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Functional Near Infrared Spectroscopy to Detect Nociception

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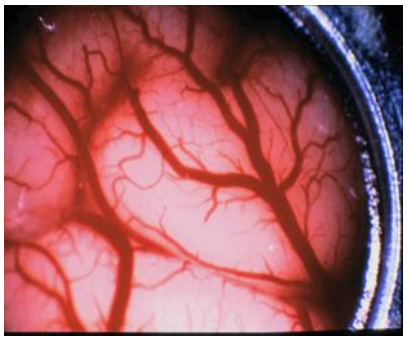
Objectives

- What is NIRS and how does it work?
- What does NIRS measure?
- How is NIRS being used clinically?
- What are our research studies?

What is NIRS?

- Optical technology
  - Light sources
  - Light detectors
  - Non-invasive
  - Portable (bedside)
  - Continuous monitor
  - Tissue oxygenation
- “Tissue Oximetry”





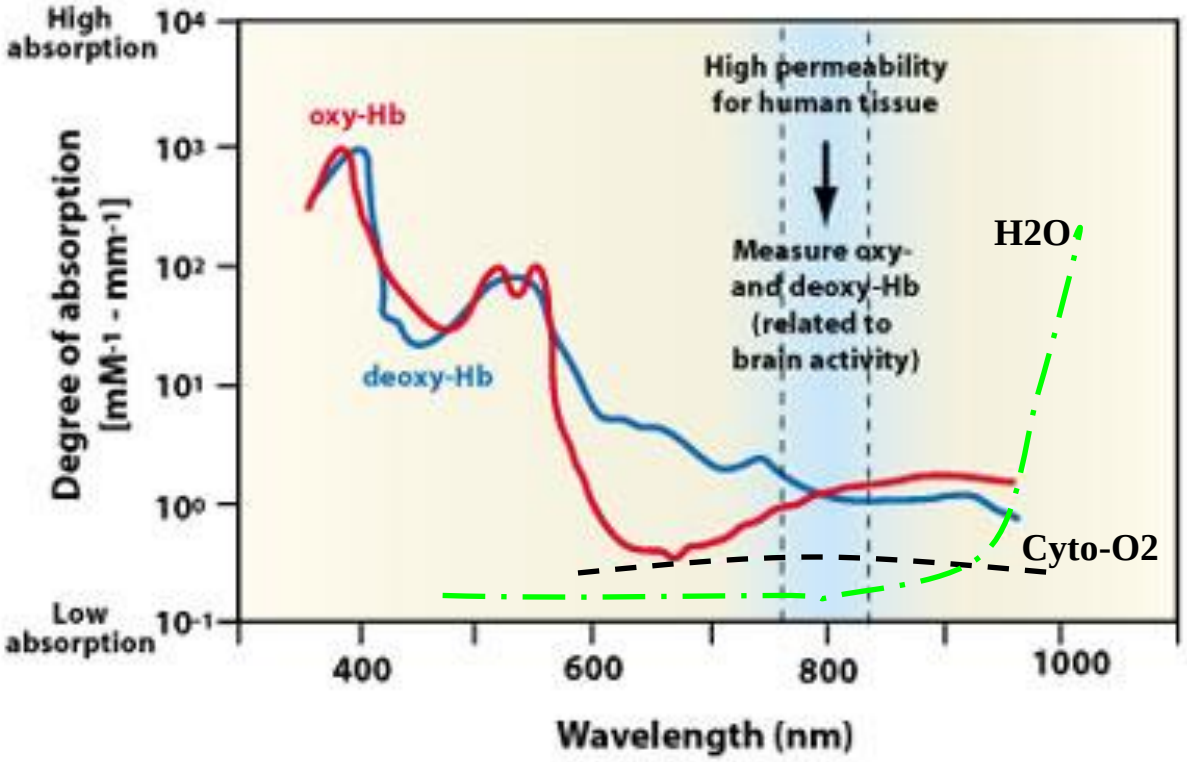
How does NIRS work?

O2 sensitive

- Hemoglobin
- Cytochrome

Other

- Water
- Melanin
- Bilirubin
- Glucose
- dyes

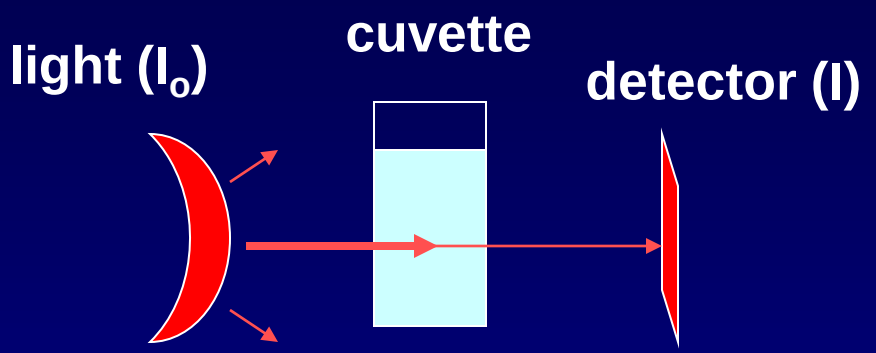


Technical limitations

- Hair
  - Absorbs light
  - Easy to measure brain from forehead
  - Difficult to measure brain where hair follicles exist
- Motion
  - Creates signal noise
  - Motionless for 5 seconds
- Ambient light
  - Quenches detectors
  - Low ambient light or shielding
- Depth
  - Superficial cortical grey matter
  - Extracranial contamination

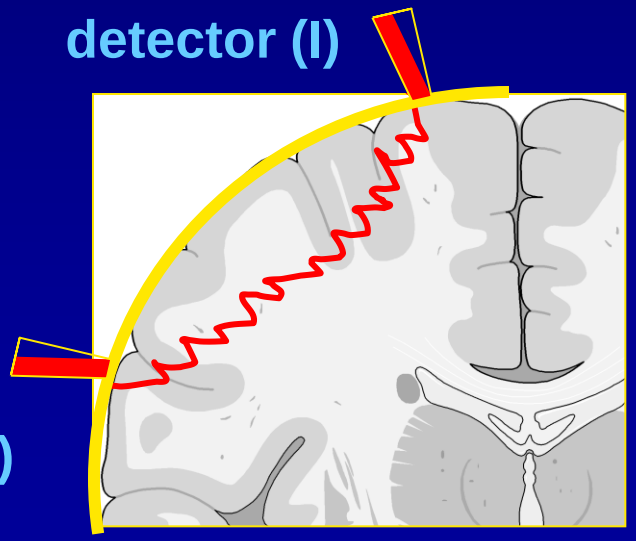
How Does NIRS Work?

- **Spectrophotometer**
  - oxy & deoxy hemoglobin (SO_2)

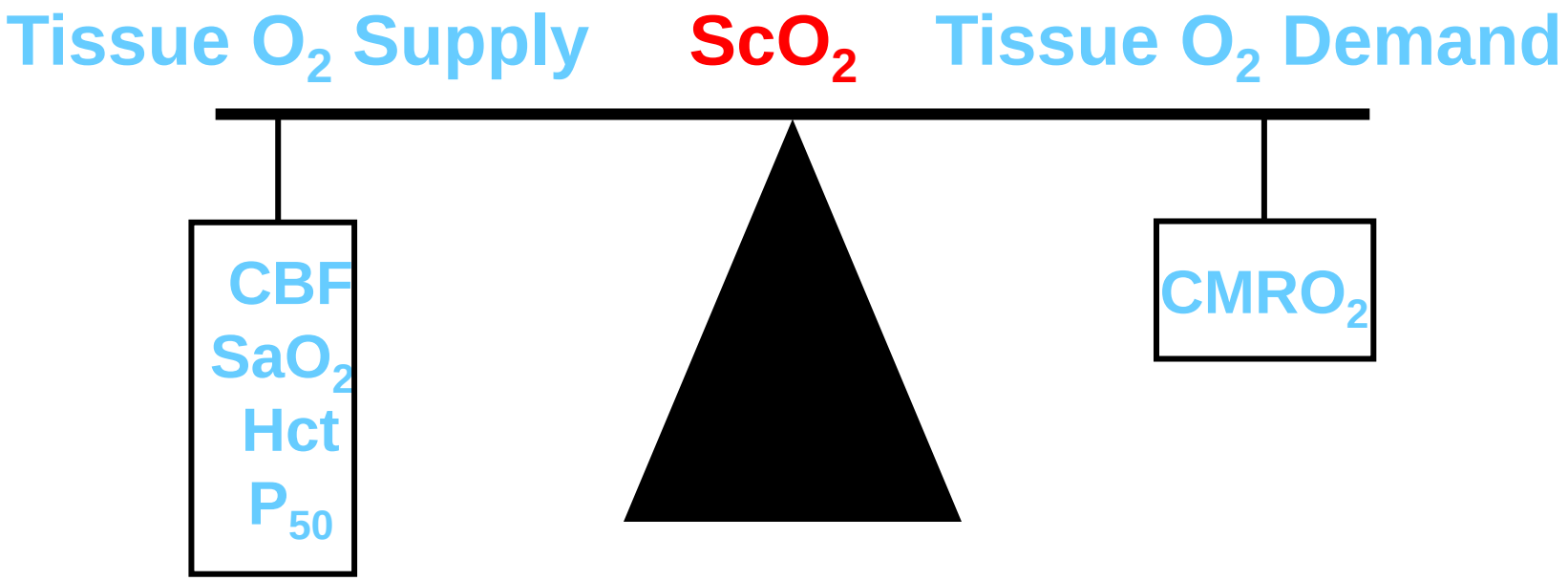


$$\text{Log}\ (\ I/I_o\ ) = SO_2$$

- **Probe**
  - sits on head
  - scalp, skull, brain



What Does NIRS Measure?

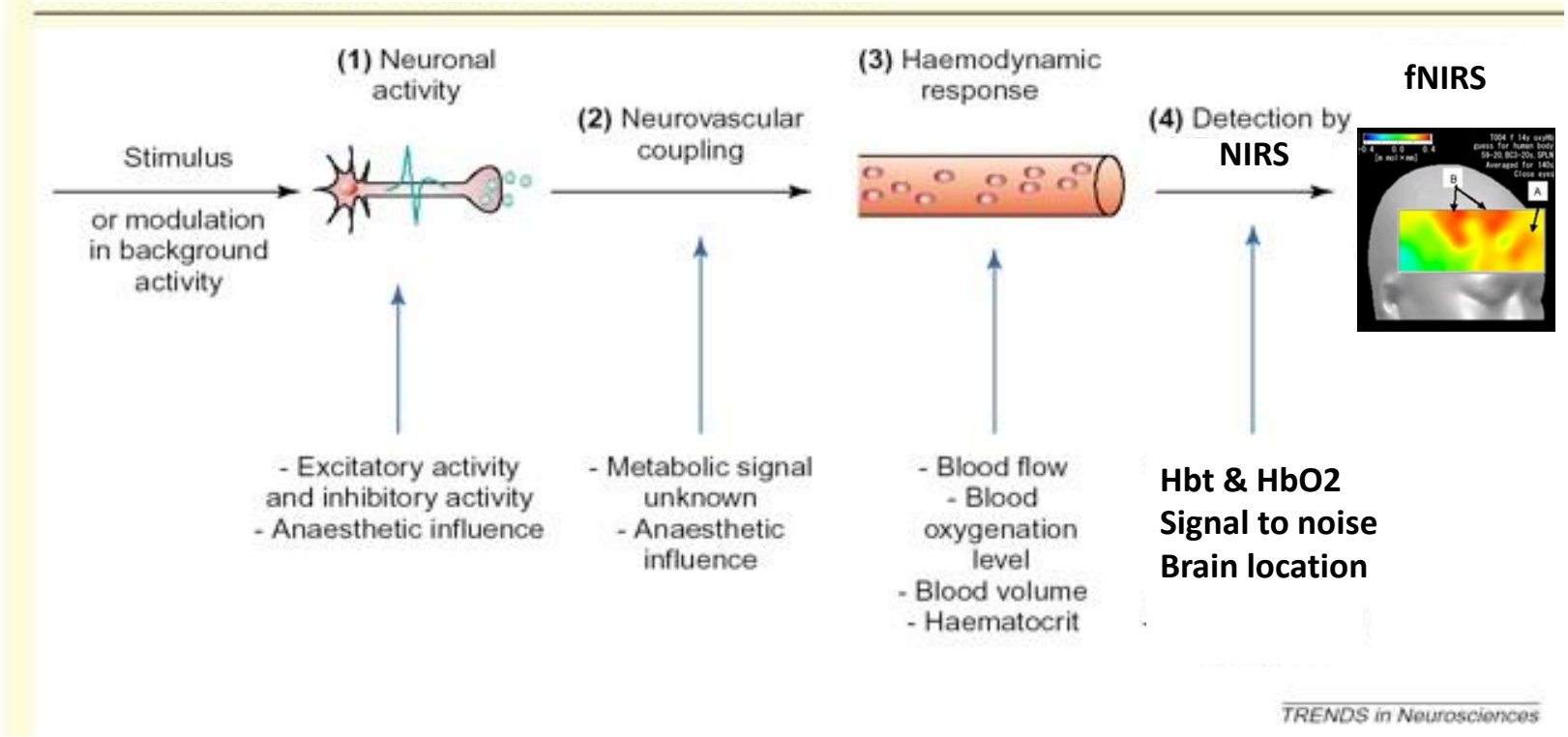


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Functional NIRS

Relies on blood flow to metabolism coupling

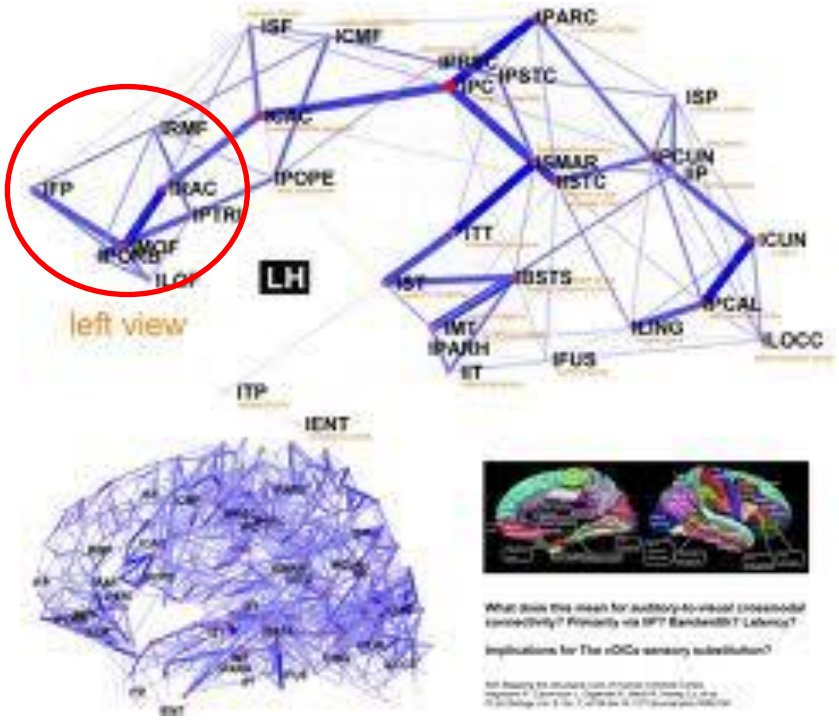
Blood flow: Hb_{total} and HbO_2

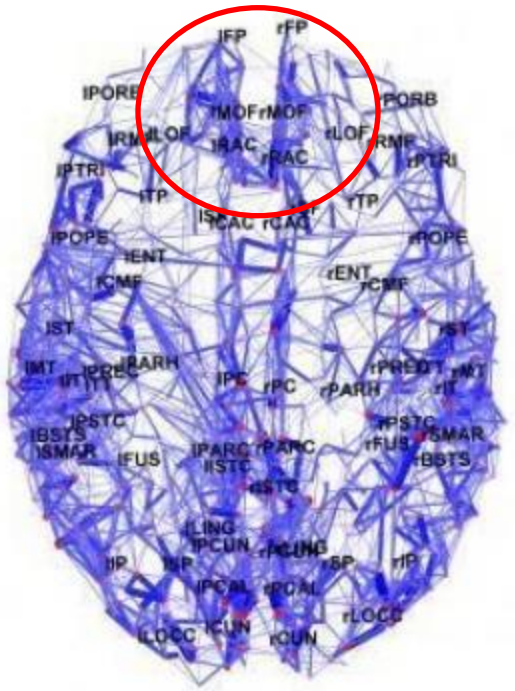


Are all NIRS devices fNIRS?

- Not all NIRS instruments can be fNIRS instruments
  - NIRS devices do a lot of signal averaging to take out noise and low signals
  - fNIRS signals so slight that typical NIRS would average signal changes out as noise
  - Functional activation also very fast
- fNIRS restricted to frontal area of brain due to hair problem
- Motion artifact also problematic

Frontal Cortex: major connection involved with most brain processing

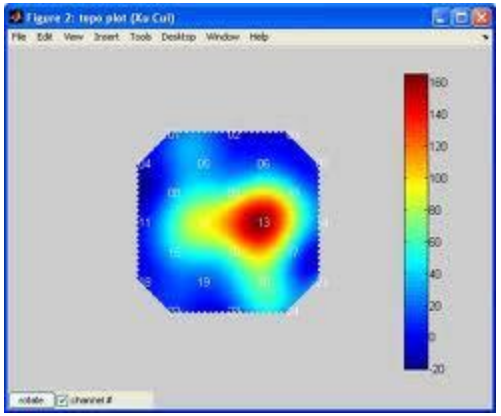




Functional NIRS

- Biopac device (not FDA)
- 3 wavelengths
- 10 detectors, 4 sources
- Image reconstruction











fNIRS Pain Study (1)

- Goal: Detect nociception in surgical patients secondary to electrical nociception
- Protocol
  - Induction of general anesthesia
  - Placement of probe on forehead
  - Electrical stimulation
    - 10-15 mAmps x 15 seconds with 30-60 seconds rest (x3)
    - 20-30 mAmps x 15 seconds with 30-60 seconds rest (x3)
    - Administration of 2 mcg/kg Fentanyl
    - Repeat low stimulation

fNIRS pain study (1)

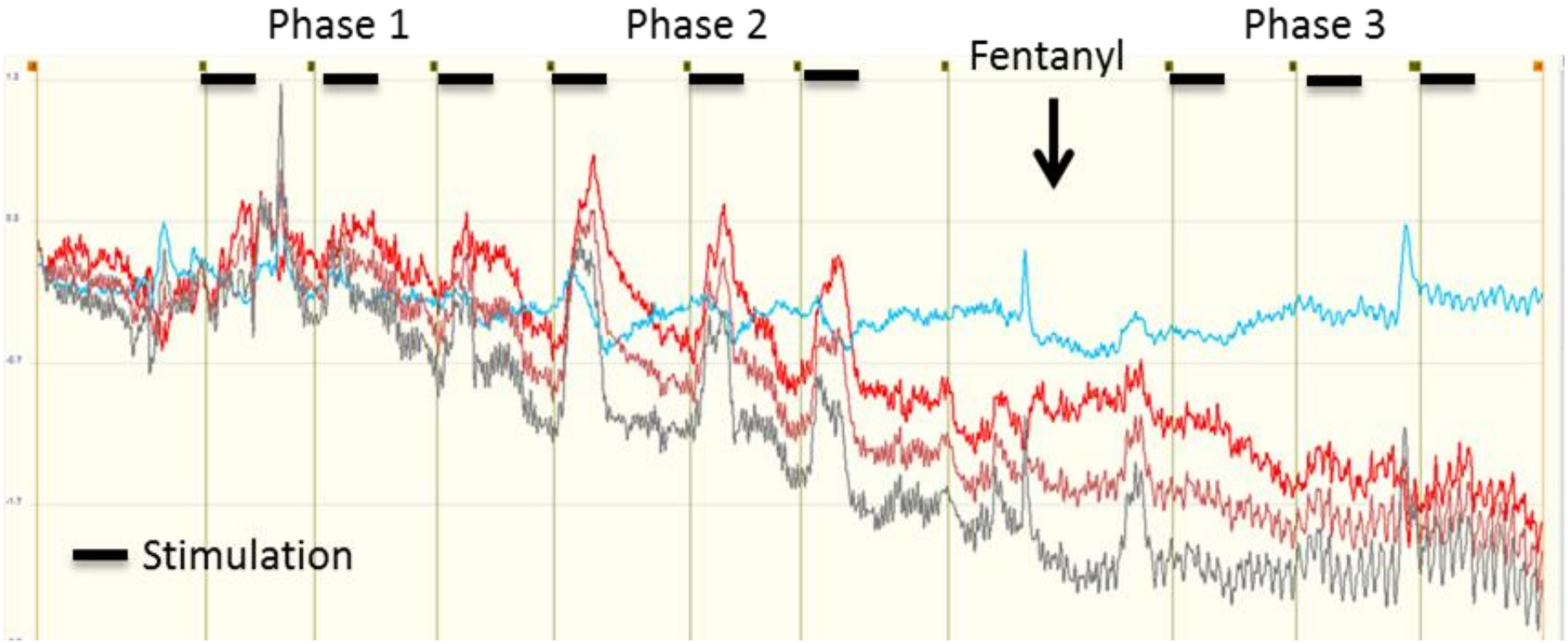


Figure 1. fNIRS recording showing changes in HbO_2 and HbT in patient 6. Oxy- is red, HbT is grey and deoxy-Hb is blue. Phase 1: Low stimulation, Phase 2: High stimulation, Phase 3: Low stimulation + Fentanyl.
Note: Increased HbO_2 and HbT with each stimulation and ablation of increase after Fentanyl.

fNIRS Pain Study (1)

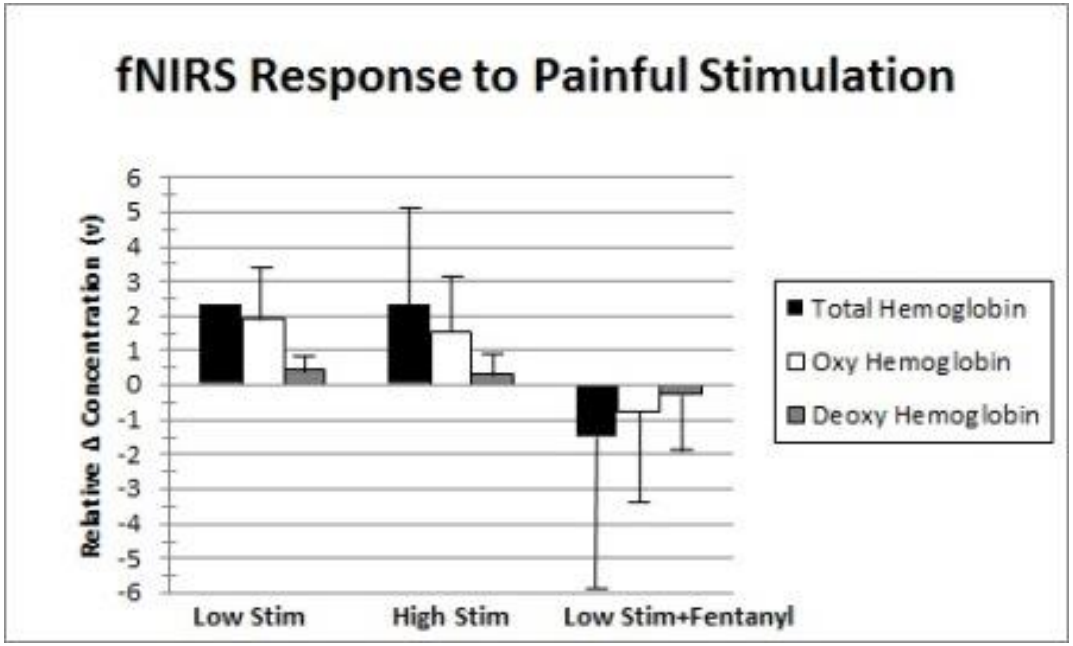


Figure 2. fNIRS response to painful stimulation in patients under general anesthesia

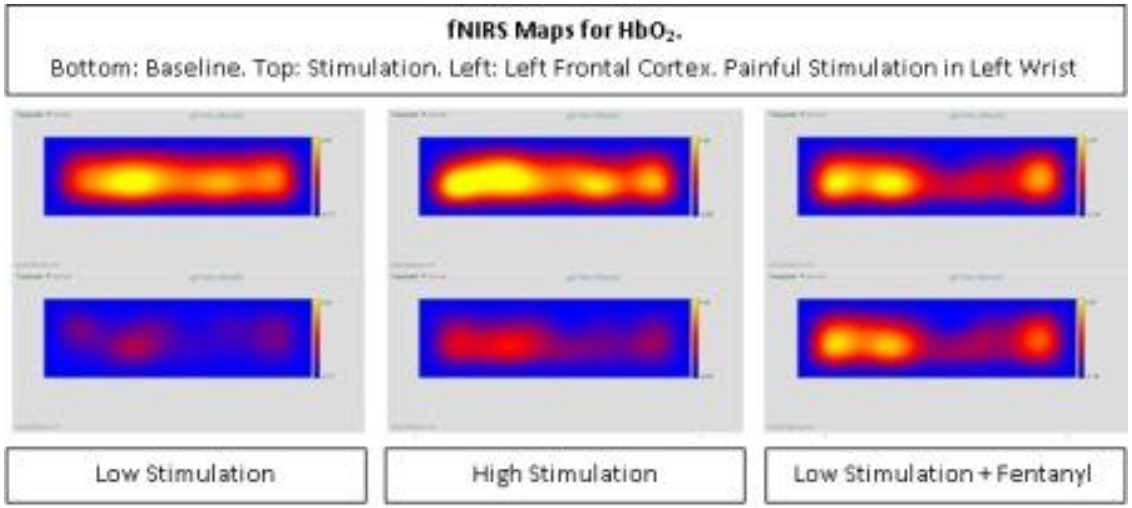


Figure 3. fNIRS maps for oxygenated hemoglobin in response to painful stimulation

fNIRS pain study (1)

				Phase 1: Low Stim		Phase 2: High Stim		Phase 3: Low Stim + Fentanyl	
Patient #	Age	Gender	Anesthesia	HbO_2	Hb Total	HbO_2	Hb Total	HbO_2	Hb Total
1	5 y	Male	S	^^	^^	^	^	-	-
2	3 y	Male	P	^^	^^	^^^	^^^	-	-
3	20 m	Female	P	^	^	^^^	^^^	-	-
4	4 y	Female	P	^^^	^^^	^^^	^^^	-	-
5	7 y	Male	P	^^^	^^^	^^^	^^^	-	-
6	8 y	Female	P	^^^	^^^	^^	^^	-	-
7	3 y	Male	S	-	-	-	-	-	-
8	2 y	Female	P	^^^	^^^	^^^	^^^	-	-
9	7 y	Male	S	-	-	-	-	-	-
10	8 y	Male	P	^^^	^^^	^^^	^^^	^^^	^^^
11	4y	Male	S	-	-	-	-	-	-
12	8y	Male	P	^^^	^^^	^^^	^^^	-	-
13	4y	Male	S	-	-	-	-	-	-
14	8y	Male	P	^^^	^^^	^^^	^^^	-	-

S = Sevoflurane, P = Propofol

Table 1. HbO_2 and HbT in frontal cortex as detected by fNIRS during 3 phases of study in neurosurgery patients. ^ Represents an increase in 1/3 stimuli, ^^ increase in 2/3 stimuli, ^^^ increase in 3/3 stimuli and - represents no change.

fNIRS Pain Study (2)

- Protocol
  - 30 patients undergoing Nuss repair of Pectus Excavatum
  - Nociceptive stimulus: Electrical impulse via nerve stimulator
  - Stimulus: 30 seconds on, 1 minute off, 10 seconds tetanus, 1 minute off
  - Prospective follow-up: Determine levels of pain and development of chronic pain post-operatively based upon use of narcotics > 4 weeks post-op
- Test of ability to predict development of chronic pain based upon heightened pain response pre-operatively as detected by fNIRS

fNIRS Pain Study (2)

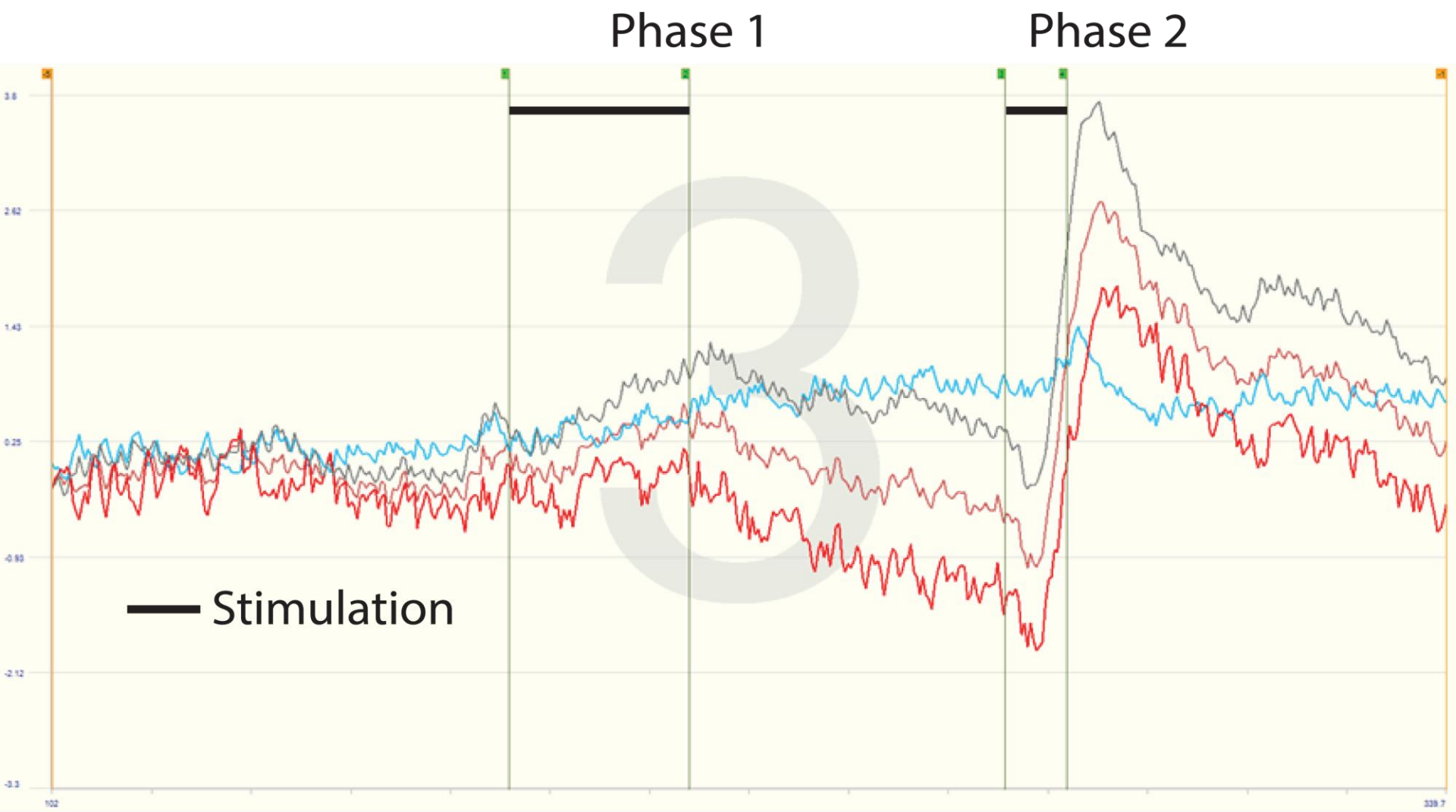


Figure 1. fNIRS recording showing changes in HbO_2 and HbT in patient 6. Oxy- is red, HbT is grey and deoxy-Hb is blue. Phase 1: Low stimulation, Phase 2: tetanus stimulation
Note: Increased HbO_2 and HbT with each stimulation.

Summary

- Increase in oxyHbg and total Hbg in response to electrical and pressure-induced pain
- Increase in oxyHbg and total Hbg occurs within 15 seconds and disappears within 15 seconds
- The greatest signal is ipsilateral to the side of the nociceptive input and signal is blocked with analgesics (fentanyl, sevo)

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