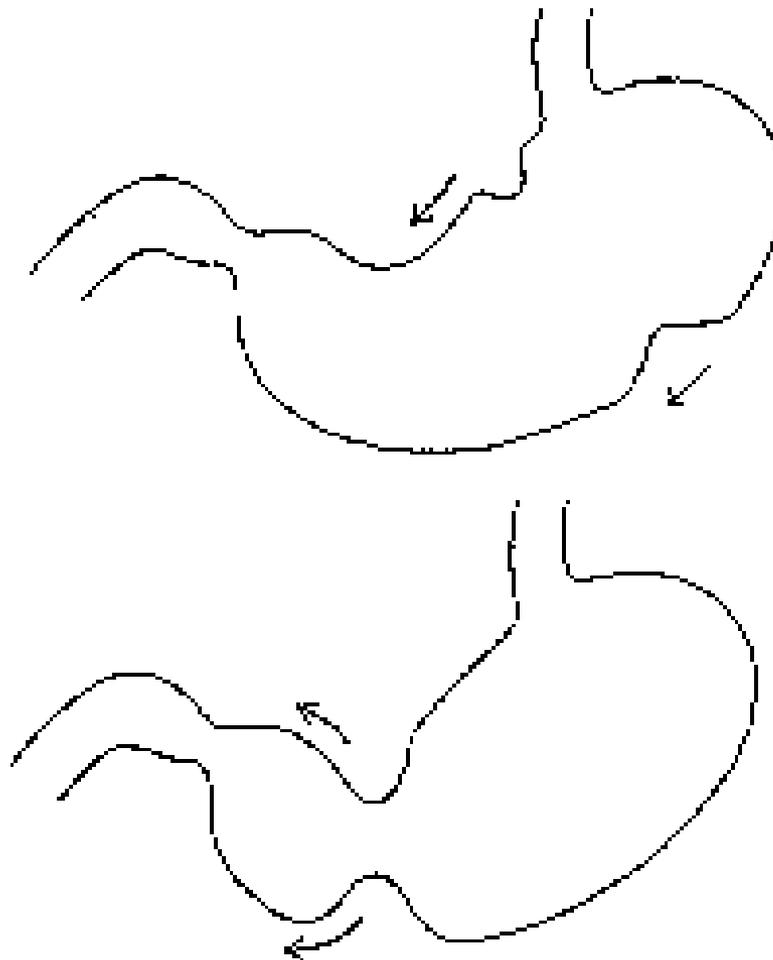
# OCTT para um Sujeito que Não Produz $H_2$ e para um Sujeito com Elevada Produção em Comparação com o Método Magnético



# Como interpretar os dados ?



# Atividade Mecânica do Estômago "Ondas Lentas"

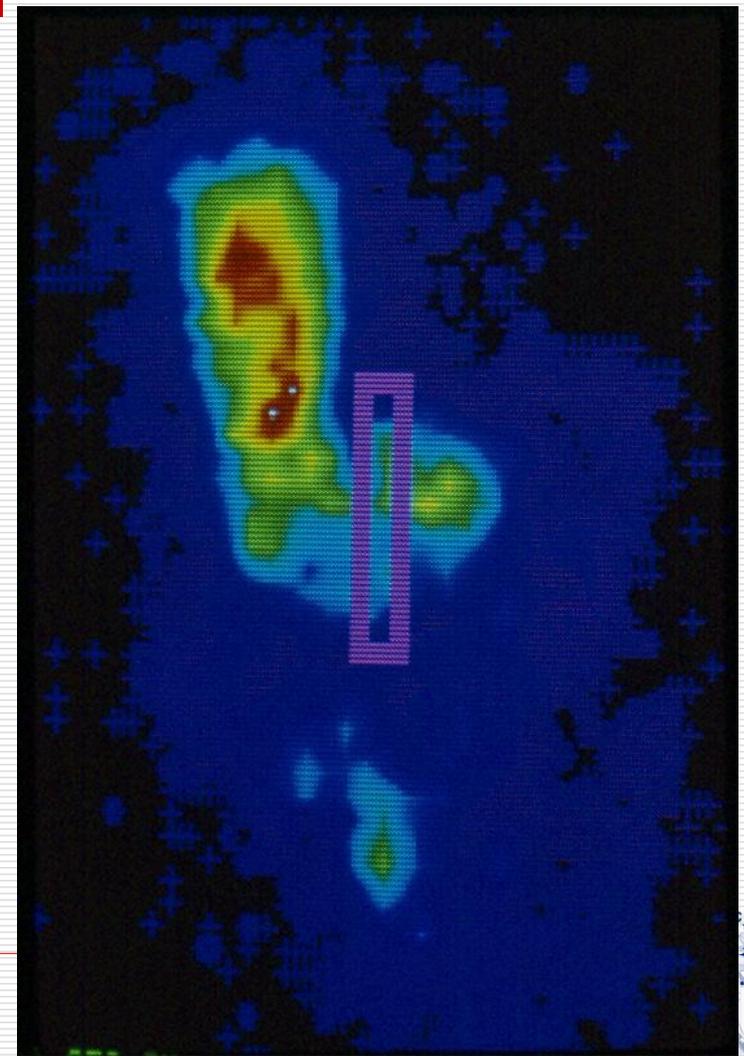
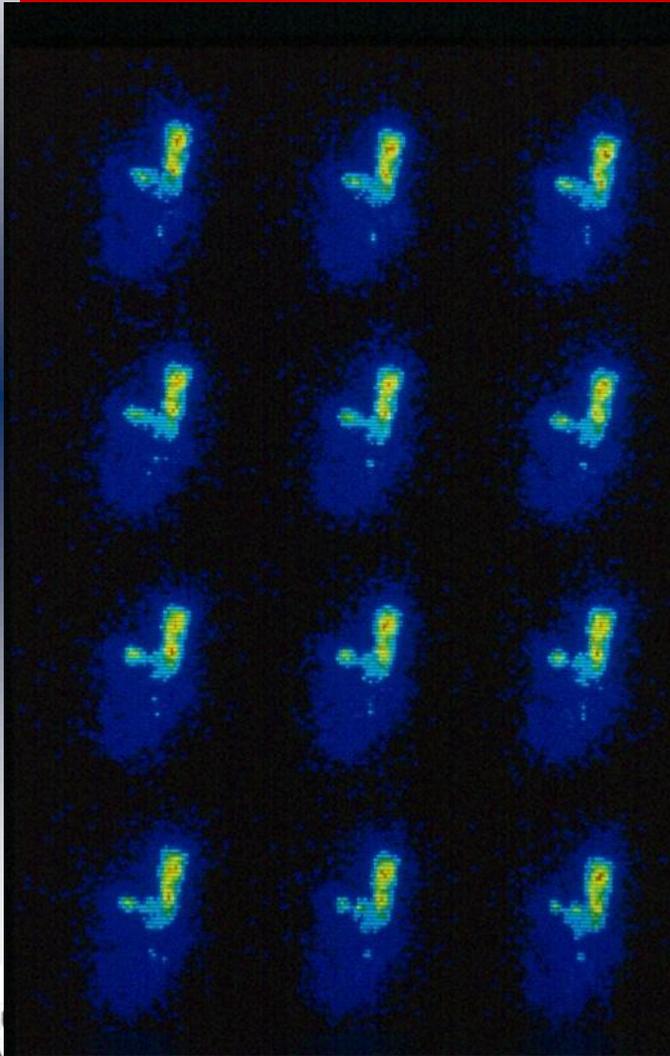


# Alimento Teste

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- As medidas com o biosusceptômetro AC (BAC) exigem a ingestão de uma refeição de prova contendo marcadores ou traçadores magnéticos inertes. A ferrita em pó e magnetita são utilizadas em concentrações de 1-4% em peso.

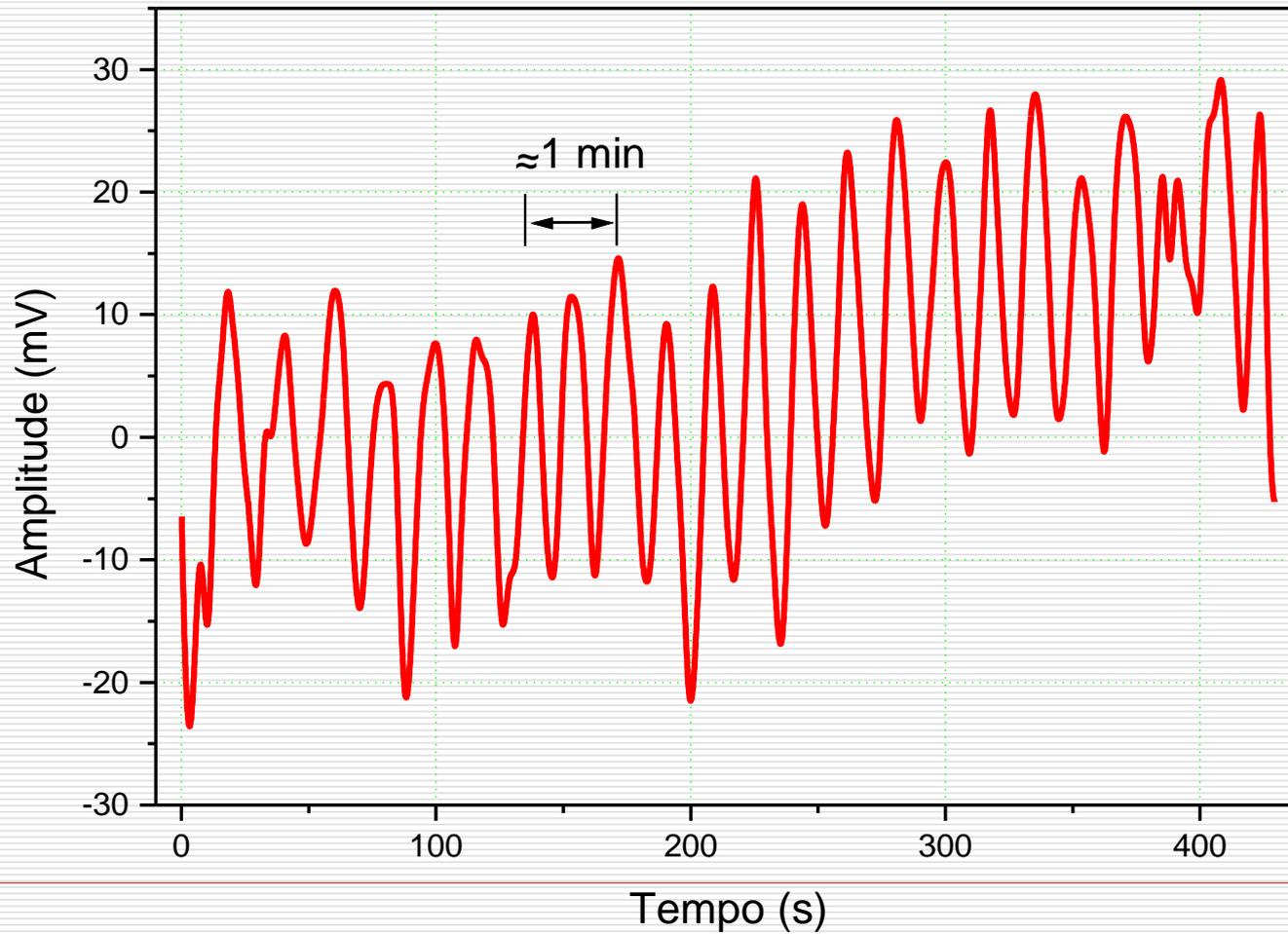
# Atividade Mecânica do Estômago



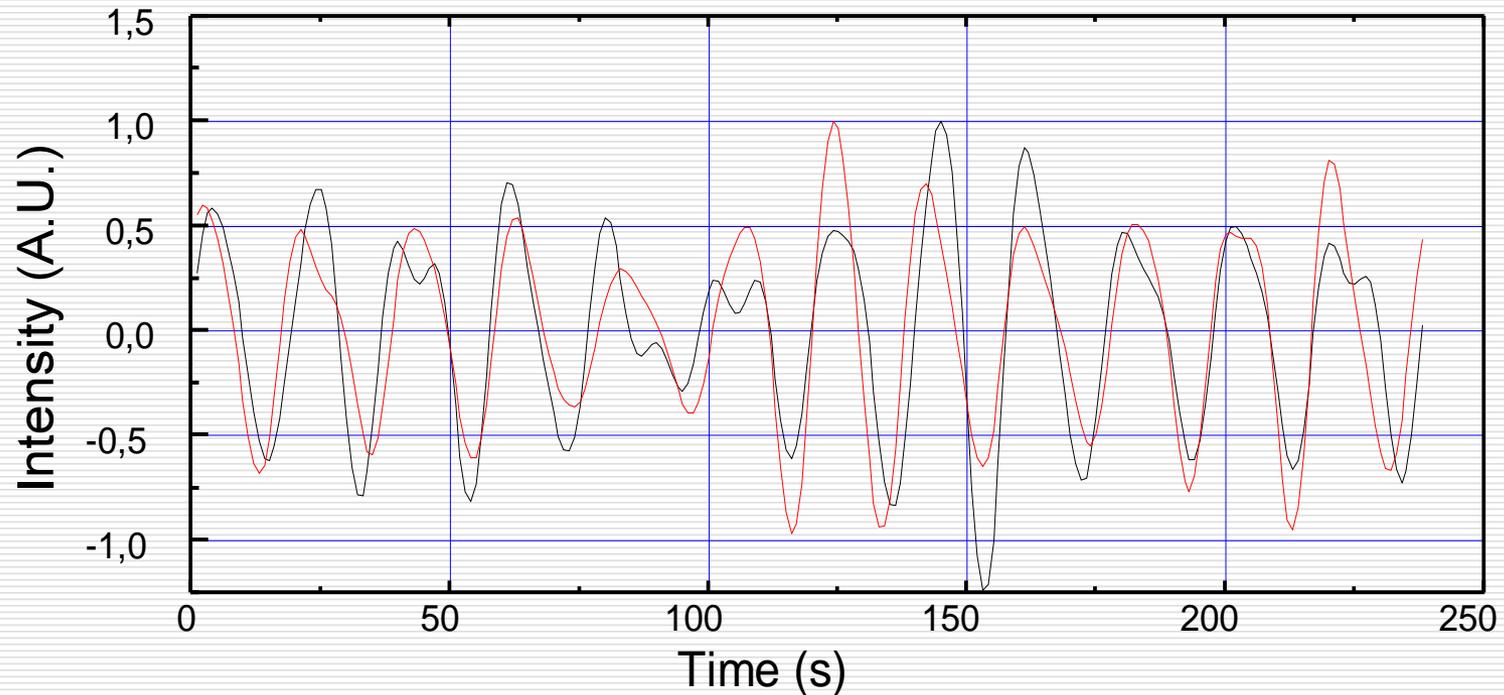
# Arranjo Experimental para Medidas Gástricas



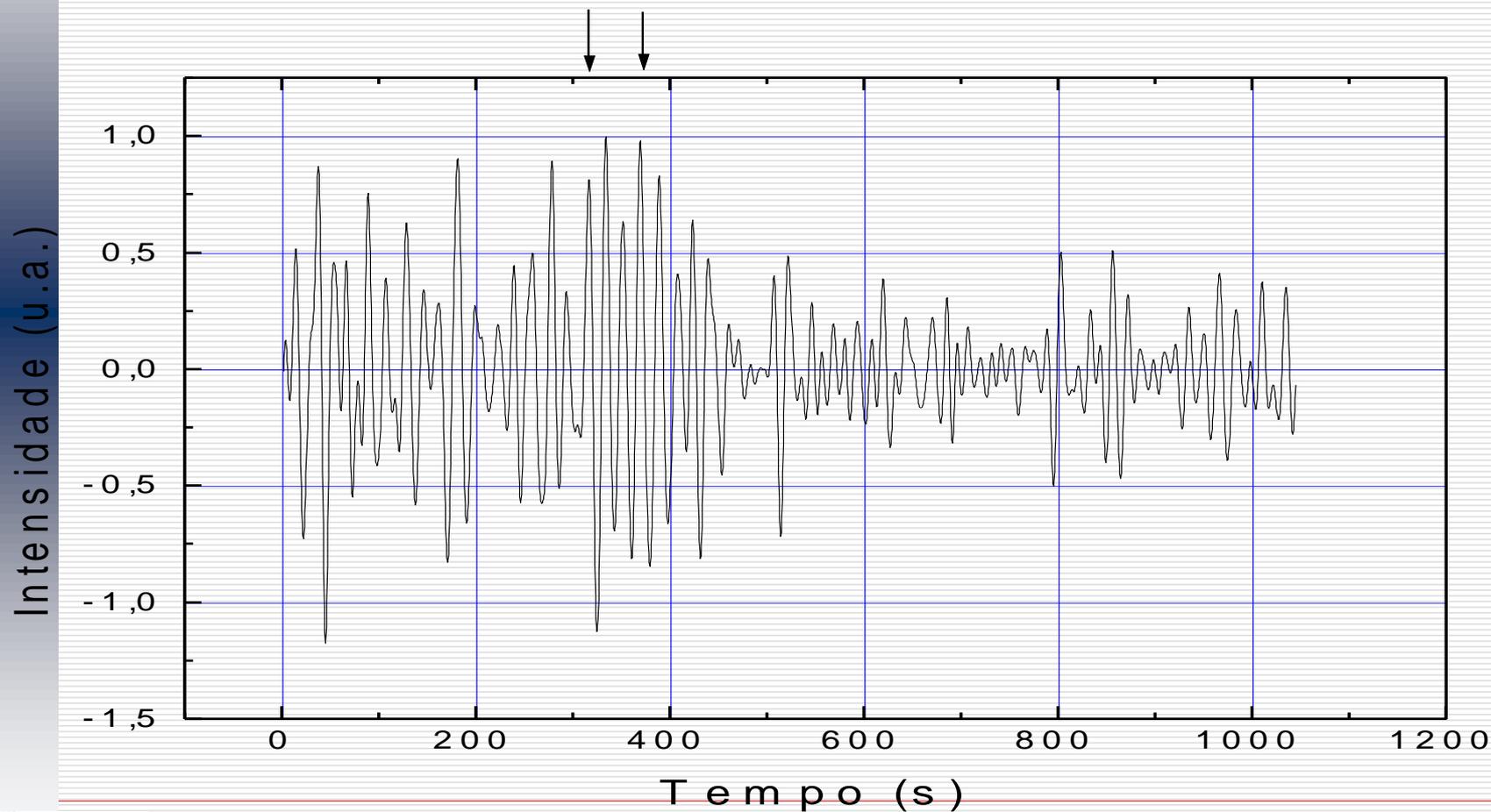
# Contrações Gástricas



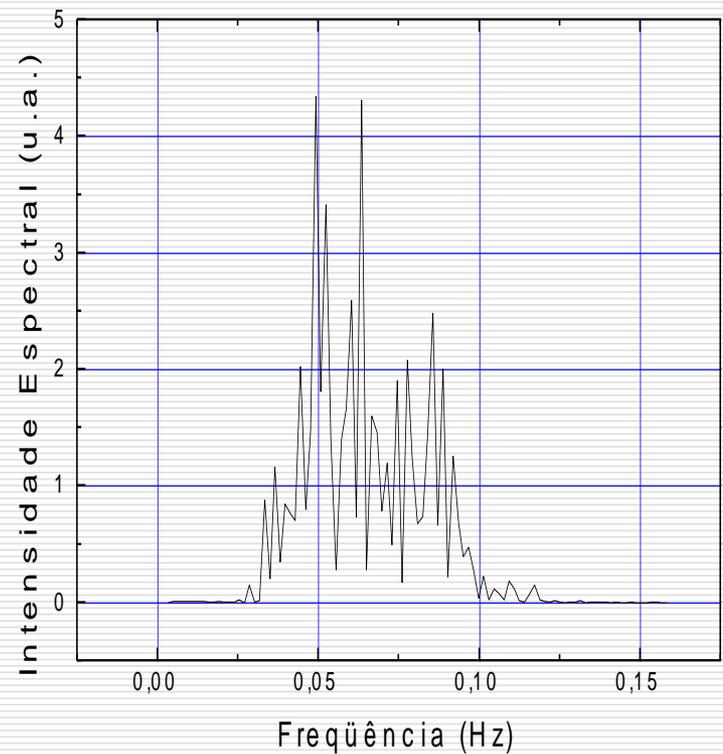
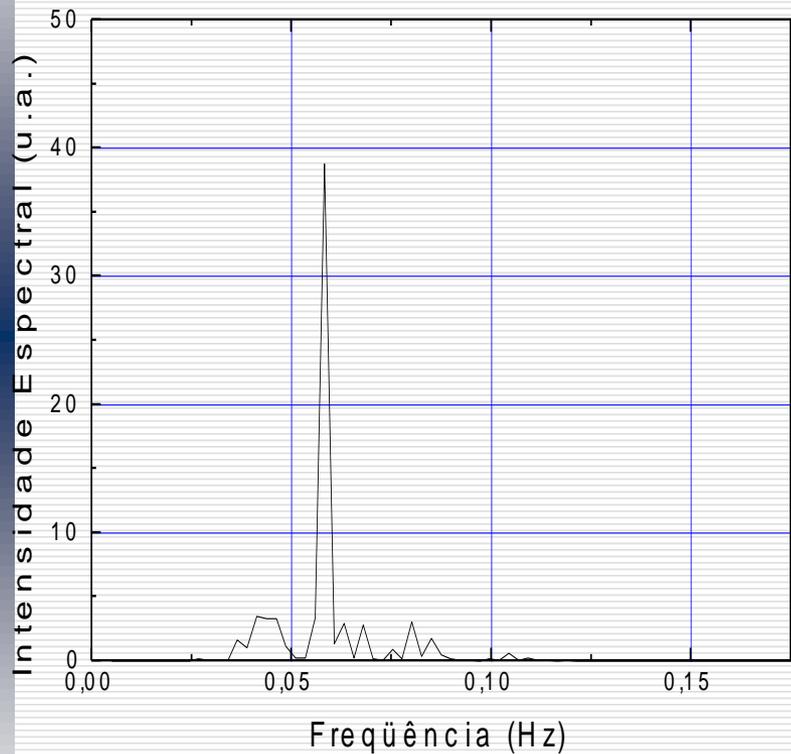
# Registro simultâneo da ACG Susceptometria & Cintilografia



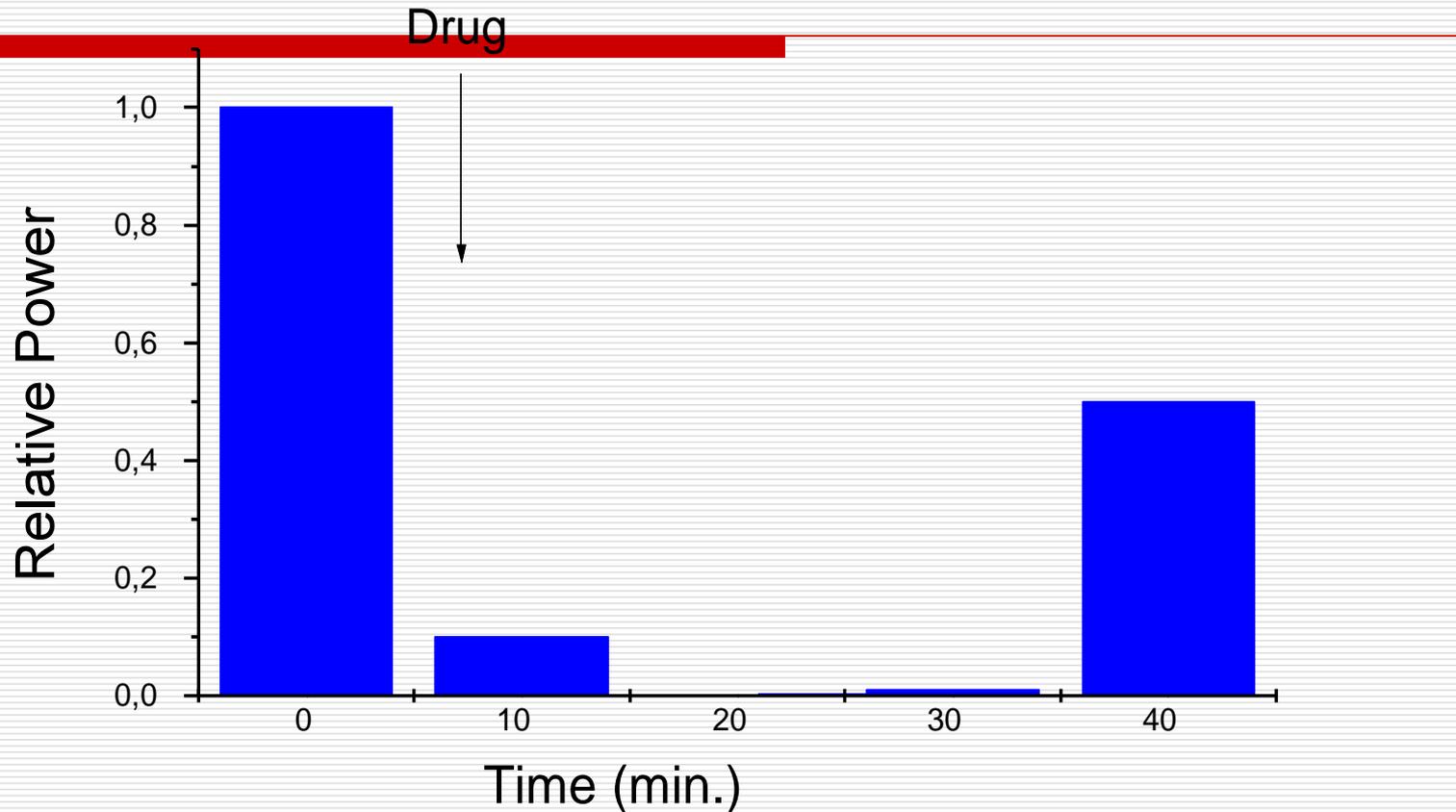
# Estudo da Ação de uma Droga



# Transformadas de Fourier (antes e depois)

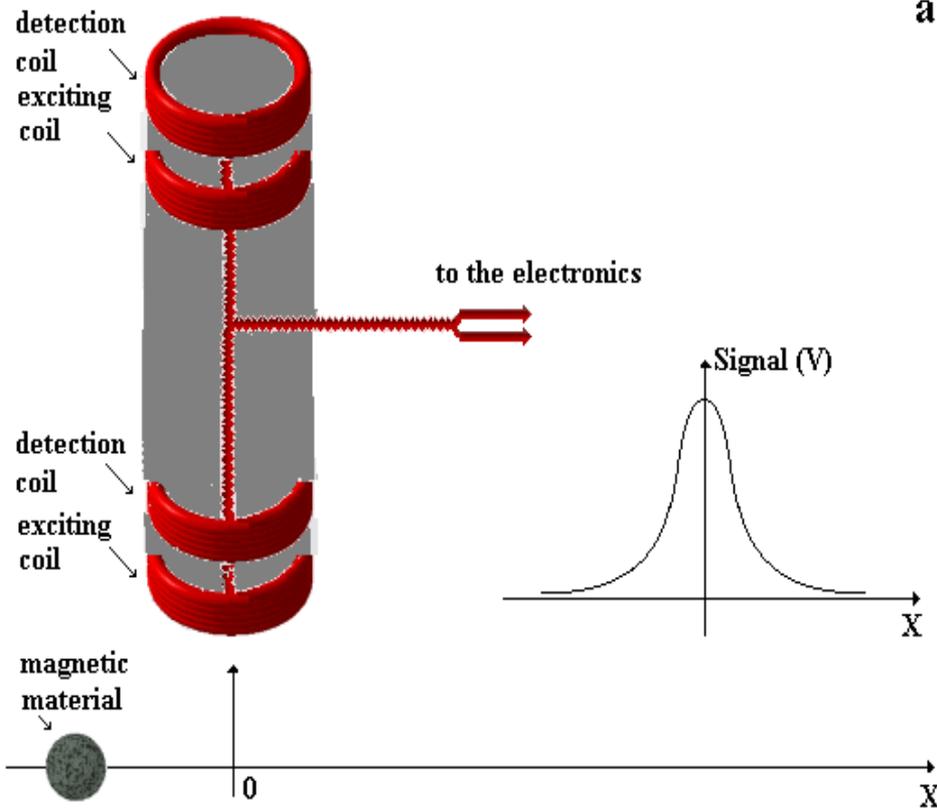


# Amplitude do Sinal Versus Tempo Devido a Ação da Droga



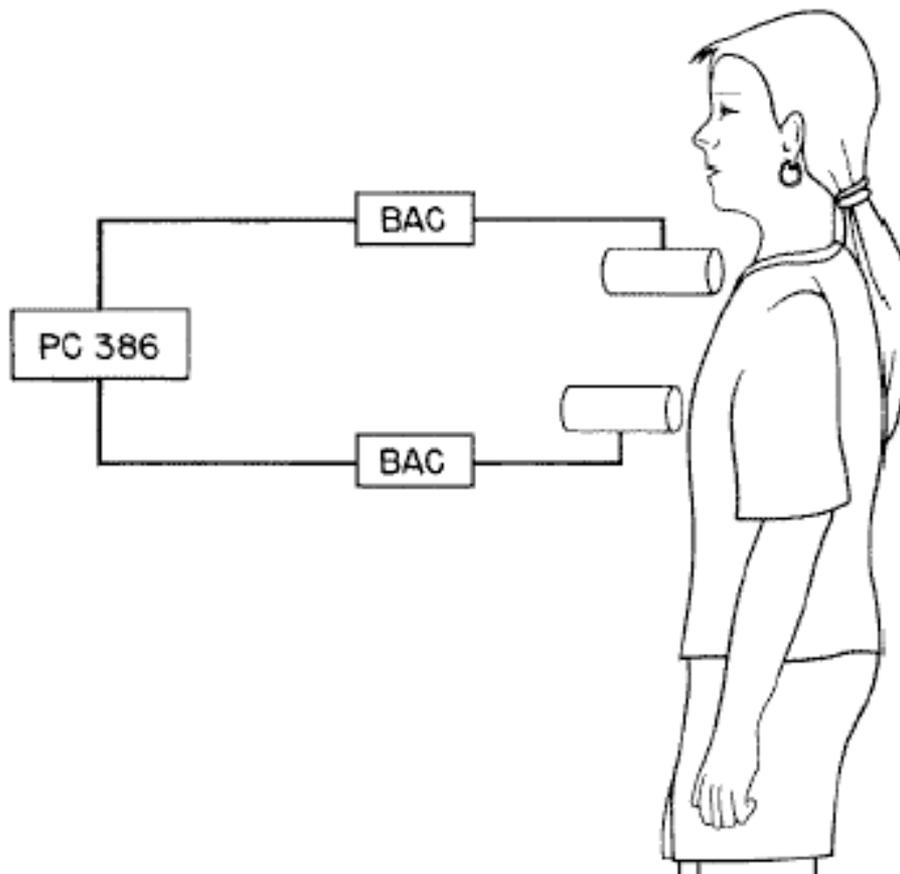
MIRANDA, J. R. A., OLIVEIRA, R. B., SOUSA, P. L., BRAGA, F. J. H. N., BAFFA, O. A Novel Biomagnetic Method to Study Gastric Antral Contractions. *Physics in Medicine and Biology*. , v.42, n.9, p.1791 - 1799, 1997.

# Tempo de Transito Esofagiano (ETT) Configuração dos Sensores



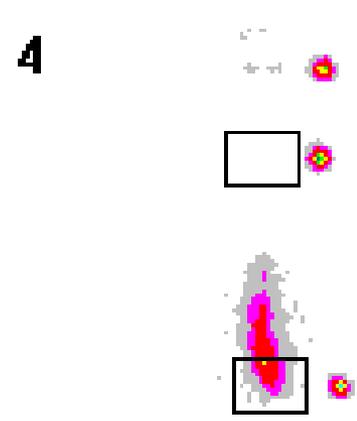
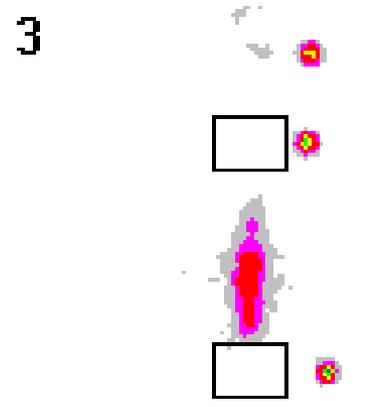
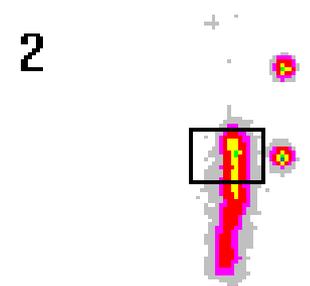
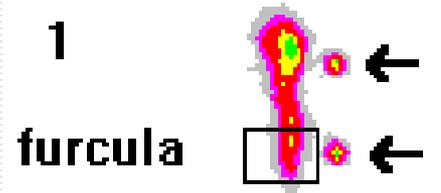
- a
- Biosusceptometro em configuração axial
  - A passagem do alimento teste magnético próximo ao a uma das extremidades produz um sinal

# Posicionamento dos Sensores

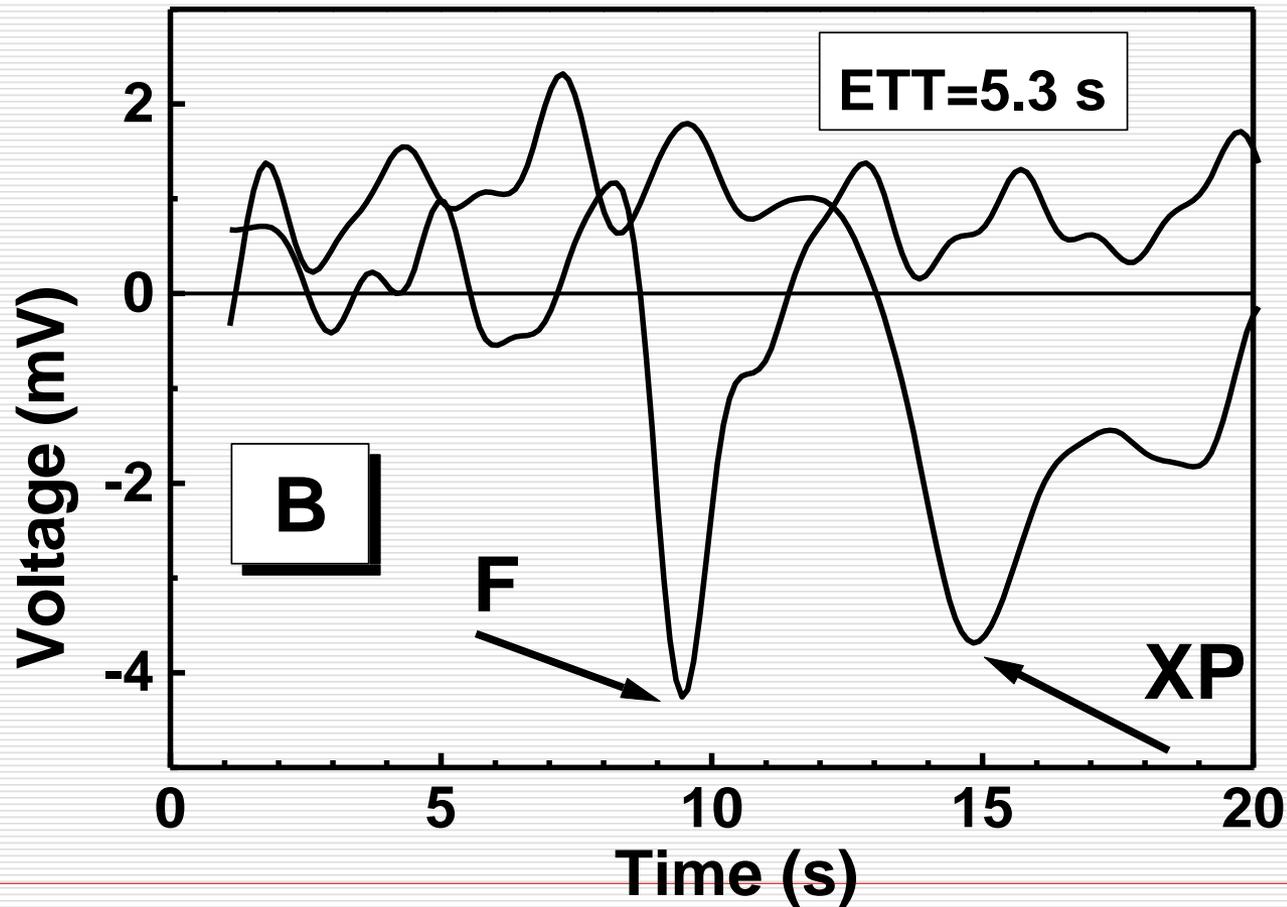


- DAGHASTANLI, N. A., BRAGA, F. J. H. N., OLIVEIRA, R. B., BAFFA, O. Oesophageal Transit Time Evaluated by a Biomagnetic Technique. Physiological Measurements v.19, n.3, p.413 - 420, 1998

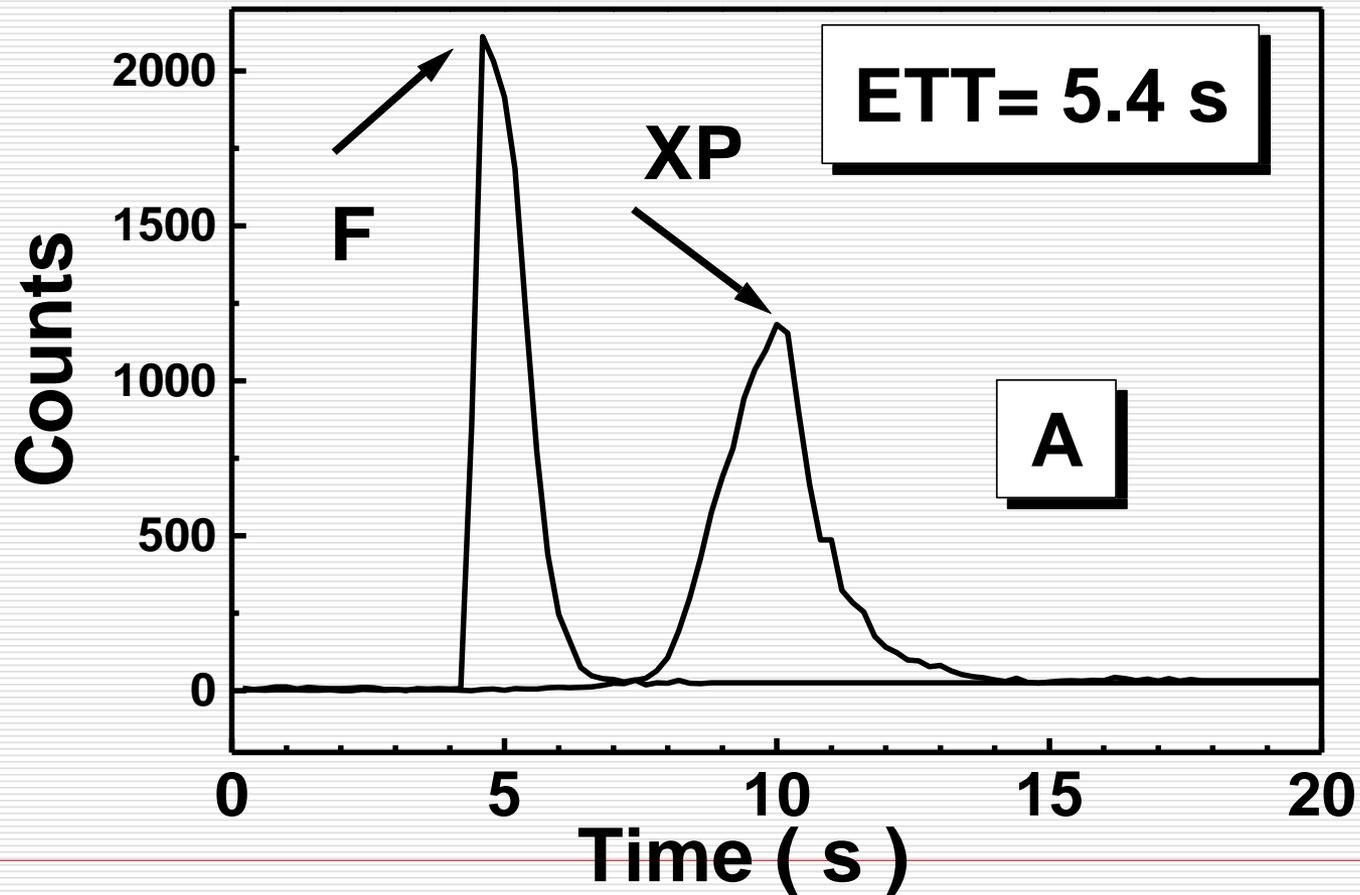
# ETT Visto pela Cintilografia



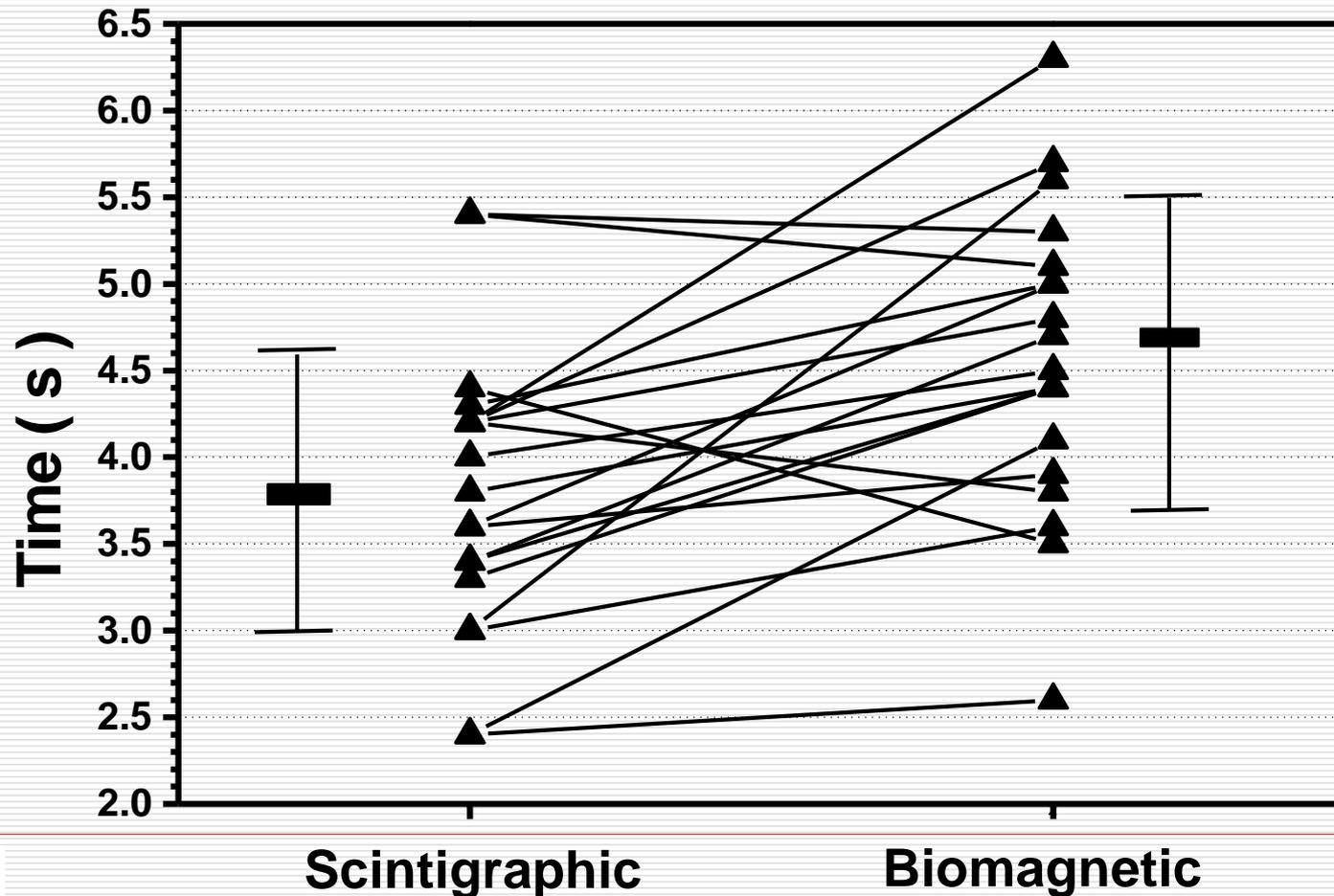
# ETT-Medida Biomagnética



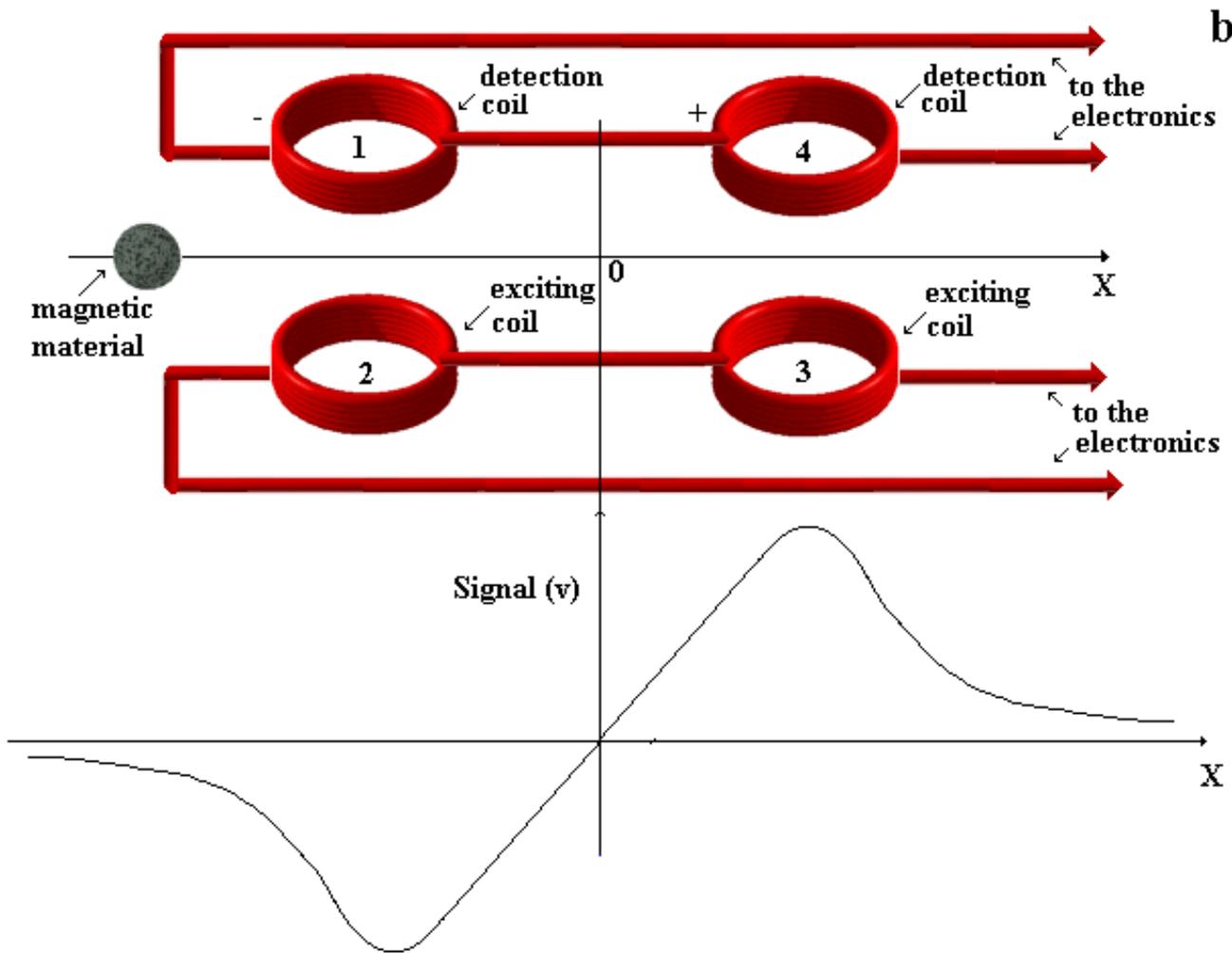
# ETT-Medida Cintilográfica



# Comparação entre os Métodos Biomagnético e Cintilográfico

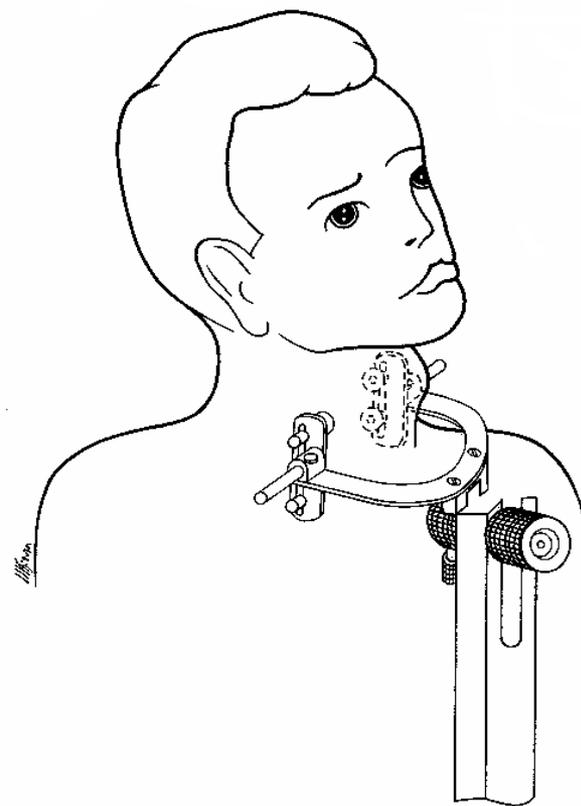
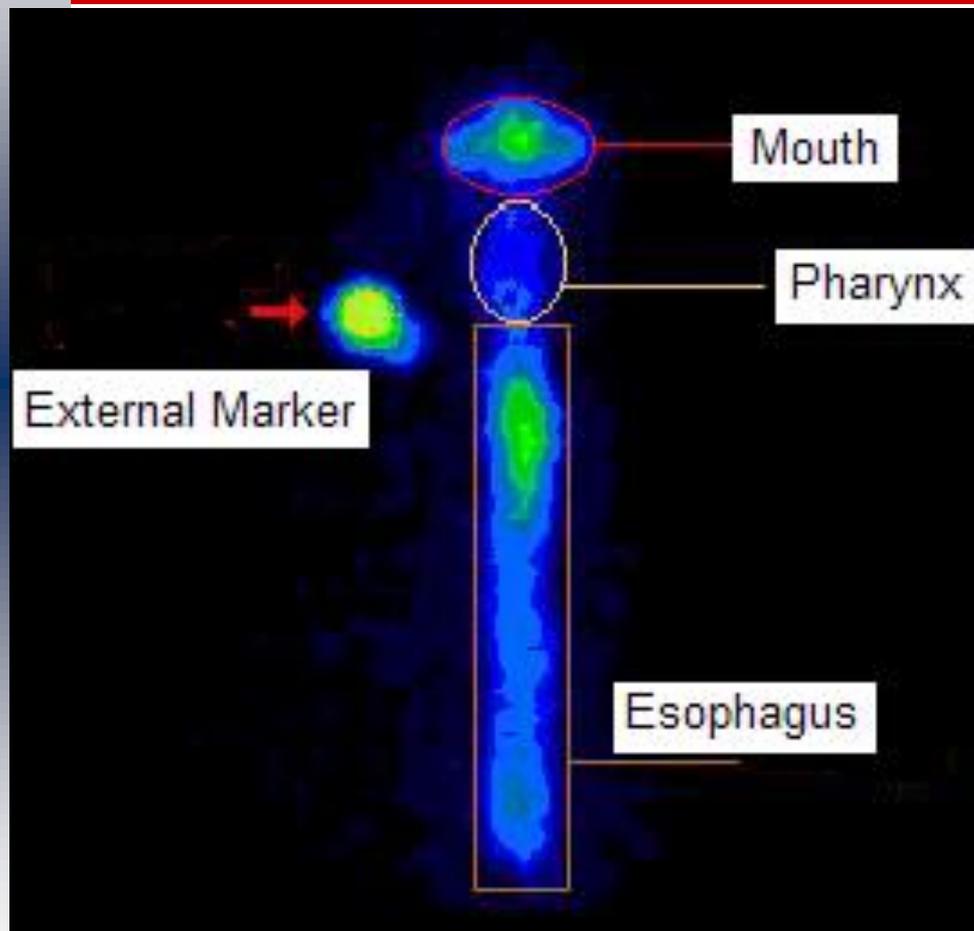


# “Clearance” e Tempo de Trânsito Faringeano

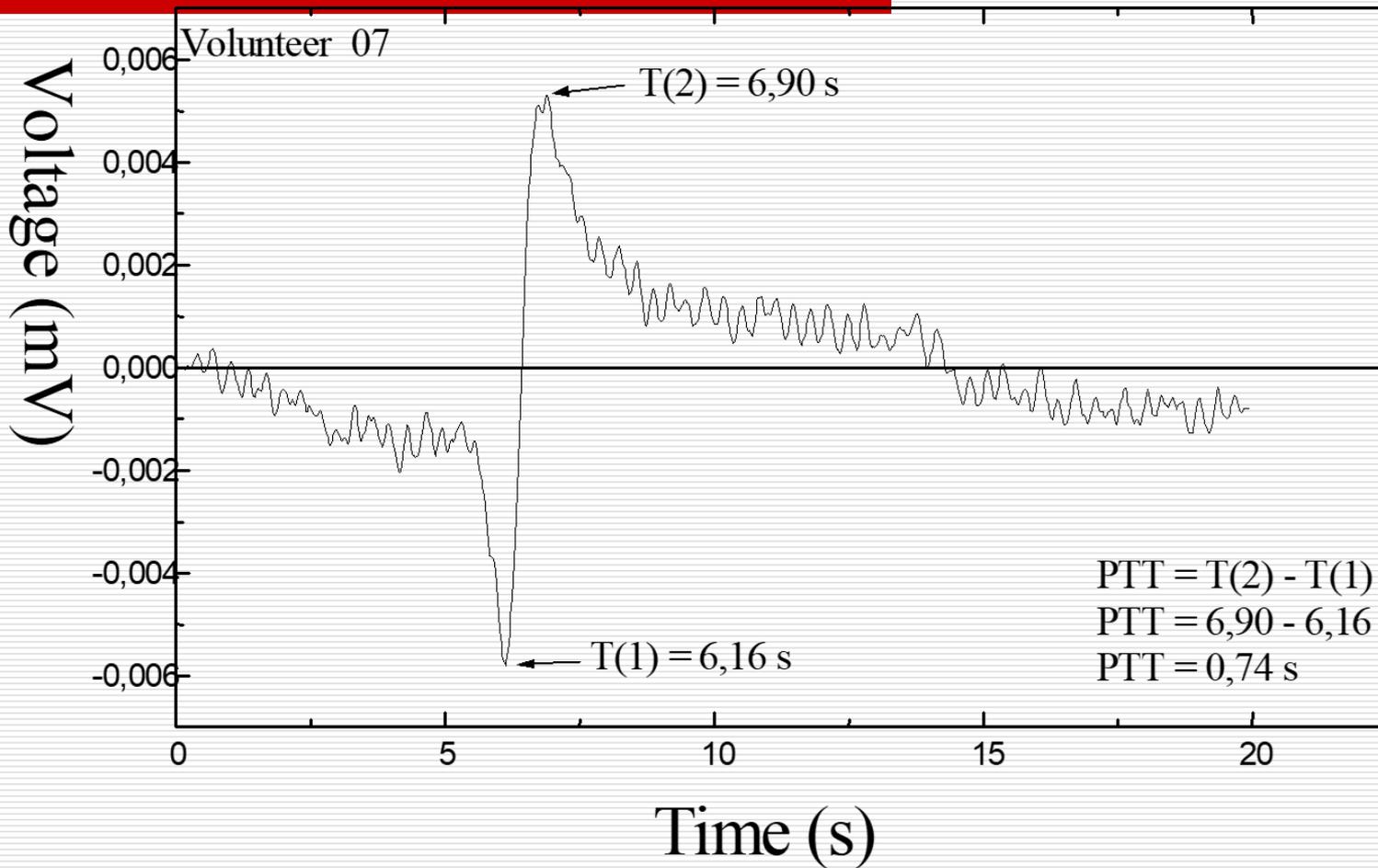


MIQUELIN, C. A.,  
BRAGA, F. J. H. N.,  
DANTAS, R. O.,  
OLIVEIRA, R. B.,  
BAFFA, O.  
Pharyngeal  
clearance and  
pharyngeal transit  
time determined by  
a biomagnetic  
method in normal  
humans.  
Dysphagia. , v.16,  
p.308 - 312, 2001.

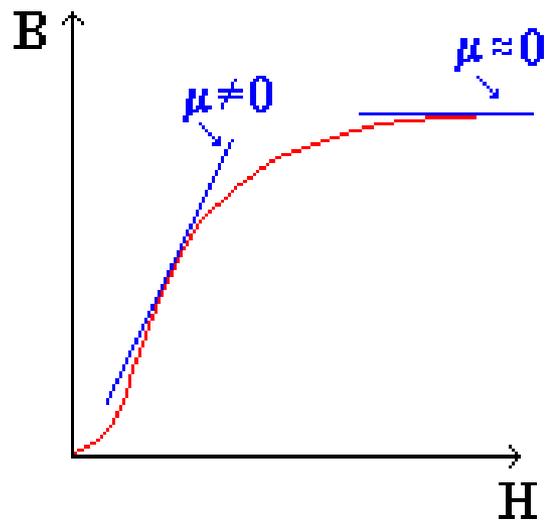
# Imagem Cintilográfica e Posicionamento dos Sensores



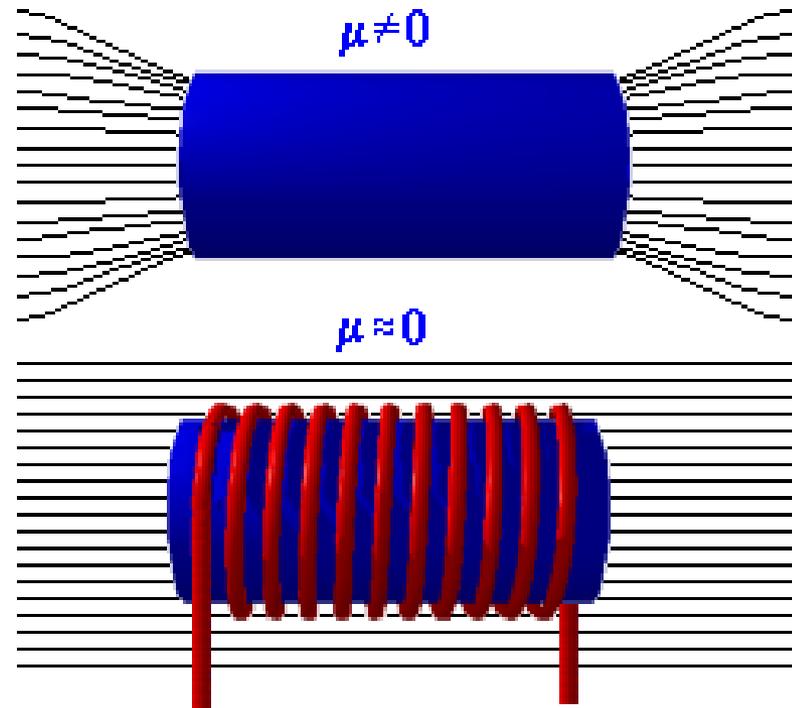
# Sinal Típico do PTT



# Princípio de Funcionamento de Um Fluxgate



(a)

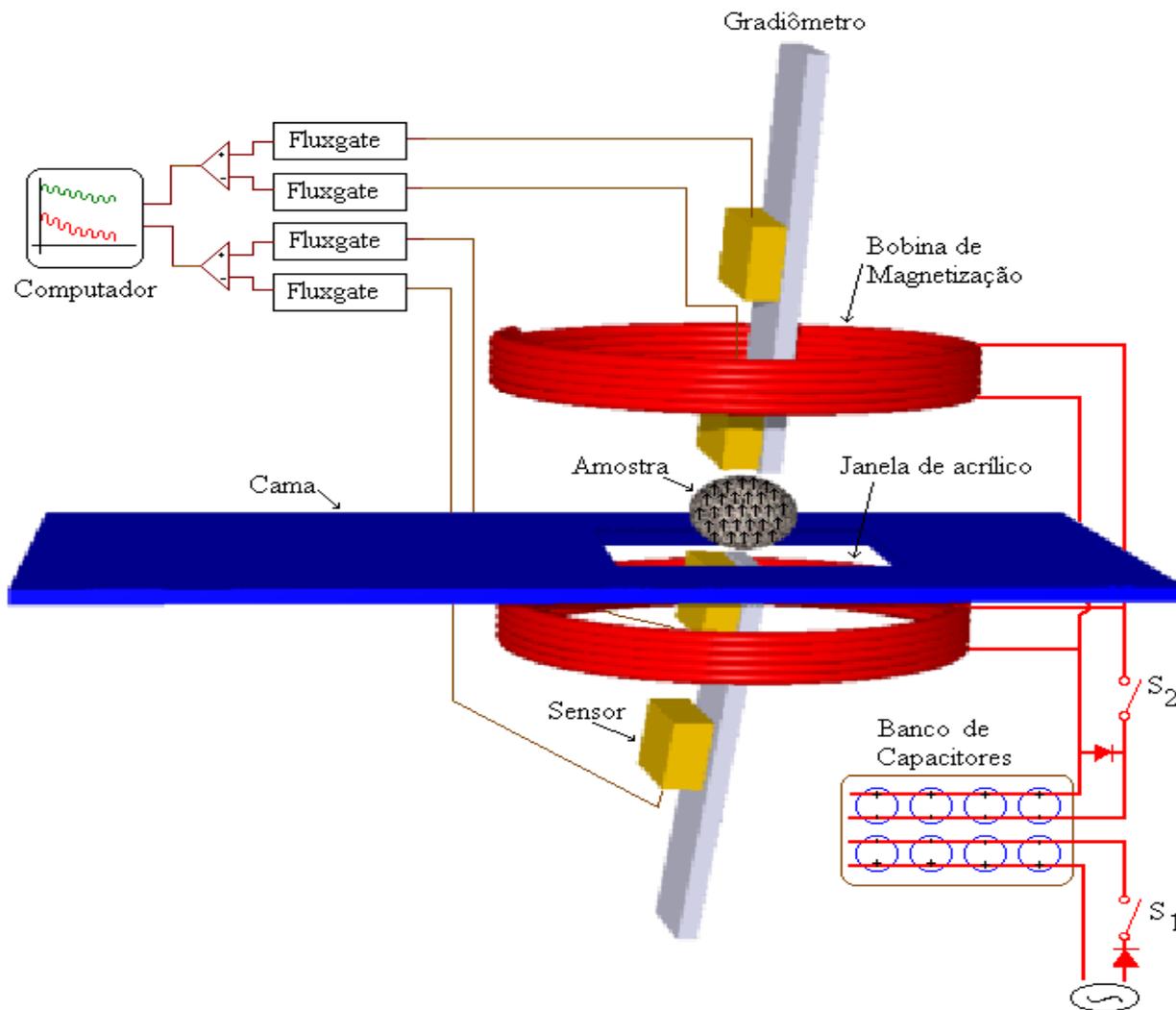


(b)

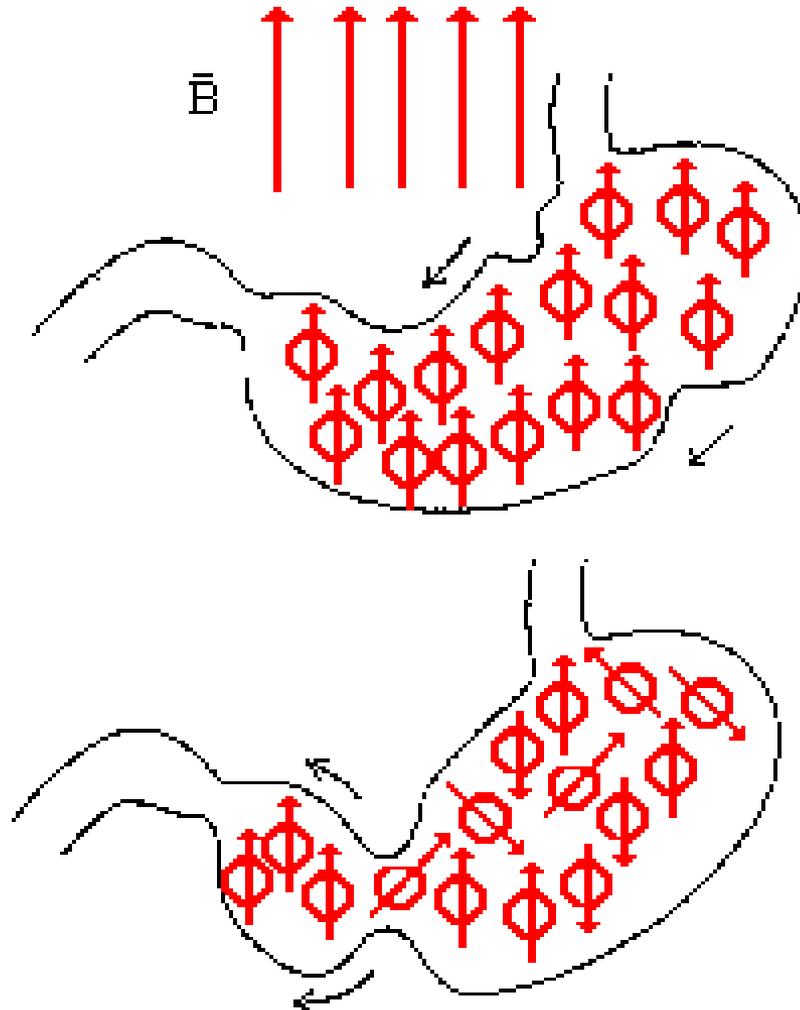
# Fluxgate com Núcleo de Anel



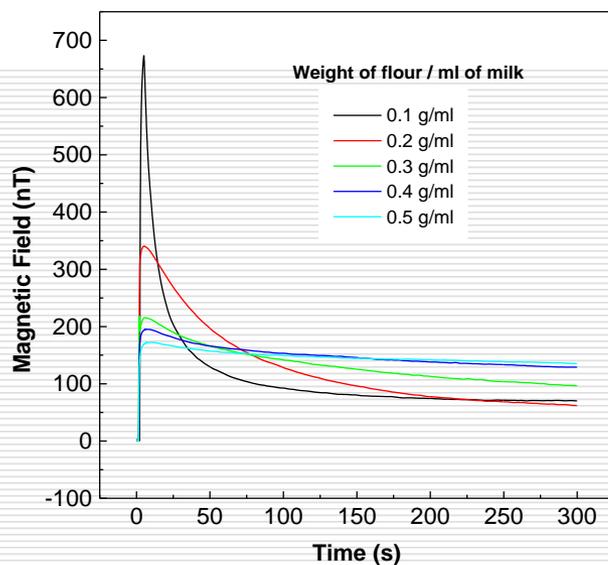
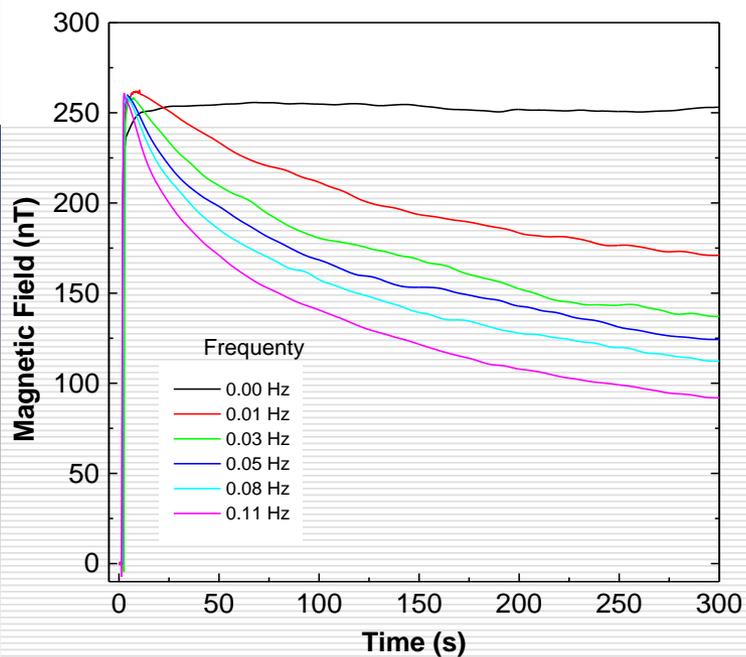
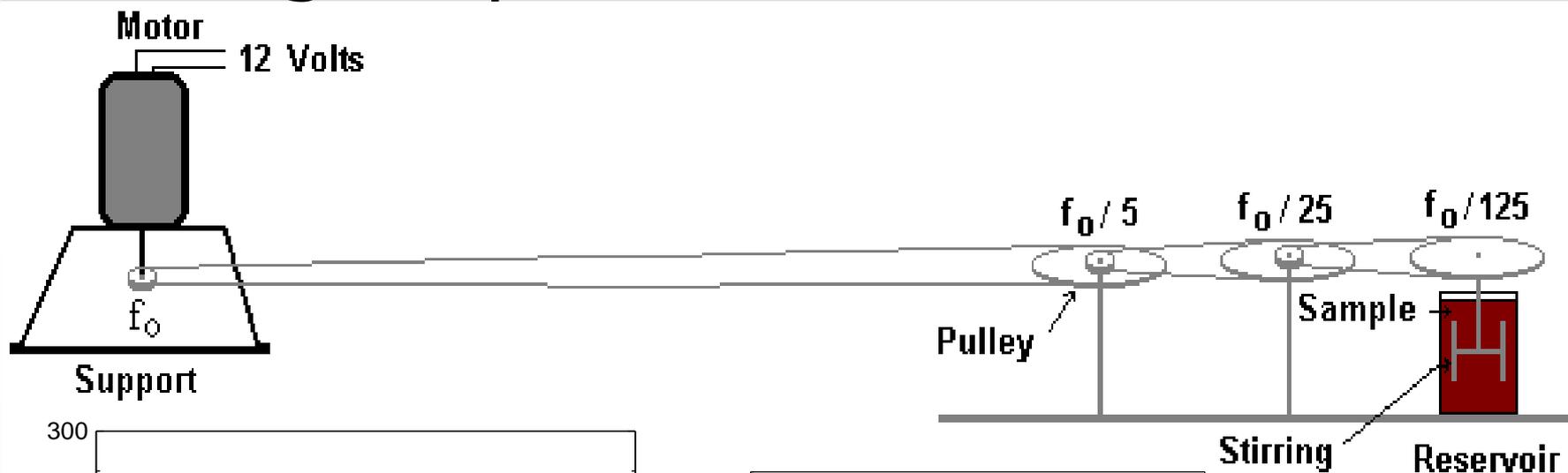
# Arranjo Experimental para Medida da Magnetização em Grandes Volumes



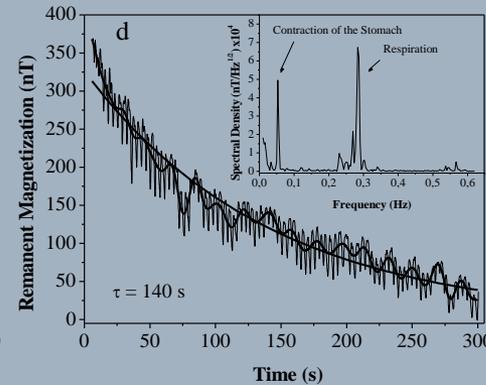
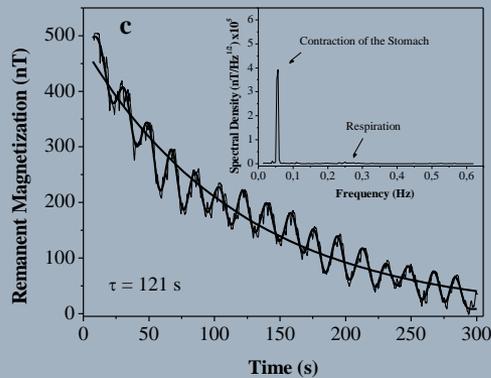
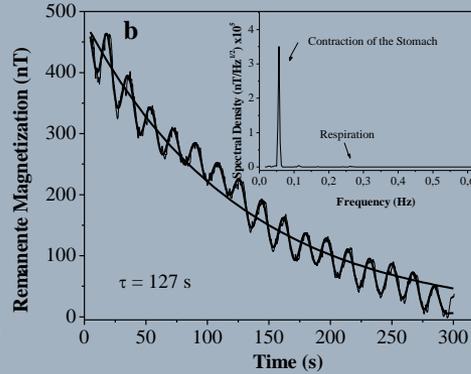
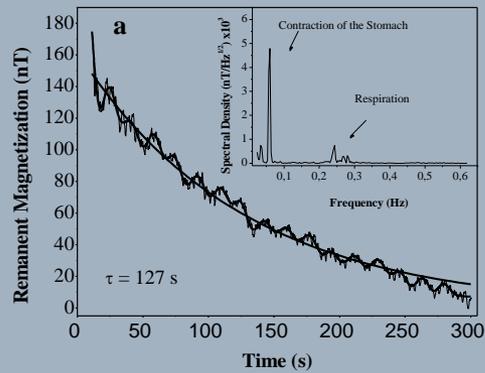
# Processo de Relaxação



# Montagem para testar o Sistema

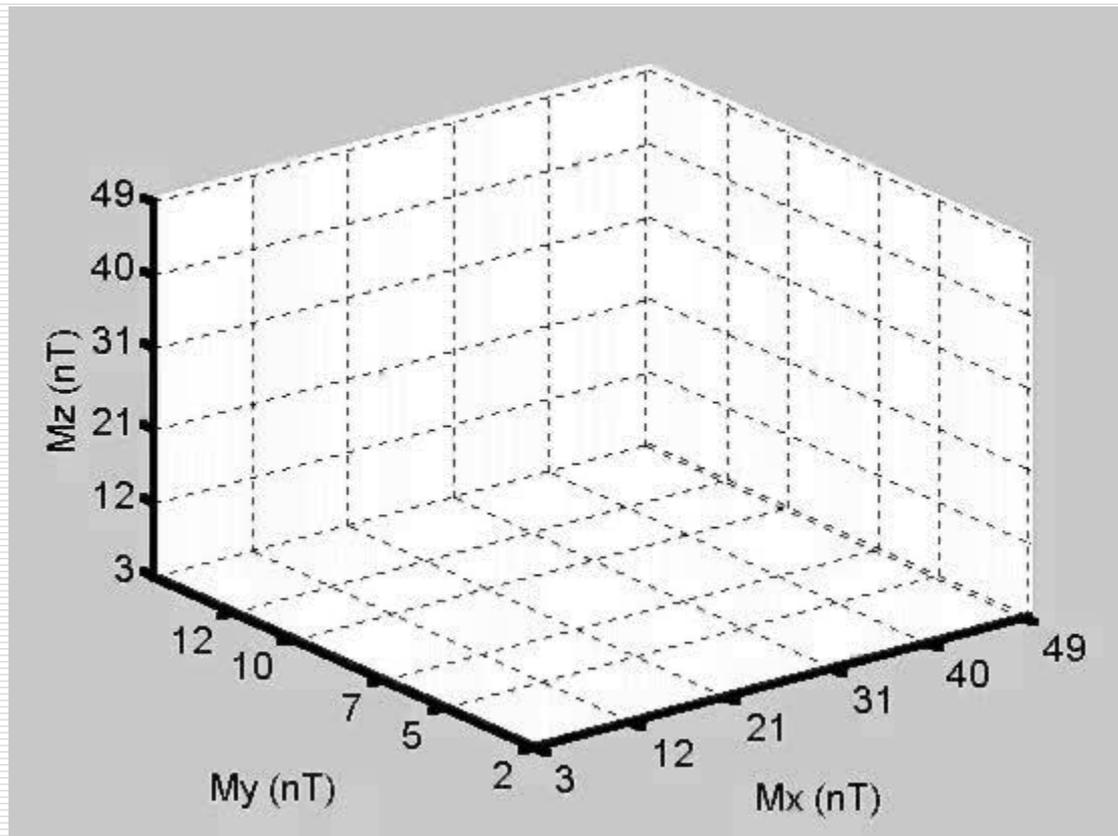


# Decaimento da Magnetização Devido à Atividade Mecânica do Estômago

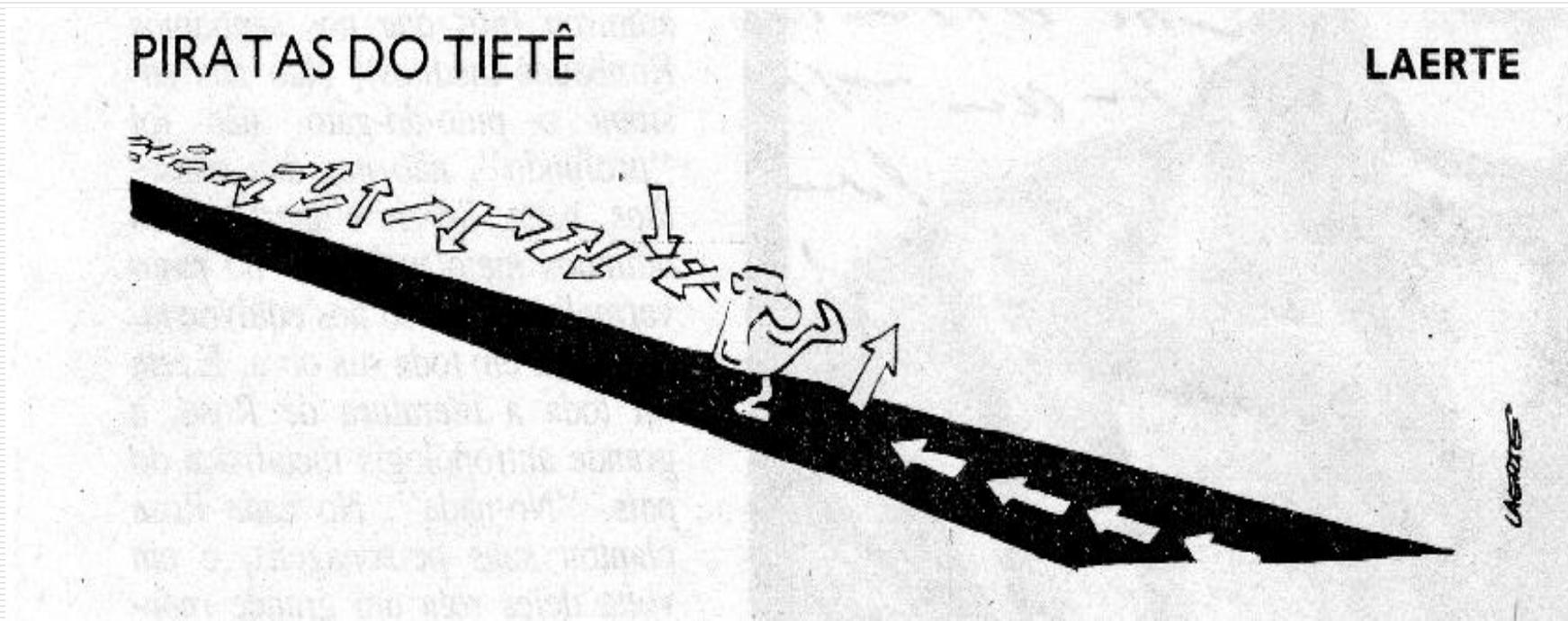


Medidas realizadas em um intervalo de 40 minutos

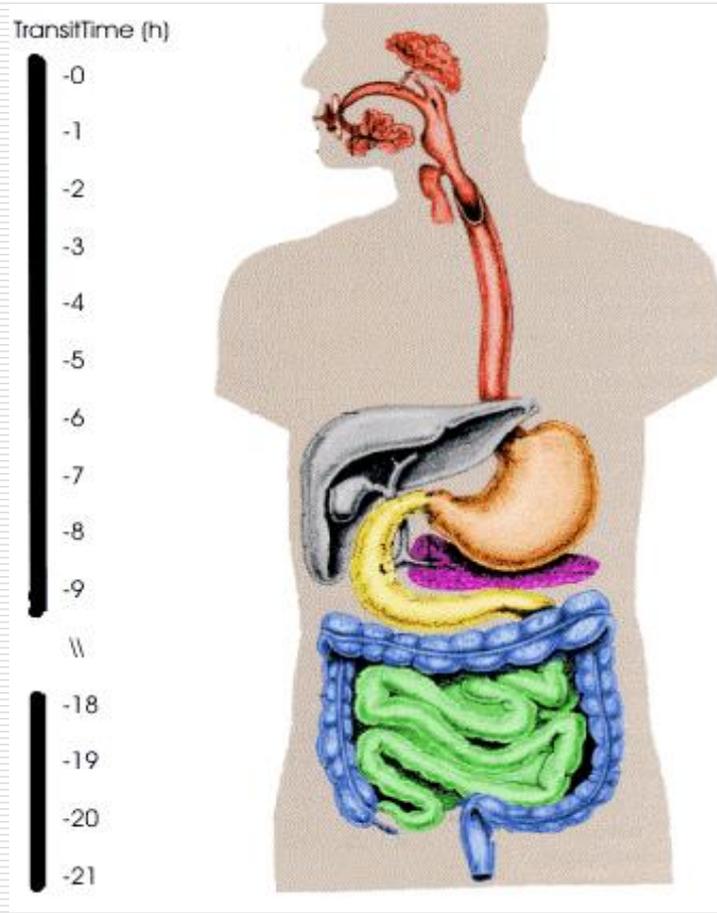
# Magnetização Remanente



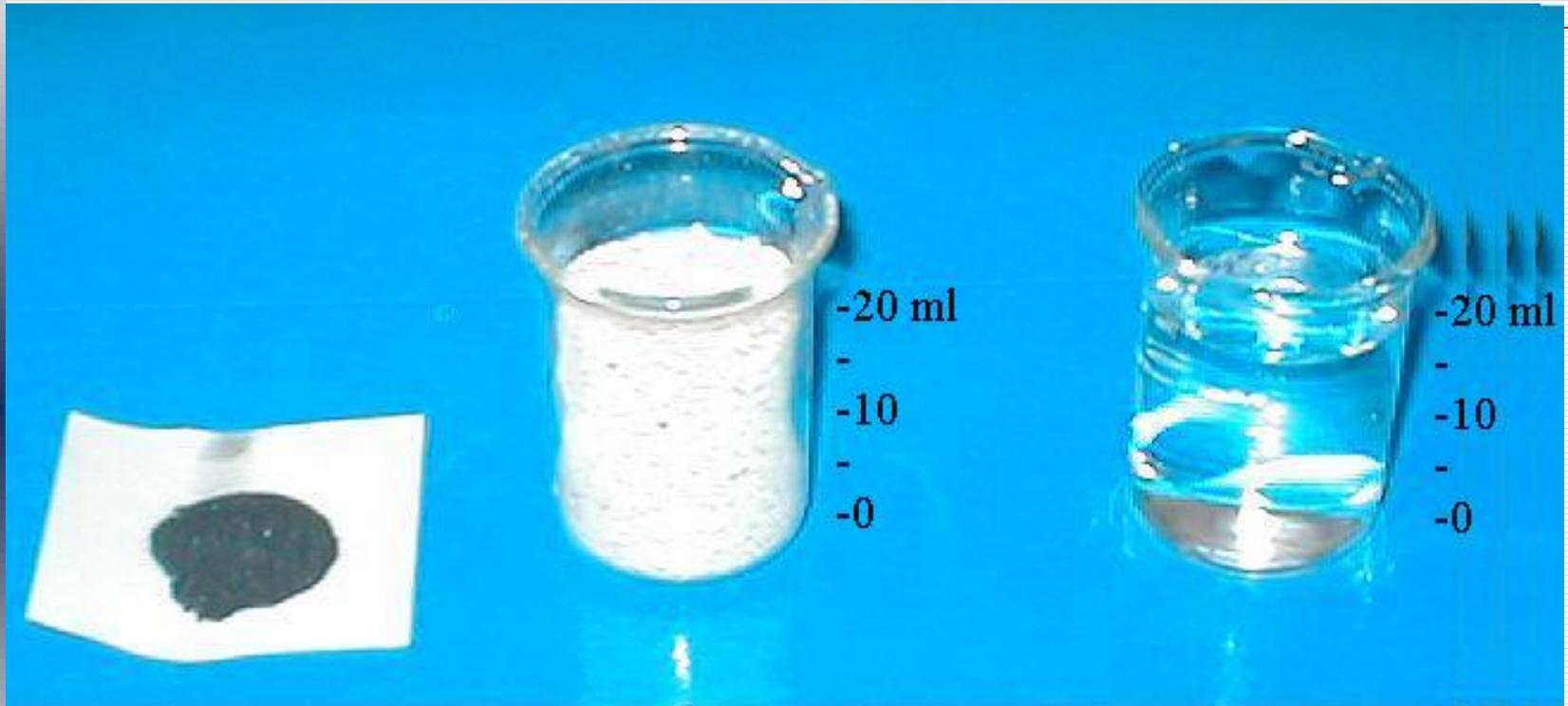
# Um Possível Mecanismo Agitador do Estômago



# Reflexo Gastrocólico



# Alimento Teste

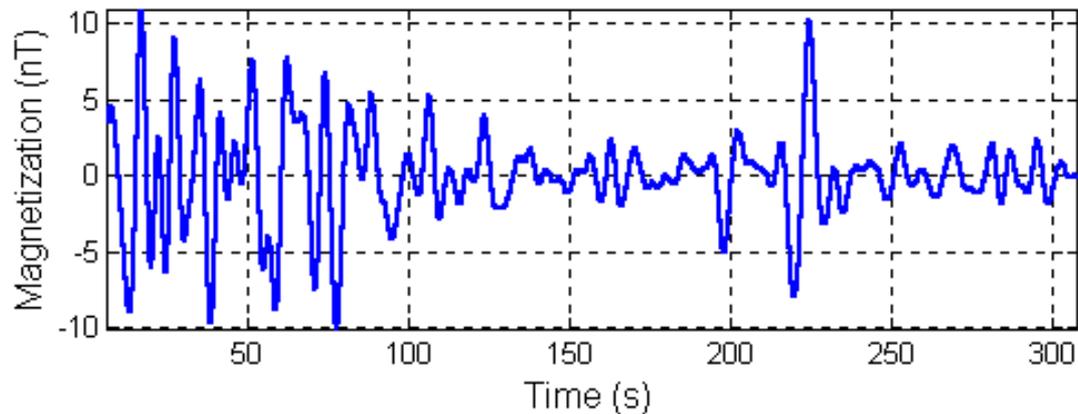
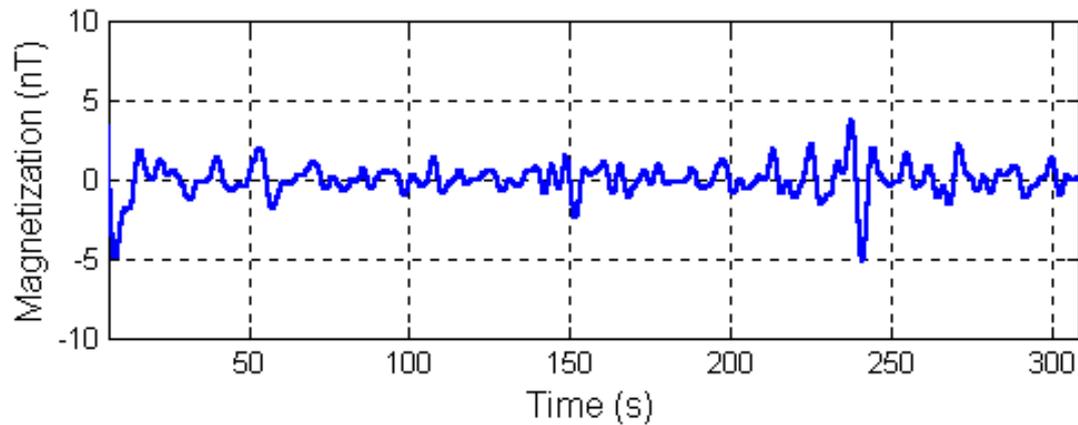


3 g magnetita  
( $\text{Fe}_3\text{O}_4$ )

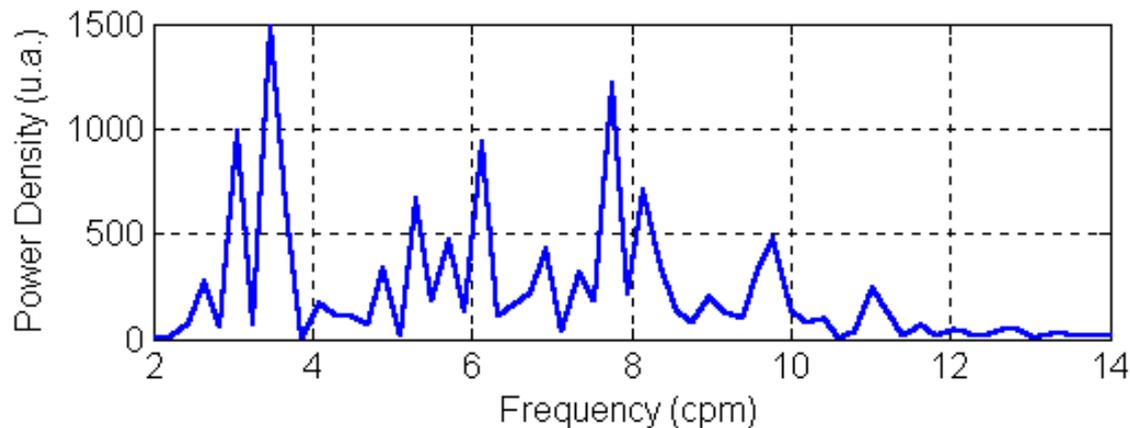
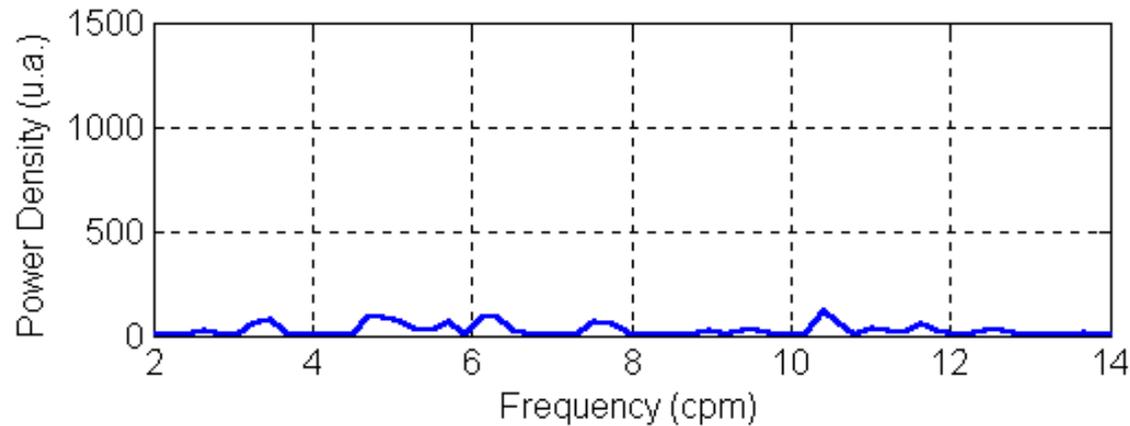
15 g aveia

Água

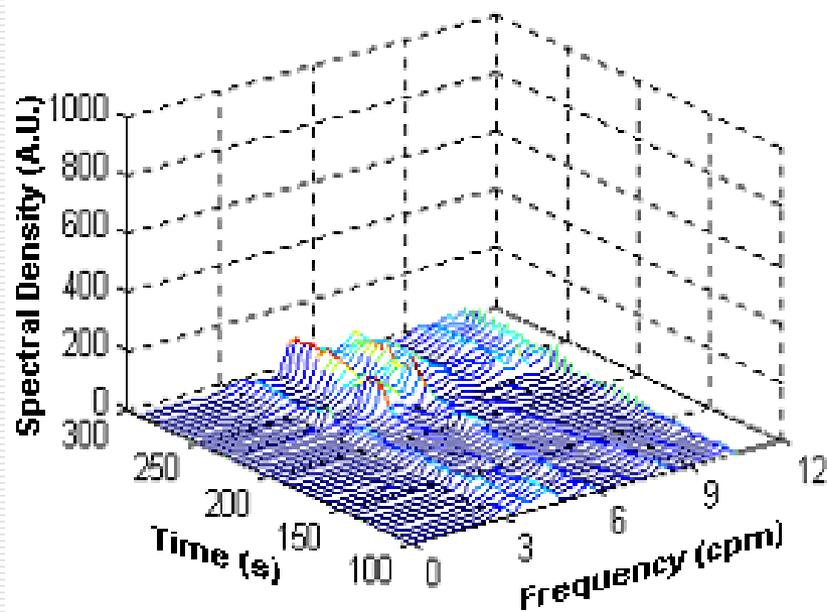
# Sinal Magnético da Região do Ceco



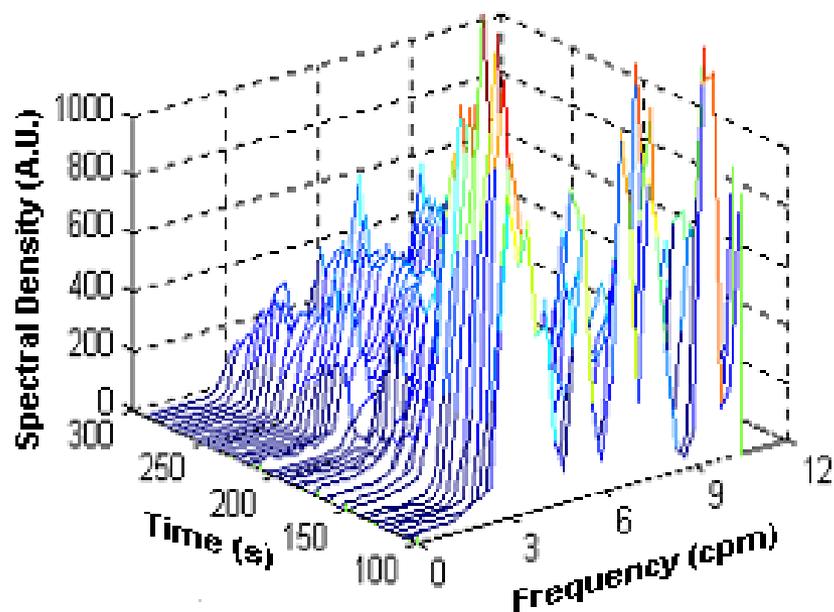
# Transformada de Fourier do Sinal Magnético



# Evolução da Componente Z do Campo magnético

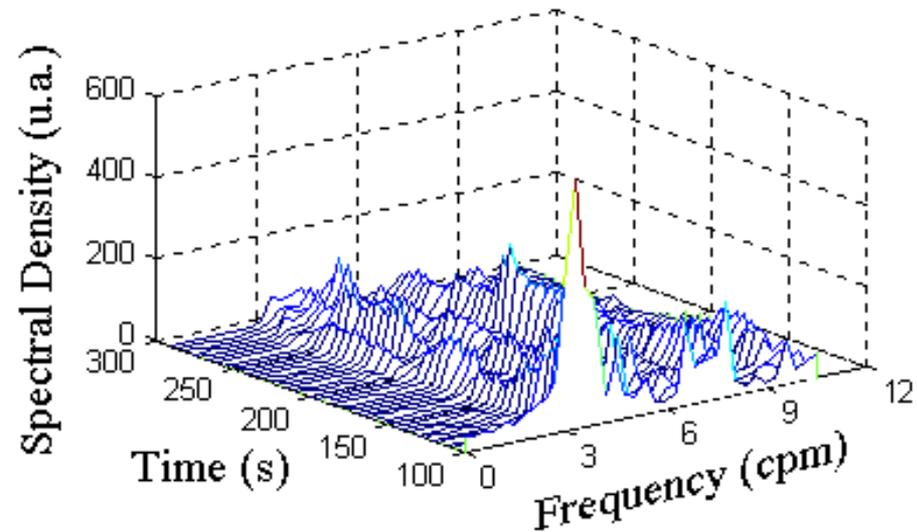


Antes da  
Refeição

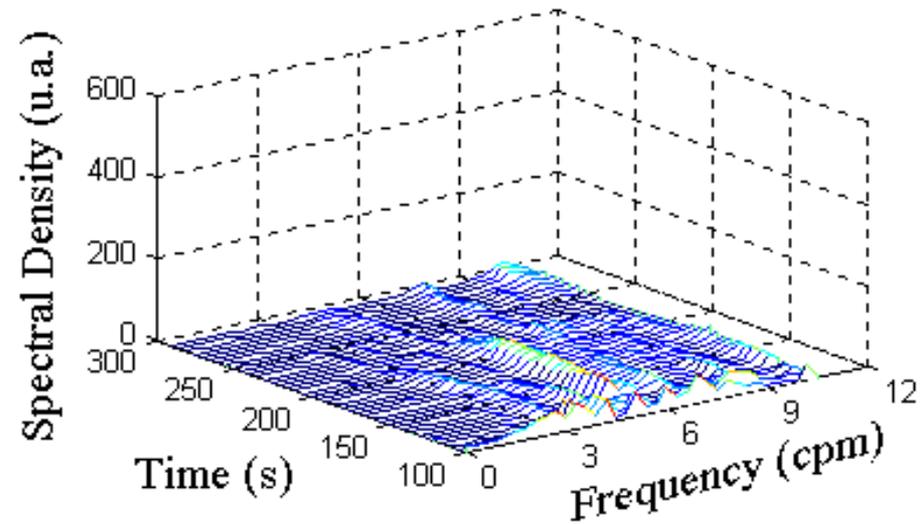


Depois da  
Refeição

# Efeito de uma droga sobre o reflexo gastrocólico (Buscopan 40 mg)



Antes



Depois



Universidade Estadual Paulista

“Júlio de Mesquita Filho”

**Instituto de Biociências de Botucatu**



# Imagens Magnéticas de Farmacêuticas Sólidas no Trato Gastrointestinal Humano

Luciana A. Corá<sup>1</sup>, Fernando G. Romeiro<sup>1</sup>, Madileine F. Américo<sup>2</sup>,  
Oswaldo Baffa<sup>2</sup>, Murilo Stelzer<sup>3</sup>, José Ricardo de Arruda Miranda<sup>1</sup>

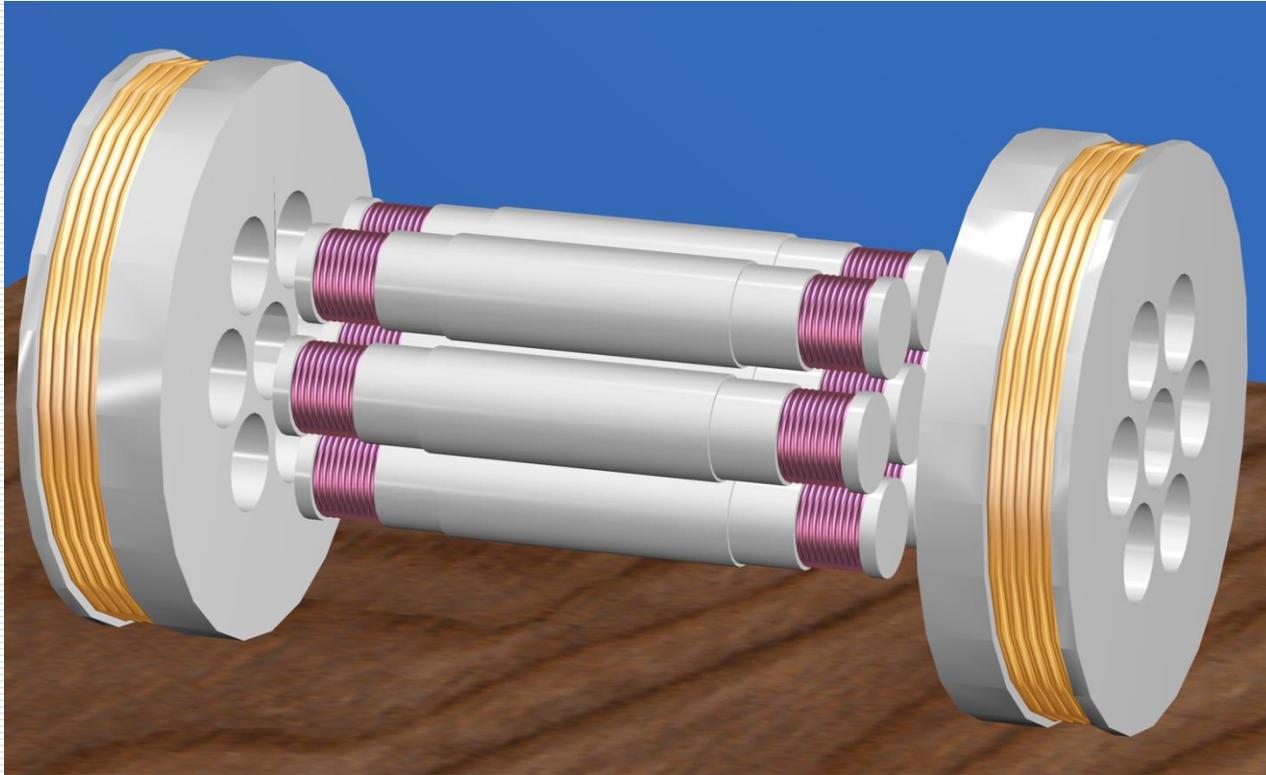
<sup>1</sup> Universidade Estadual Paulista – UNESP, Botucatu

<sup>2</sup> Universidade de São Paulo – USP, Ribeirão Preto

<sup>3</sup> Universidade Federal de São Carlos – UFSCar



# BAC multi-sensor



# Materiais e Métodos

## Obtendo as formulações magnéticas

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### → Pílulas

#### Compressão Direta

**1,00 g ferrita ( $\text{MnFe}_2\text{O}_3$ ); 0.63 g excipientes**

**Eudragit<sup>®</sup> E100 e S100**

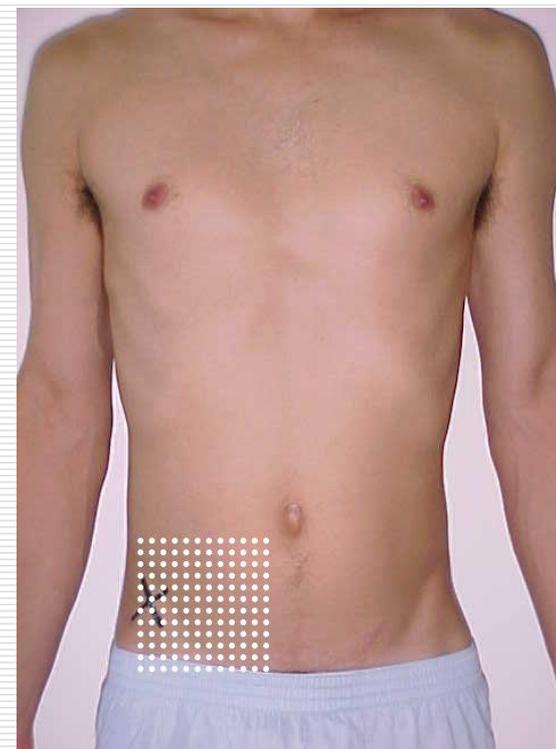
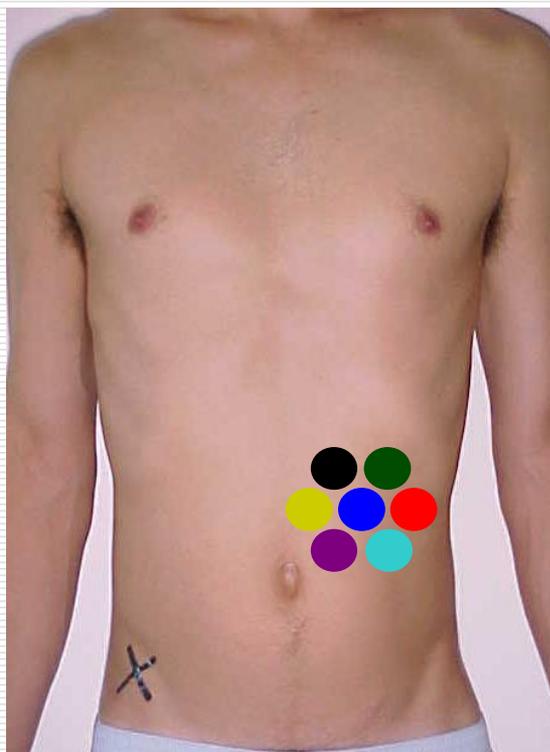
### → Cápsulas

**Coni-Snap<sup>™</sup>, size n<sup>o</sup> 00**

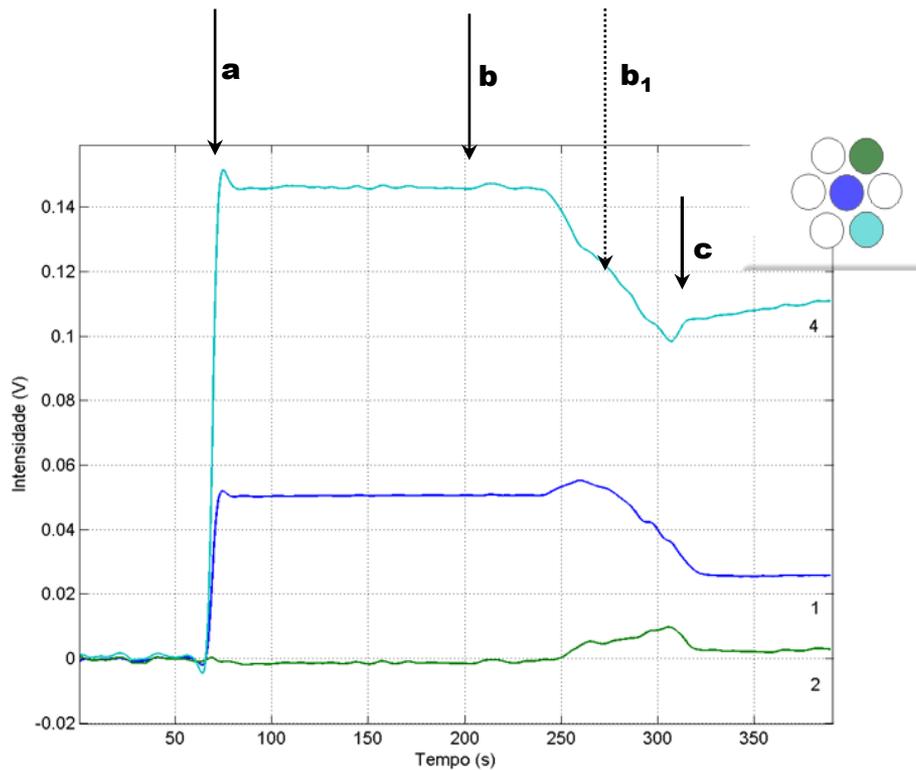
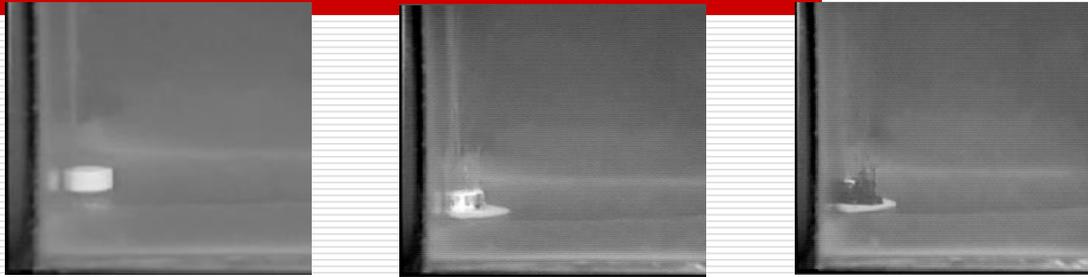
**1,00 g ferrita ( $\text{MnFe}_2\text{O}_3$ ); 0.53 g excipientes**

**Eudragit<sup>®</sup> S100**

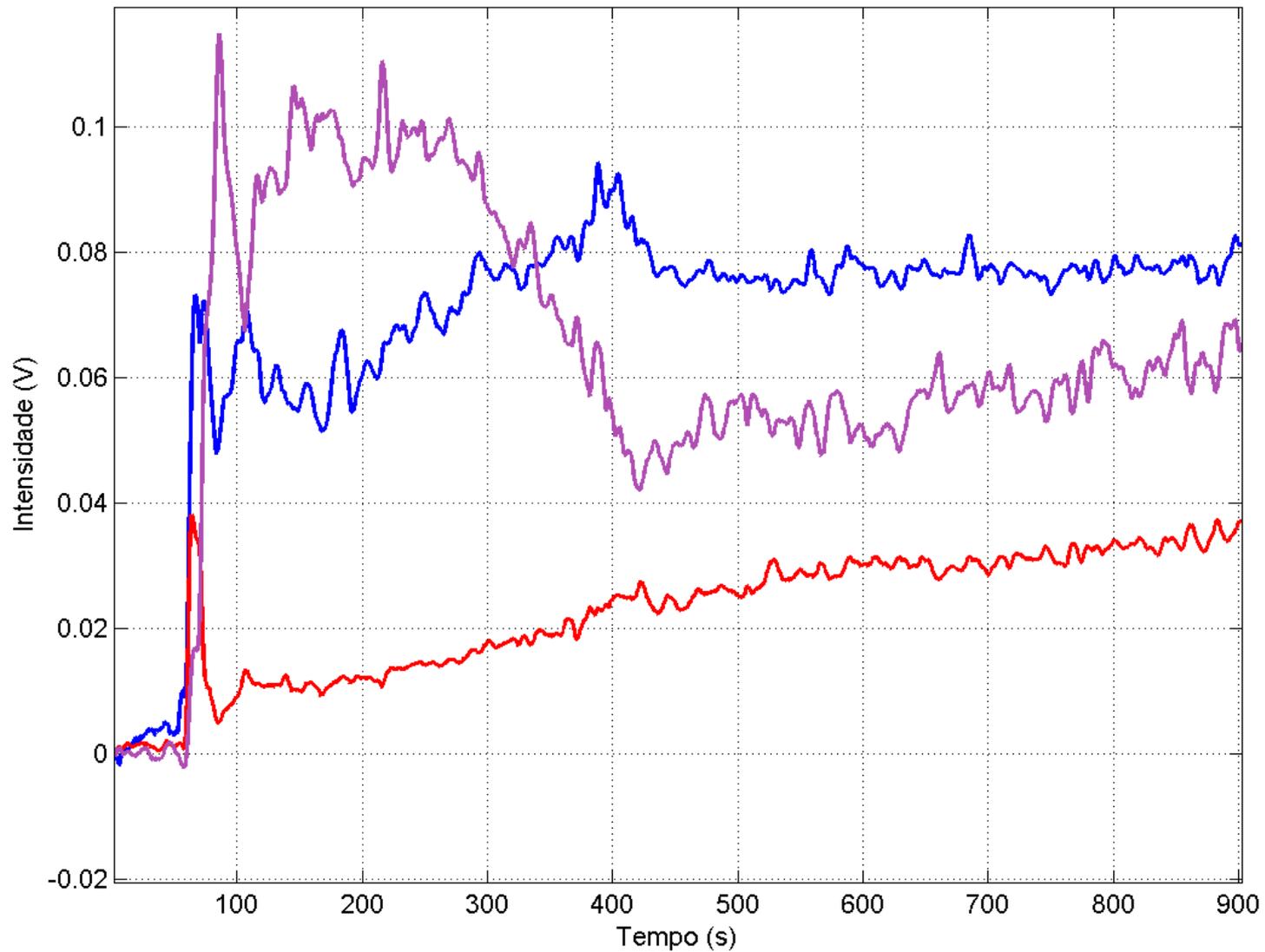
# Posicionamento dos sensores para aquisição dos sinais



# Desintegração *in vitro*



# Desintegração do comprimido no estômago



# Imagem da desintegração da pílula magnética na região do estômago



$t_1$



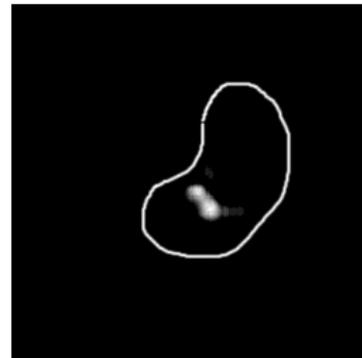
$t_2$



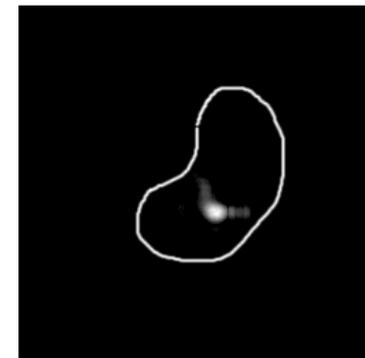
$t_3$



$t_4$

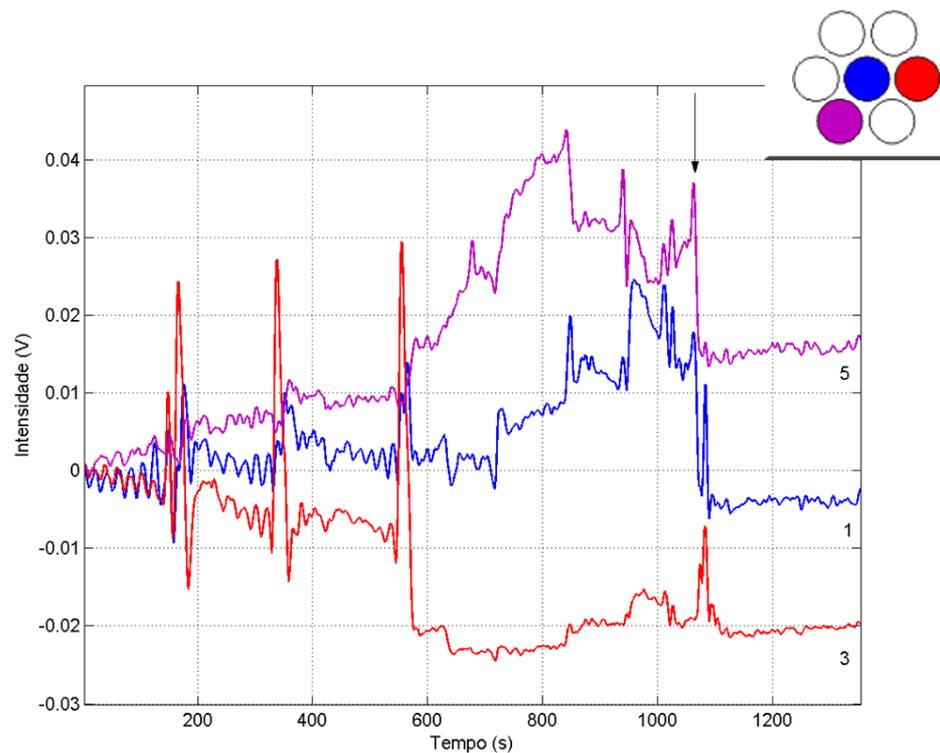
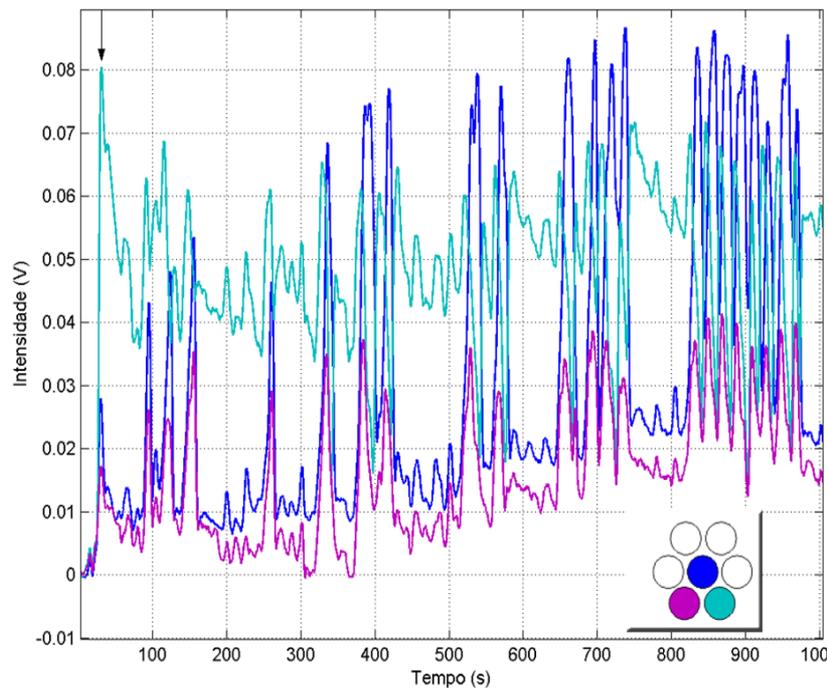


$t_5$

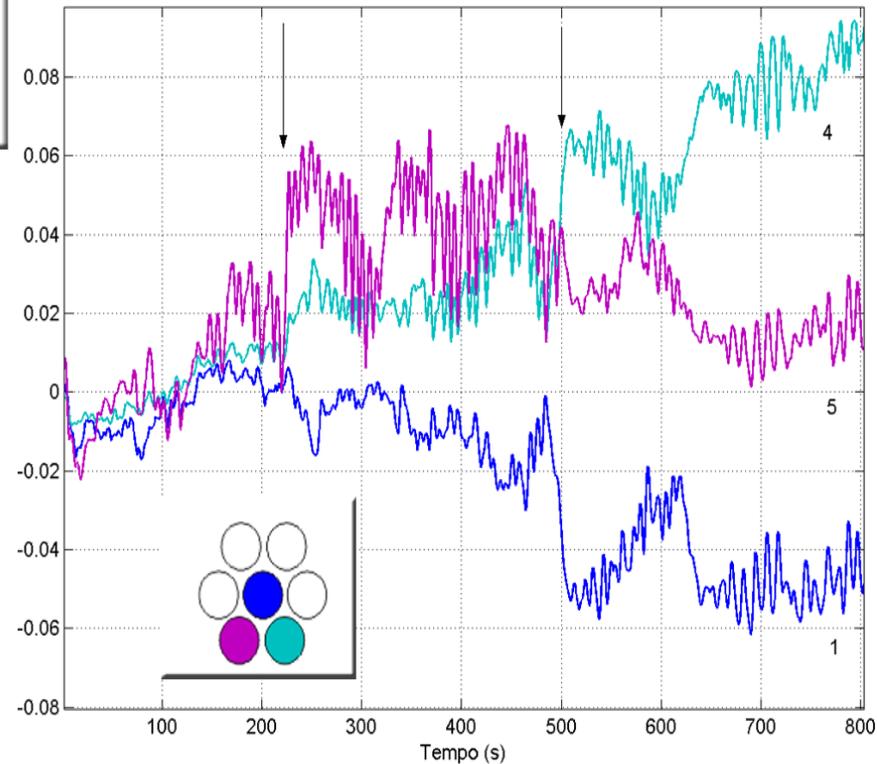
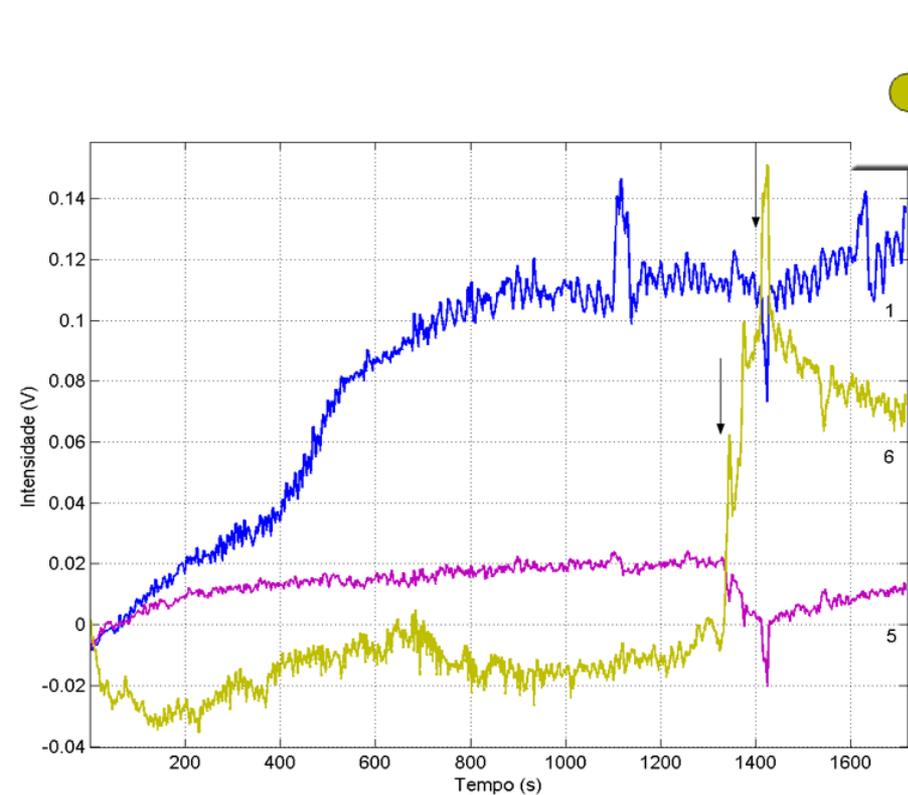


$t_6$

# Tempo de retenção gástrica



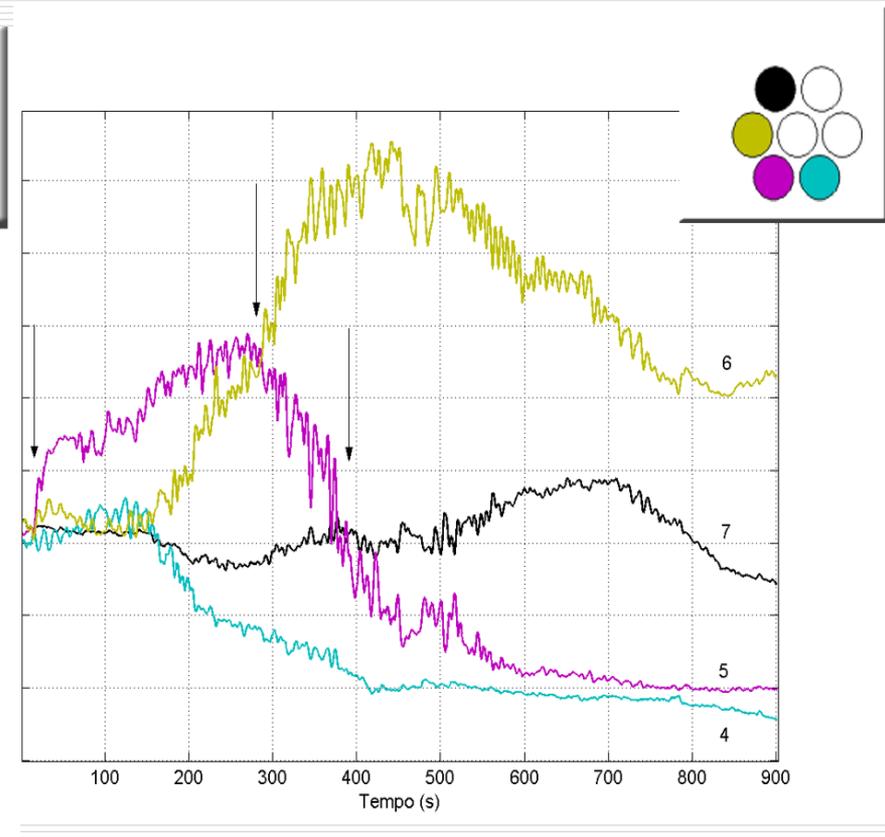
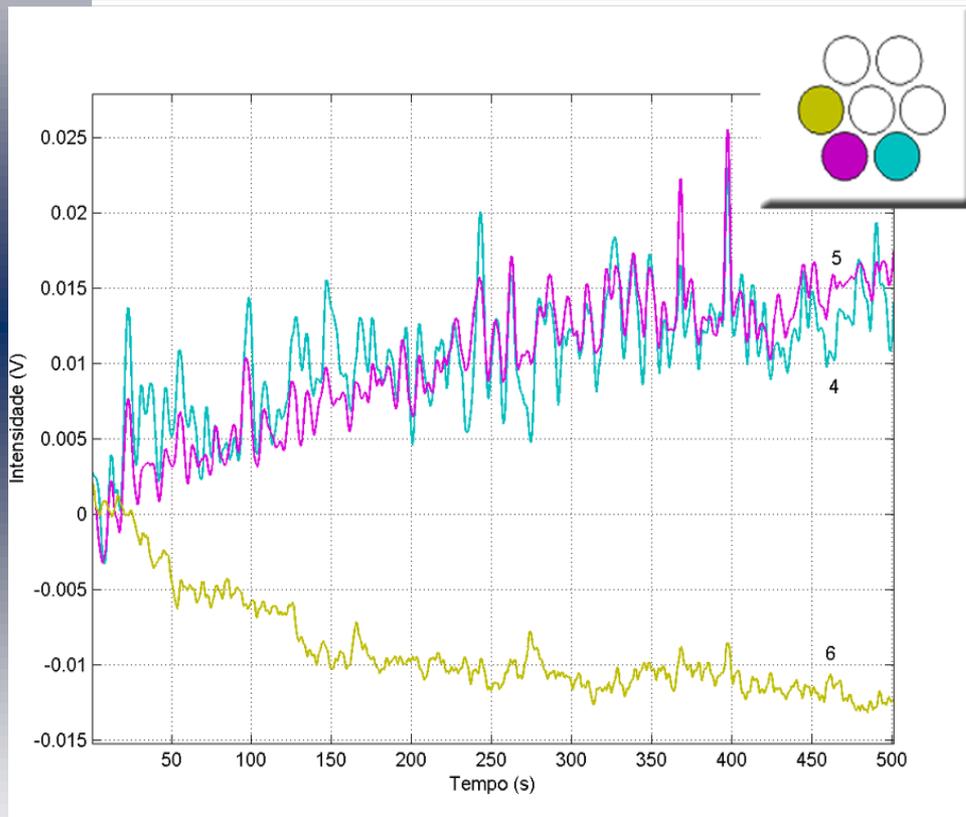
# Chegada da pílula magnética no cólon



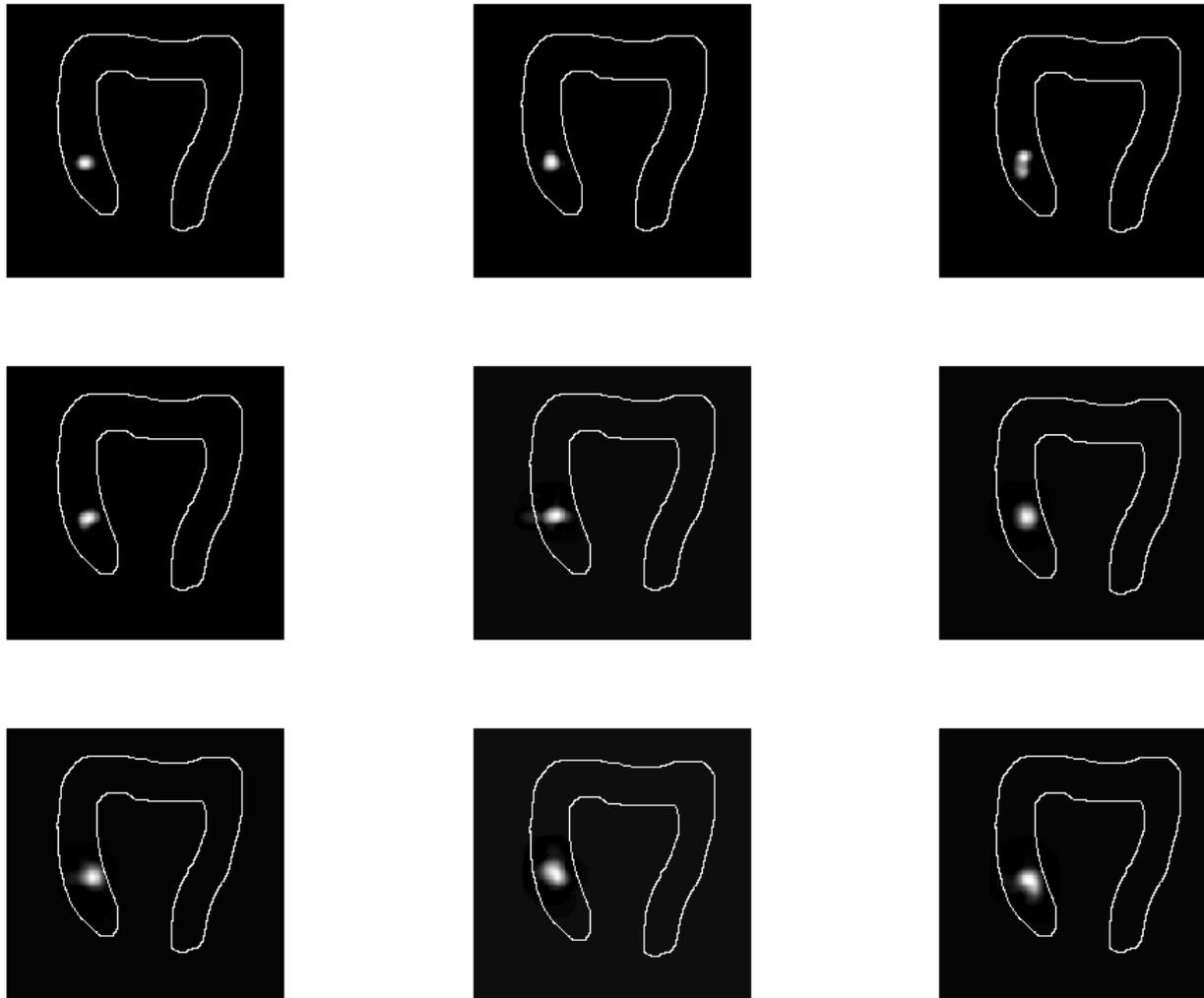
# Tempo de trânsito gastrintestinal e Tempo de Desintegração

Subject	Time (min)			
	GRT	SITT	OCTT	DT
1	70	121	191	152
2	130	150	280	90
3	60	160	220	60
4	42	200	242	52
5	32	145	177	184
6	45	180	225	60
7	55	210	265	120
8	27	180	207	70
9	80	180	260	90
<b>X</b>	<b>60.11</b>	<b>169.55</b>	<b>229.66</b>	<b>97.55</b>
<b>SD</b>	<b>31.31</b>	<b>28.11</b>	<b>34.91</b>	<b>45.70</b>
<b>CV (%)</b>	<b>52.08</b>	<b>16.57</b>	<b>15.20</b>	<b>46.84</b>

# Desintegração do comprimido c6lon

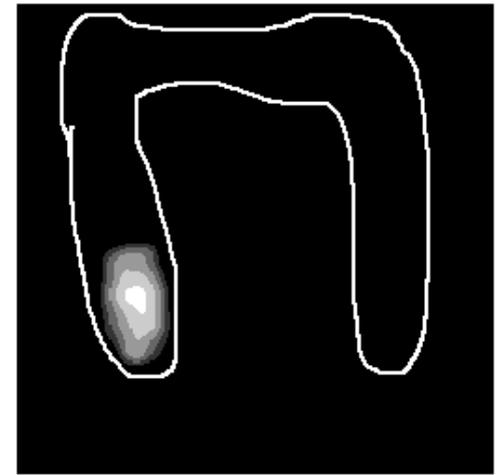
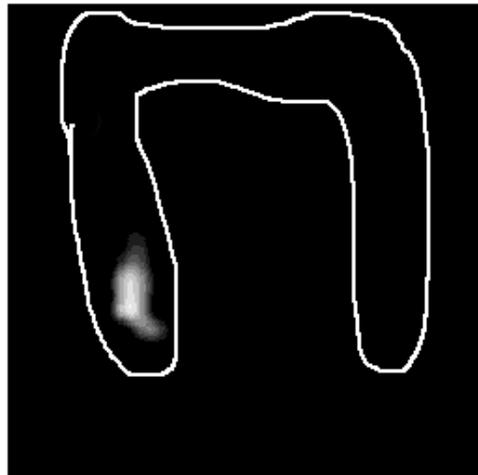
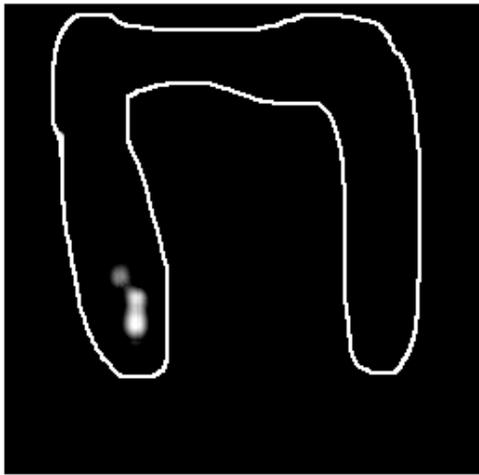


# Seqüência de imagens da desintegração do comprimido no estômago



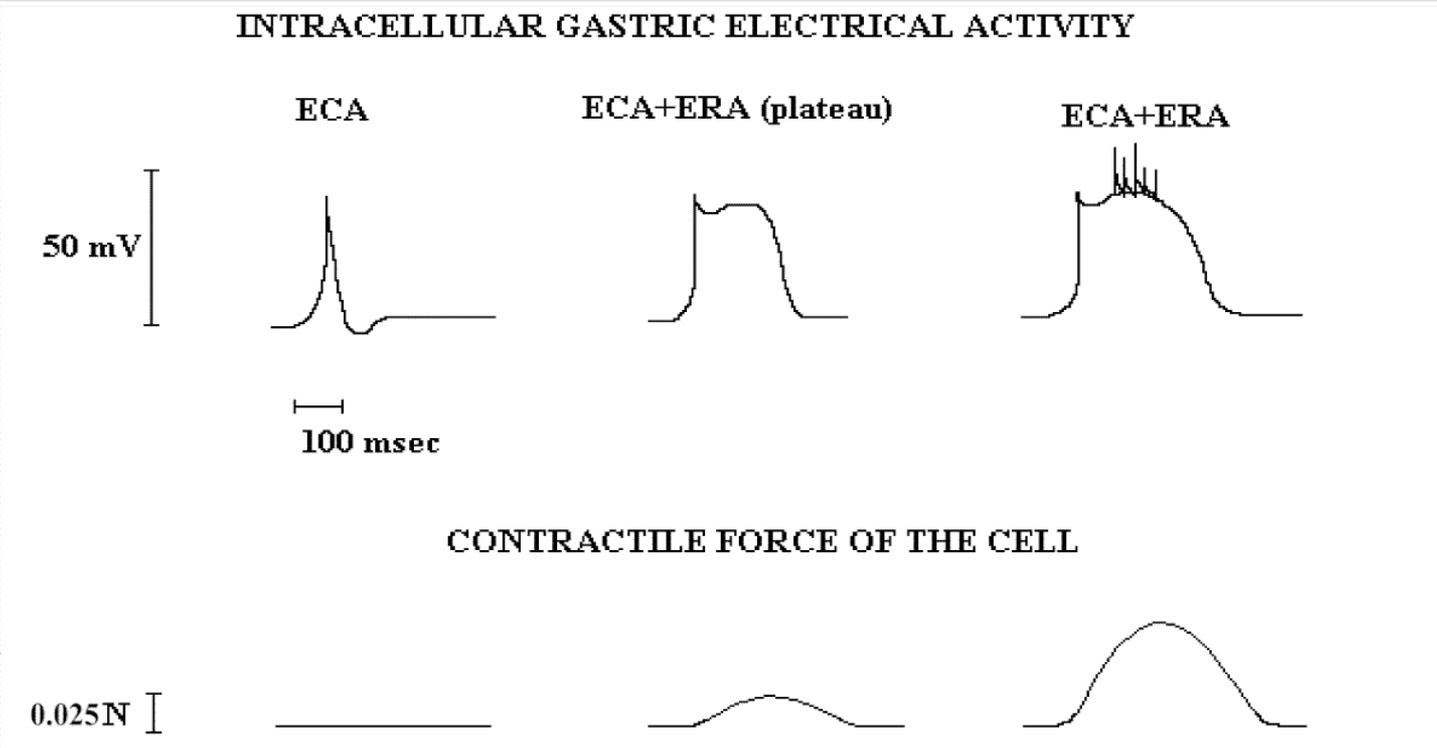
# Desintegração do cápsula magnética no cólon

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# Atividades Eletromecânicas

- ❑ BER/EC → 50mHz, sempre presente, modelada por um dipolo de corrente, equação do cabo e osciladores
- ❑ ERA → acoplamento eletromecânico
- ❑ Ondas de contração → Função do estomago

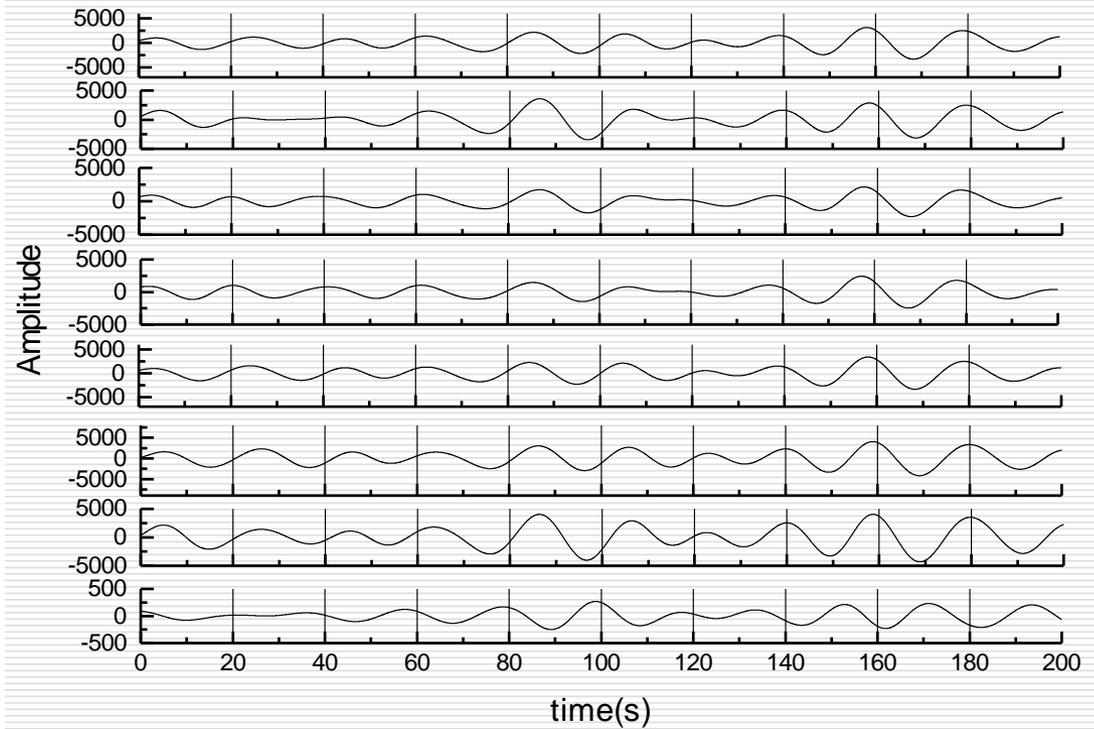
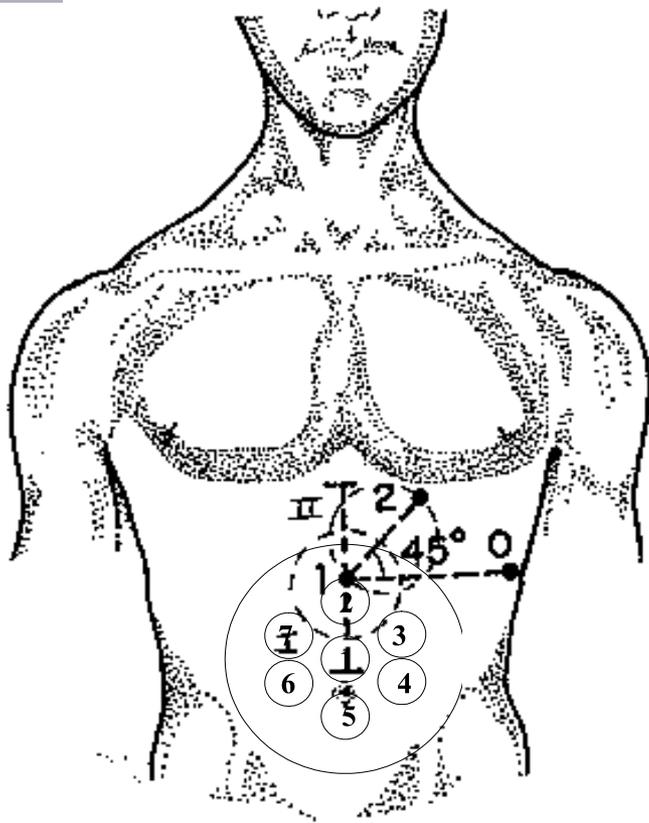


# Biogradiometro Monocanal

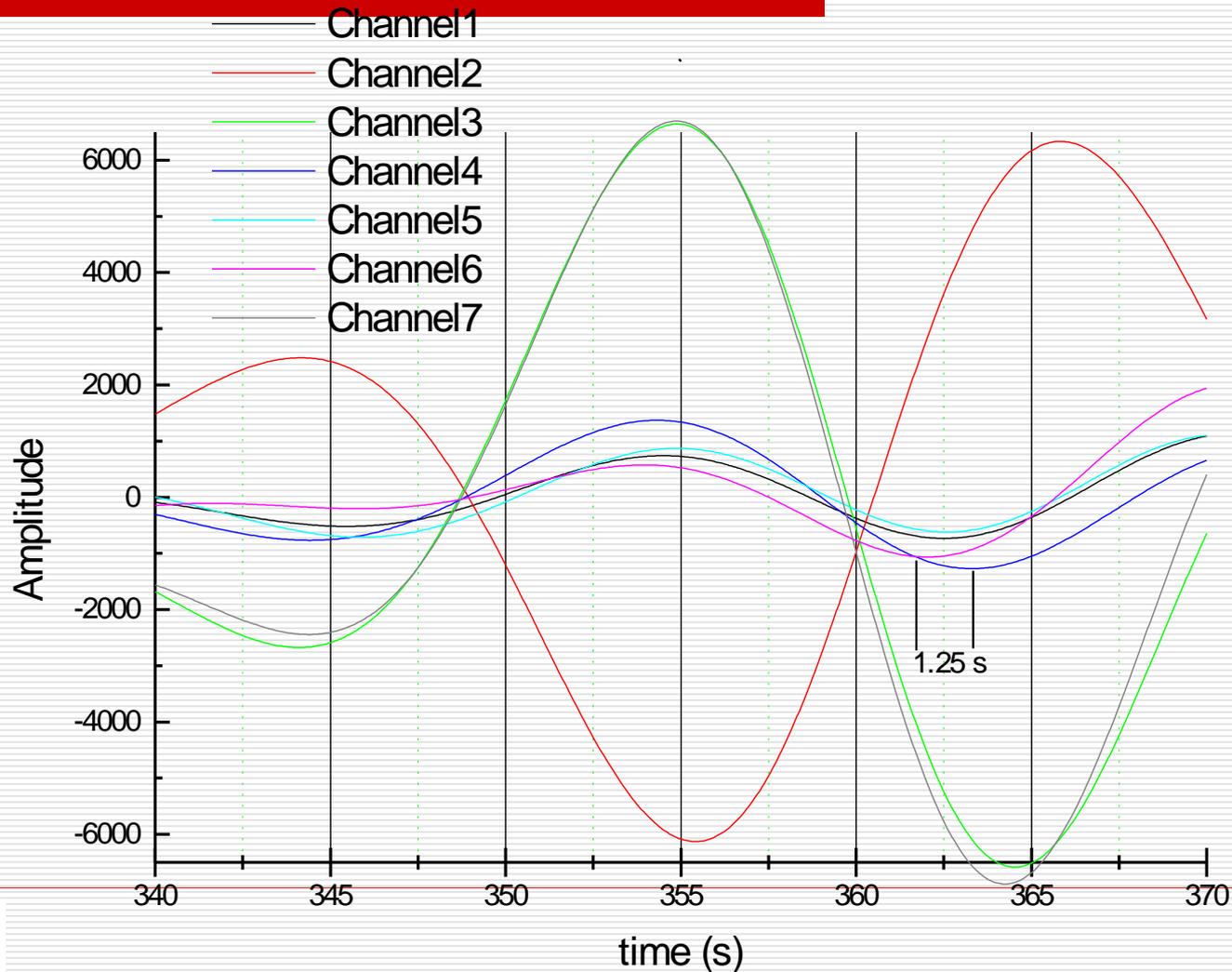


Vista de um biogradiometro monocanal, com um SQUID, gradiometro com 2,5 cm de diâmetro e 7 cm de linha de base, posicionado sobre o estomago para medidas de MGG. A componente vertical vertical do campo é medida.

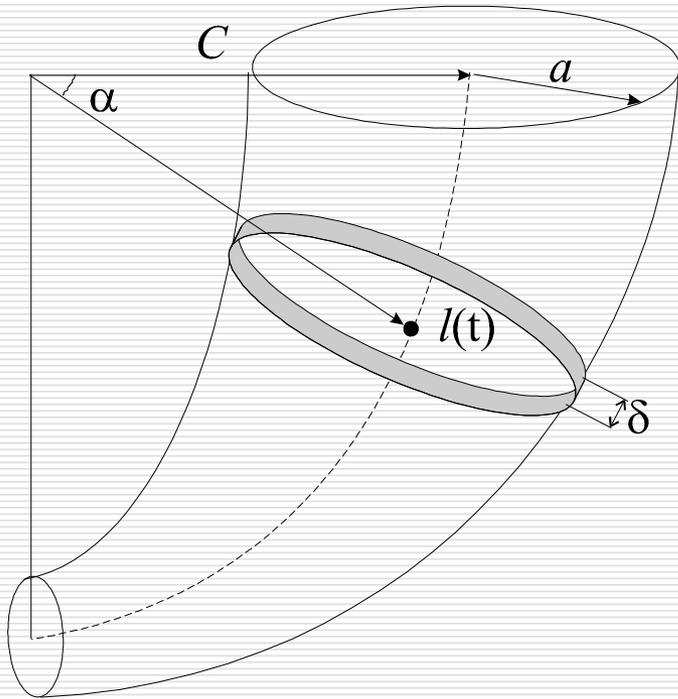
# Posicionamento dos sensores e eletrodos para MGG & EGG --Registros Típicos



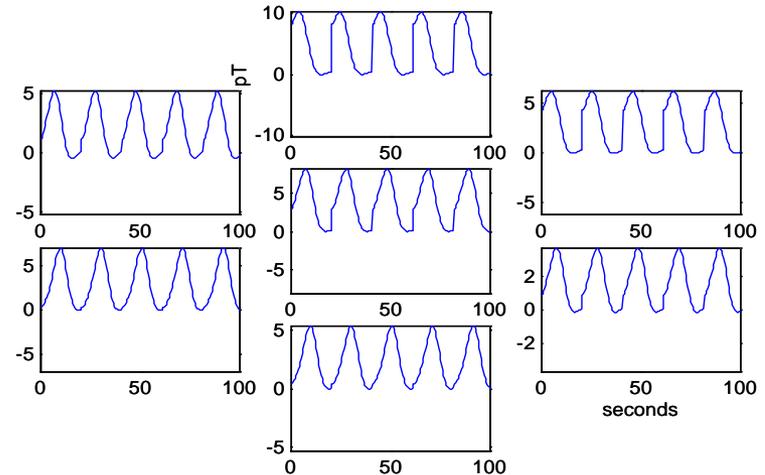
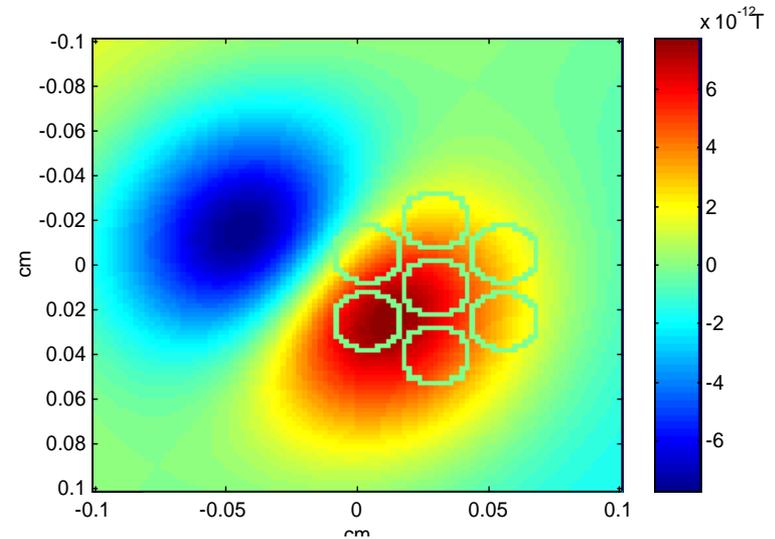
# Segmento de Traçado de MGG Mostrando Defasagem



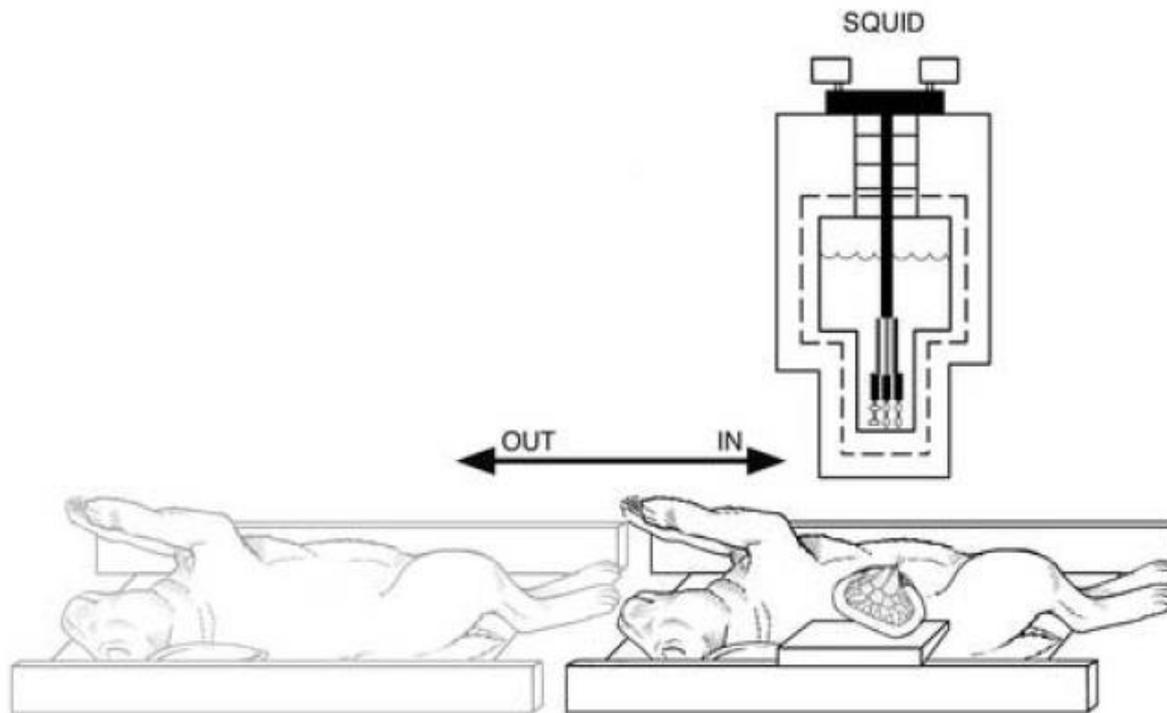
# Modelando a Atividade Elétrica



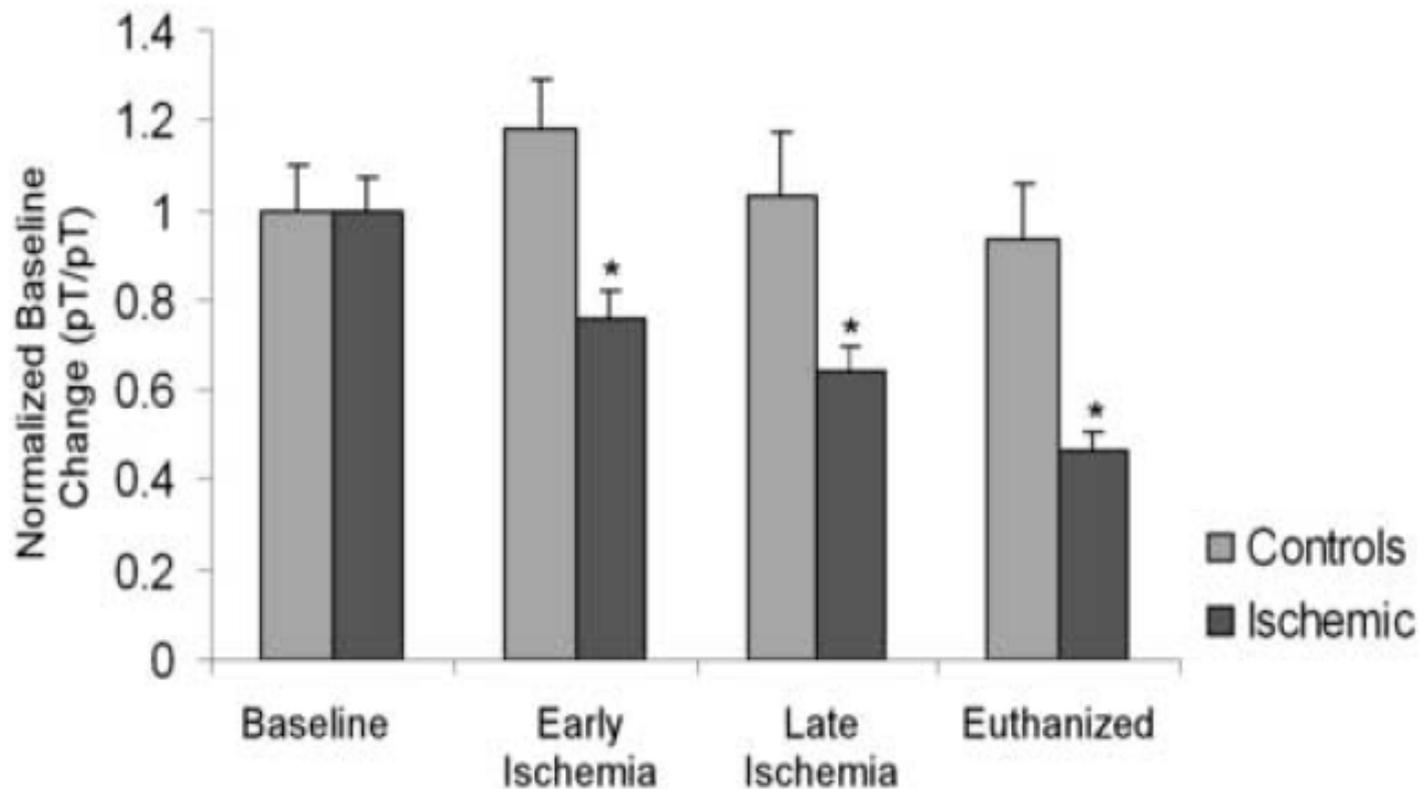
$$B = \frac{Q\mu_0}{4\pi R^2} \frac{1}{\left(1 - \frac{a^2}{R^2}\right)}$$



# Estudo da isquemia



# A isquemia leva a um diminuição da amplitude do sinal



# Outras pesquisas

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- ❑ Weitches et al, “drug delivery”
- ❑ Bradshaw et al, isquemia mesentérica

# Agradecimentos

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