Neurological Complications in EOS and Neuromonitoring Issues

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ICEOS Meeting San Diego 2013

Disclaimer

Consultancy Agreements: Depuy Synthes, Medtronic

New Neurological Deficit (NND) Associated With Spine Surgery

1064 New Neurologic Deficits / 108,419 Procedures 1%

Revision cases 1.25% Primary cases 0.89%

Pediatric cases 1.32% Adult cases 0.83%

Neuromonitoring was used fot 65% of cases

Deficit	Number	IOM changes	Recovery		
			No recovery	Partial	Complete
Nerve Root	662	11%	4.7%	46.8%	47.1%
Cauda Equina	74	8%	9.6%	45.2%	45.2%
Spinal Cord	293	40%	10.6%	43 %	45.7%

Kojo Hamilton and Al. Spine 2011

New Neurological Deficit (NND) Associated With Spine Surgery

Type of Scoliosis
Pediatric < 21 Y

	N	Nerve Root	Cauda Equina	Spinal Cord	Total
Congenital	2045	0.98% (20)	0.05% (1)	0.98% (20)	2.00% (41)
Neuromuscular	4855	0.39% (19)	0.06% (3)	0.58% (28)	1.03% (50)
Idiopathic	11,741	0.31% (36)	0% (0)	0.43% (50)	0.73% (86)

Kojo Hamilton and Al. Spine 2011

New Neurological Deficit (NND) Associated With Spine Surgery

Type of procedure in EOS

36 Children

Mean age at initial implantation 4.8 years
Mean F.U. 51 Months (24-117)

3 patients IOM changes during surgery (8%)

2 Upper Extremity Motor Alerts for 2 VEPTR placements

1 VEPTR Removal Brachial plexus palsy recover in 10 weeks
2 Reducing VEPTR tension IOM normalized

1 Lower Extremity Motor Alerts for a VEPTR revision

Wake-up test, neurologic deficit, implants revised, IOM improved
Lower extremity weakness (2 additional procedures; partial revision then implant removal)
Recover after 3 months

Wudbhav N. Sankar and Al. Spine 2010

New Neurological Deficit (NND) Associated With Spine Surgery

NND in EOS

30 patients underwent 180 cases

150 Cases monitored

14 spinal cord monitoring alerts

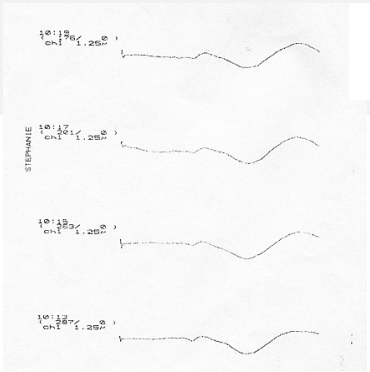
47% of the patient cohort
9.3% of the cases

No permanent neurologic deficit
Except a L5 nerve root traction injury with partial recovery

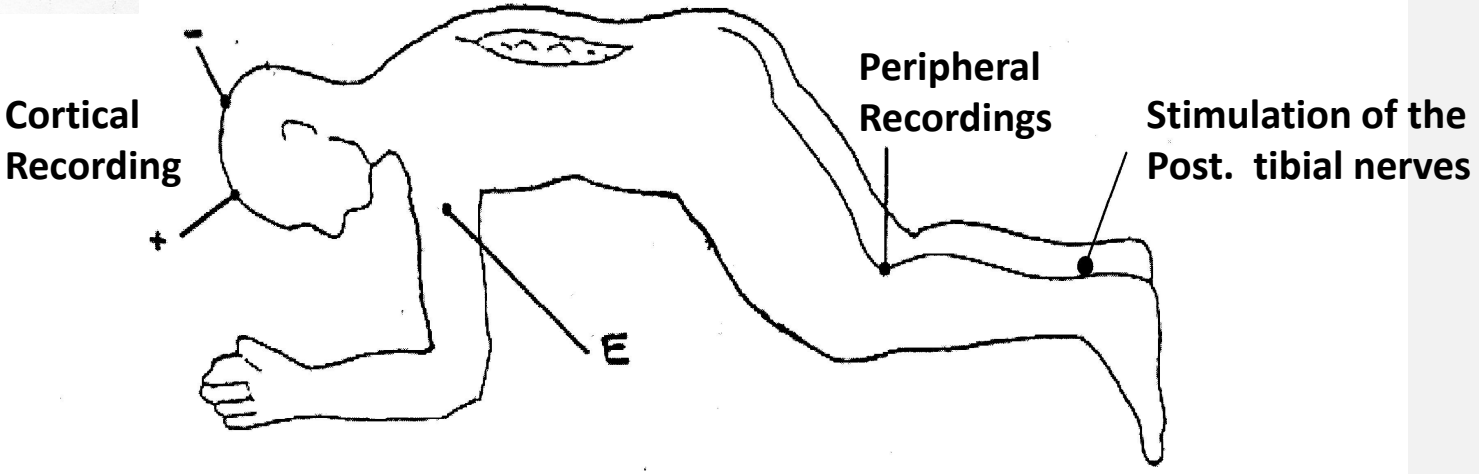
Intraoperative Neuro Monitoring

- Purpose
  - Prevent Neural Injury
  - Early Detection of Neural Injury
  - Early Treatment of Neural Injury

SomatoSensory Evoked Potentials (SSEP)



Assess the functional integrity of sensory pathways



Stimulation: 0,2ms, ~3Hz, ~25mA
Recording: 5Hz-1kHz, 10ms/div, 300 stimulations
Acquisition time~ 1.5mn

SomatoSensory Evoked Potentials (SSEP)

SSEP altered by

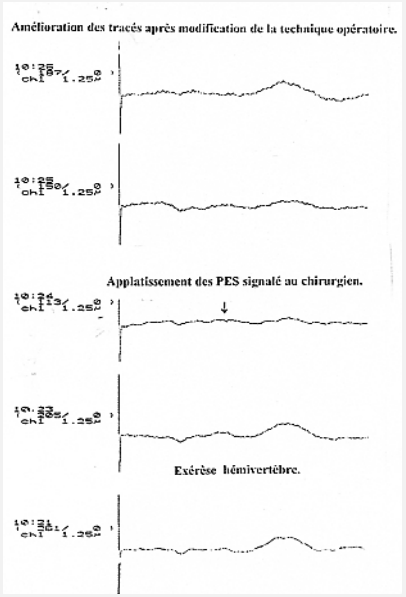
- ***Surgical manoeuvres*** **(mechanical, local ischemia)**
- ***Low blood pressure Anesthesiologist +++***
- **Hypothermia**
- **Hematocrit decrease**
- **Volatile agents such as**
  - **Isoflurane**
  - **Halothane**
  - **Nitrous Oxyde**

Warning signals:

Decrease in amplitude > 50%

and/or

Increase in latencies > 10%



SomatoSensory Evoked Potentials (SSEP)

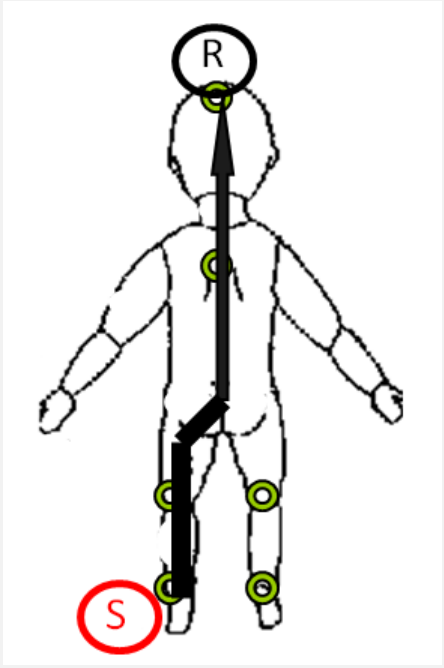
Disadvantages

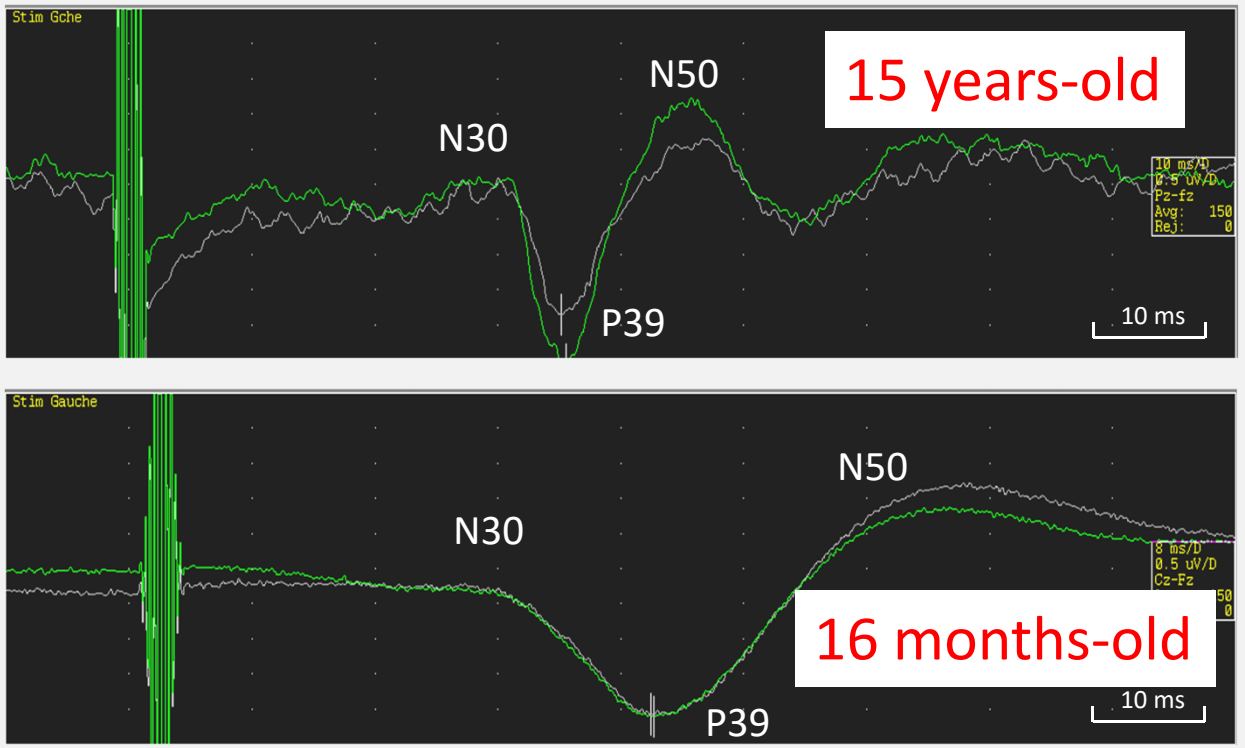
- ***Assess only the functional integrity of spinal cord dorsal column***
- ***Few cases of Post Op. paraplegia with preserved intraoperative SSEPs have been reported***
- ***Sensitive to anesthetics***
  Avoid Halogenated gases
- ***Acquisition time*** **> 1mn**

Advantages

- ***Nuwer 1995*** **51263 interventions**
  92% sensitivity (417 True + , 34 False -)
  98% specificity
- **Easy to implement**
- **No contraindications**
- **Cervical spine monitoring is possible**
- **Can be combined with other techniques**

SomatoSensory Evoked Potentials (SSEP) In EOS





The morphology of SSEP is different in young children.

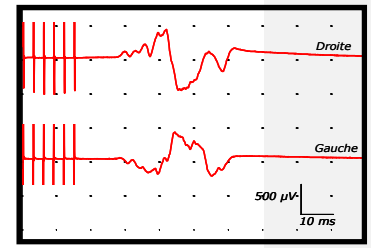
The amplitude of cortical SSEP can decrease during the averaging in young childs.

Warning signals are thus more difficult to detect in young childs compared to adolescents.

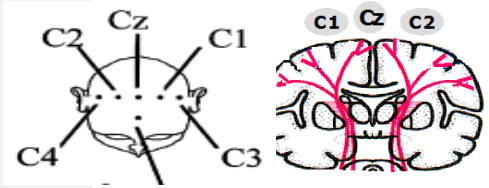
Motor Evoked Potentials (MEP)

Assess the functional integrity of motor pathways

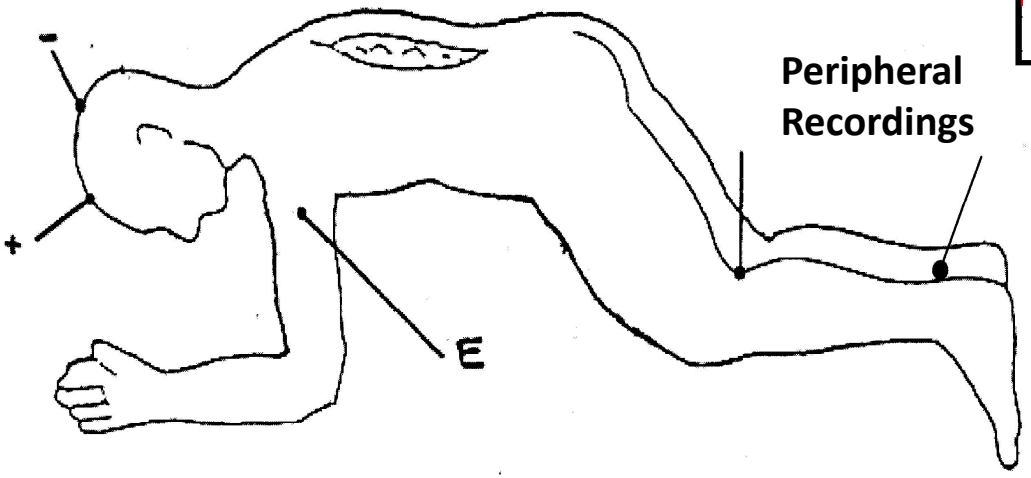
Spinal cord is the target



C1 C2 Electrical Cortical Stimulation



Peripheral Recordings



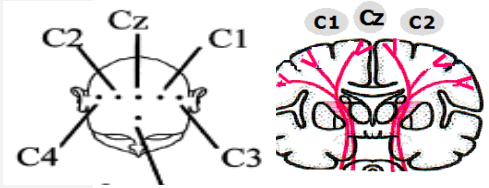
Stimulation: 5-7 pulses, Intensity 250-750 V
Duration of each pulse 0.5ms
Interval inter stimuli 2-4ms
Recording: Lower Limb muscles

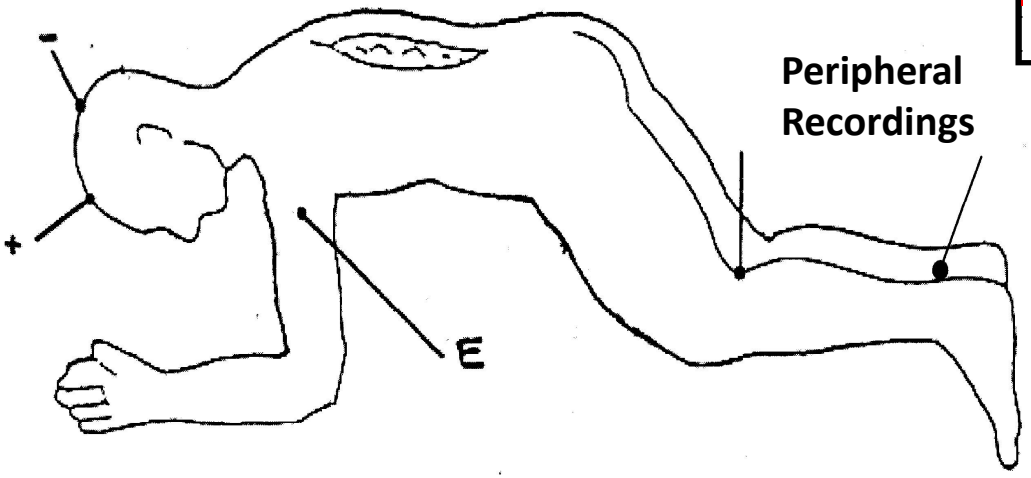
Motor Evoked Potentials (MEP)

Assess the functional integrity of motor pathways

Spinal cord is the target

C1 C2 Electrical Cortical Stimulation





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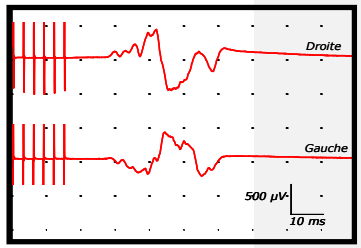


Advantages

- Selective and specific of motor pathway
- Lateralization
- No need for averaging

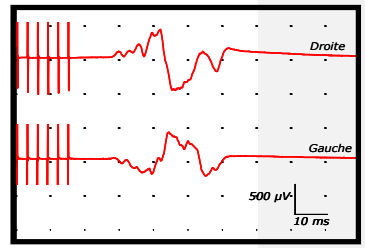
Disadvantages

- Curarization has to be interrupted
- Adverse effects
- Difficult in children under age 4

Motor Evoked Potentials (MEP)

Assess the functional integrity of motor pathways

Spinal cord is the target



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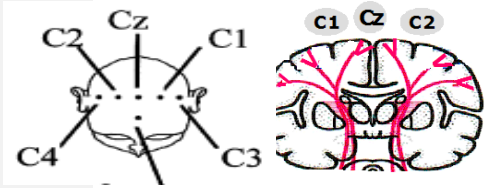

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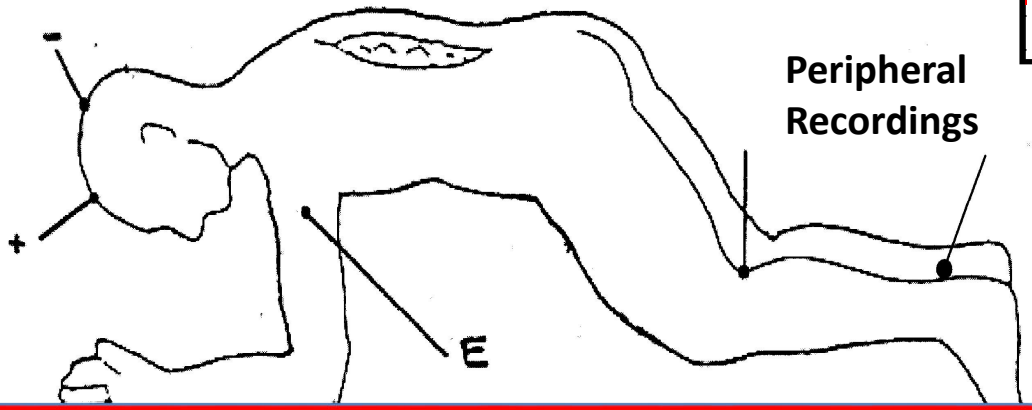


Adverse effects

Tongue or lip laceration	29/15,000
Mandibular fracture	1/15,000
Cardiac arrhythmia	5/15,000
Epileptic seizures	5/15,000
Scalp burn	2/15,000
Intraoperative awareness	1/15,000

Safety of intraoperative MEP MacDonald J Clin Neurophysiol. 2002; 19: 416-29

MEP Before the age of 4Y

Difficult because incomplete maturation of motor pathways

Response facilitation methods are currently being developed

Increase in the threshold voltage for sufficient MEP response.

Longer stimulating pulse trains

Greater need to adjust stimulating scalp electrodes.

Limitation of depressant anesthetics

Lieberman JA and Al. The effect of age on motor evoked potentials in children under propofol/isoflurane anesthesia. Anesth Analg 2006

MEP Before the age of 4Y

Temporal facilitation

Train-of-five pulse, 400–700 V; time constant 100s; interstimulus interval 2 ms

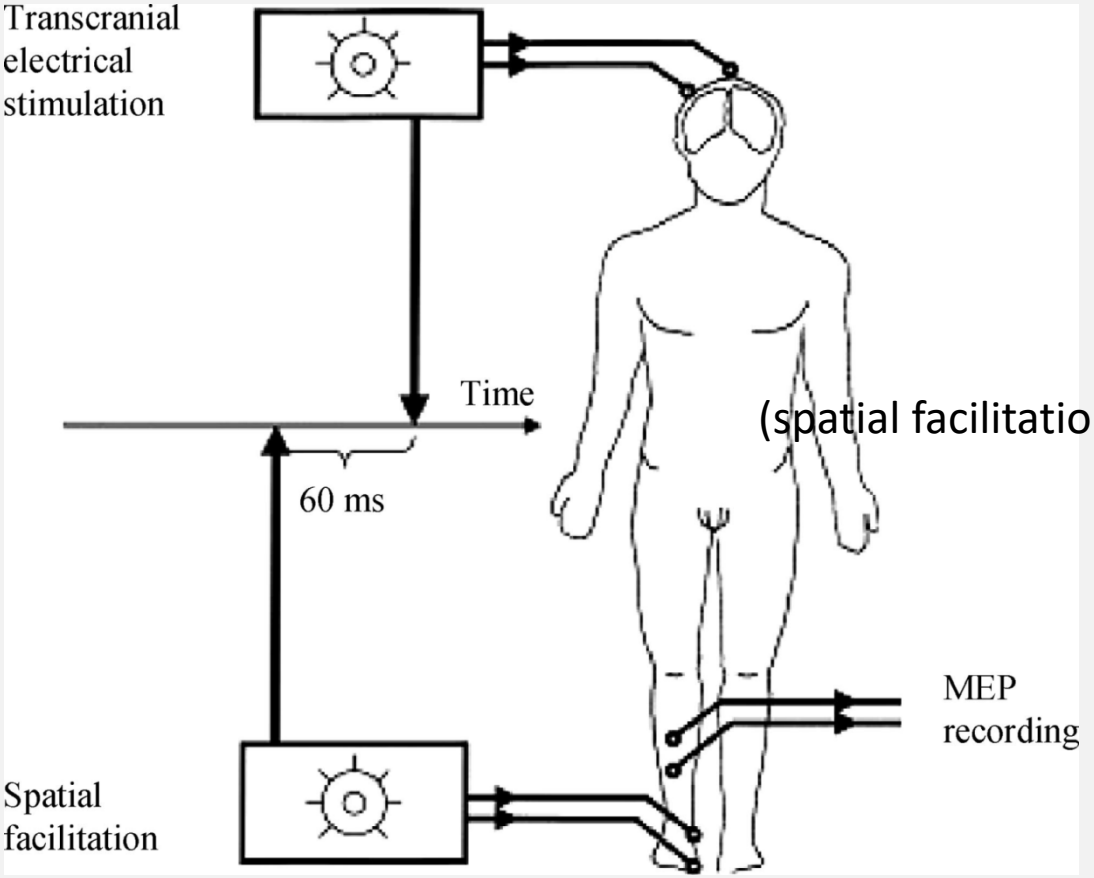
The anode was placed at the Cz position and a ring of 4 cathodes approximately 6 cm apart.

MEPs were recorded with needle electrodes from the left and right tibialis anterior muscles.

Frei FJ and Al. Intraoperative monitoring of motor-evoked potentials in children undergoing spinal surgery. Spine 2007

MEP Before the age of 4Y

Spatial facilitation



(spatial facilitation)

An electrical stimulus to the medial border of the foot is applied 60 ms before the transcranial electrical stimulus.

Frei FJ and Al. Intraoperative monitoring of motor-evoked potentials in children undergoing spinal surgery. Spine 2007

MEP Before the age of 4Y

Overall Series

Temporal facilitation alone, reliable MEPs: 78% (105 of 134)

Temporal and spatial facilitation, reliable MEPs in 96% (129 of 134)

Age Under 6

Reliable MEPs were documented in 86% (18 of 21) in children <6 Y

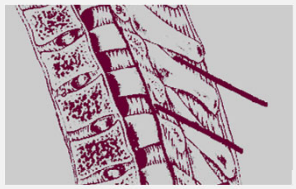
Frei FJ and Al. Intraoperative monitoring of motor-evoked potentials in children undergoing spinal surgery. Spine 2007

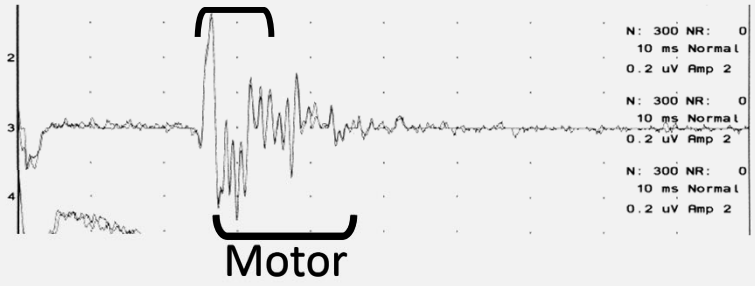
Neurogenic Mixed Evoked Potentials (NMEP)

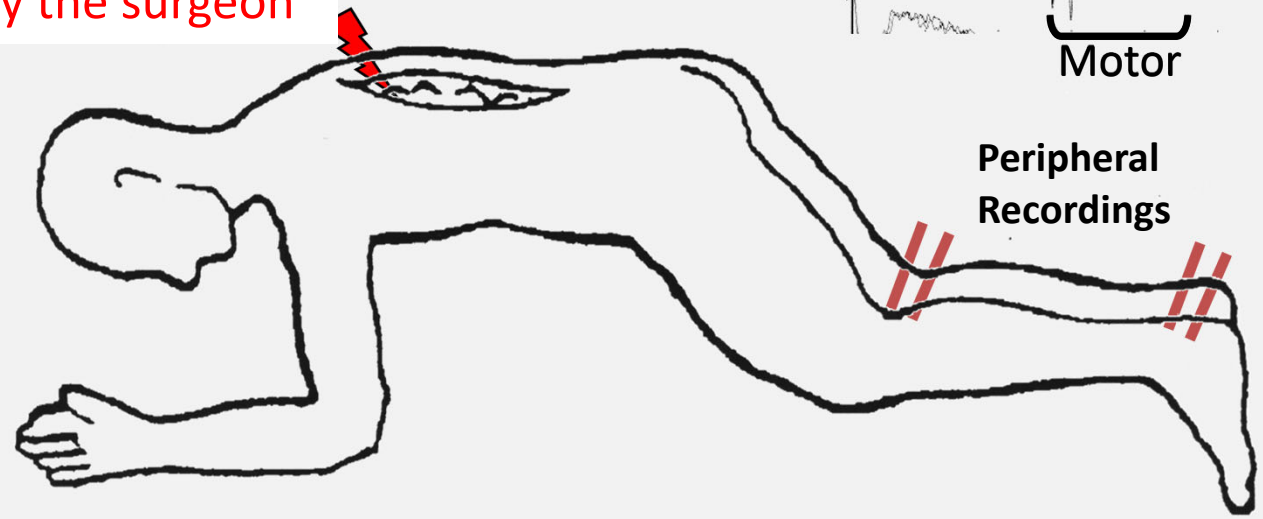
Spinal cord is the target

Stimulation : 20-50 mA, duration 1 ms, frequency 4.1 Hz
Recording : 20 Hz – 3 KHz, 8 ms/div, 1 µV/div, 20-50 stimulations
Require patient curarization

Spinal electrodes inserted by the surgeon







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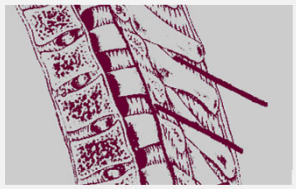
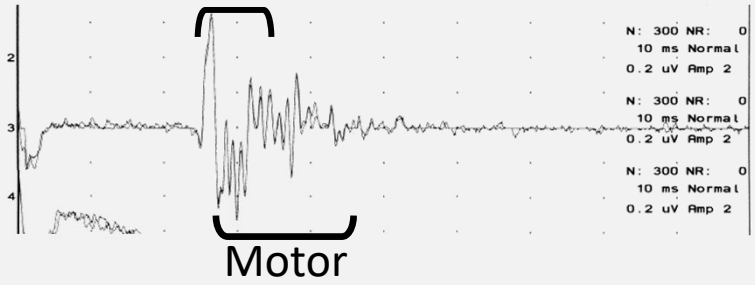




Advantages
- Fast and easy to implement
- Resistant to most anesthetics
- Sensitive
- Determination of lesional level

Disadvantages
- Relative specificity
- Require curarization
- Terminal medullary conus not monitored

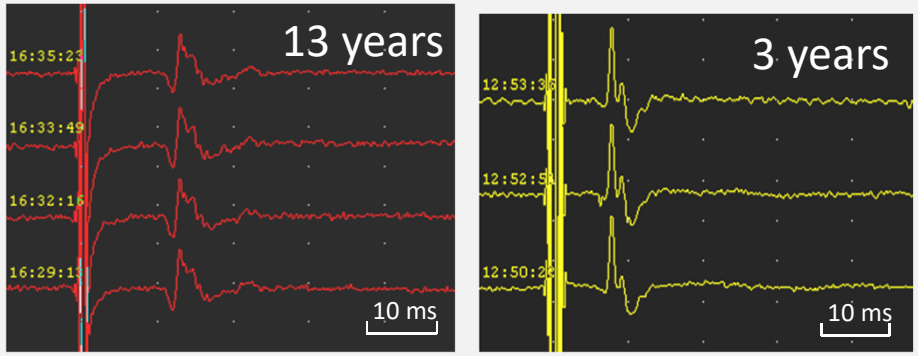
Neurogenic Mixed Evoked Potentials (NMEP In EOS

Easy to perform in children before the age of 4

But

- NMEP are not specific of motor pathways
- NMEP do not allow to monitor the conus terminalis.

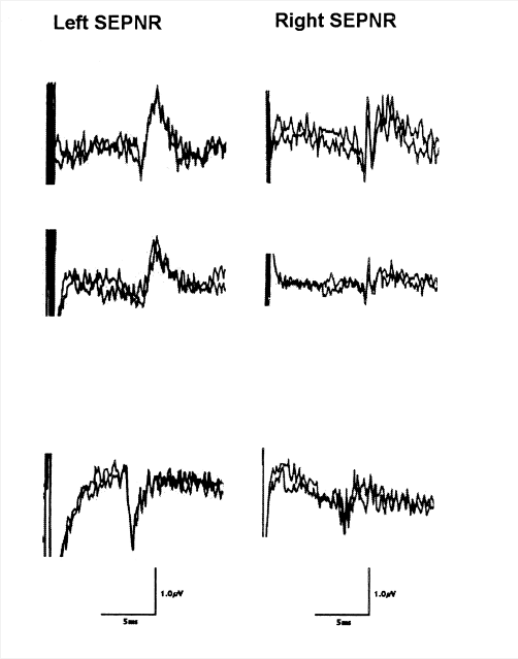
The spinal electrode has to be
above the vertebral level T8 ++++



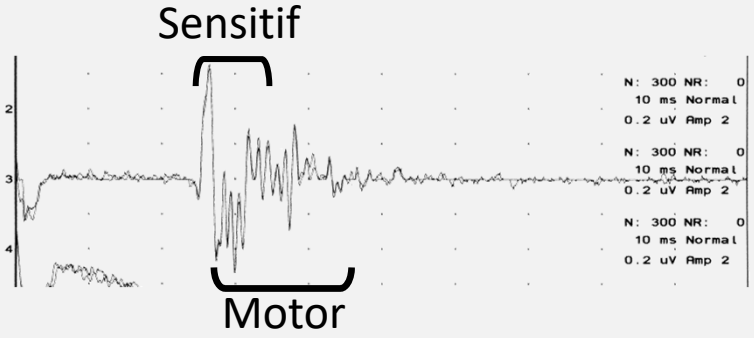
Neurogenic Mixed Evoked Potentials (NMEP In EOS

Controversies

Anterior spinal cord injury with preserved neurogenic evoked potentials
R E Minahan and Al. Clinical Neurophysiology 2001



Combined spinal cord monitoring using neurogenic mixed evoked potentials and collision techniques
Y Pereon and Al. Spine 2002



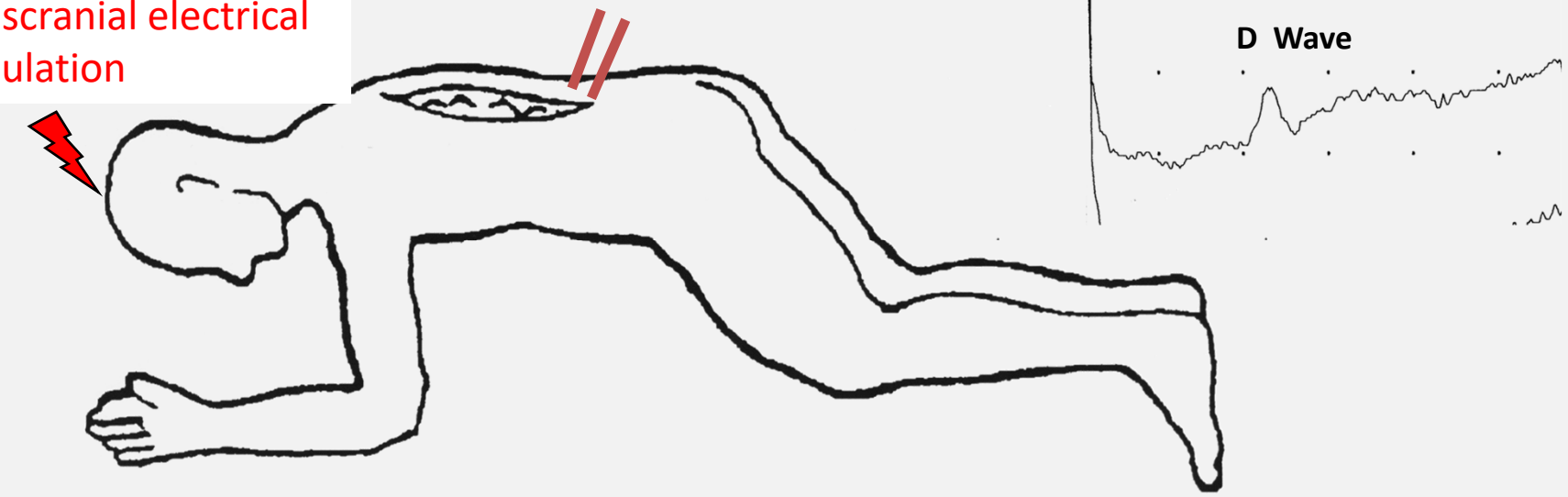
D Waves

Stimulation : 80-100 mA, durée 0.5-1 ms, frequency 0.8 Hz
Recording: 5 Hz – 3 KHz, 3 ms/div, 20 µV/div, 5-10stimulations
Patient curarisé

Spinal cord is the target

Transcranial electrical stimulation

Distal spinal cord recording T11



Advantages
- Very rapid acquisition
- Specific of motor pathway
- Determination of lesional level
- Pronostic value

Disadvantages
- Electrode in the surgical field
- Laterality cannot be distinguished
- Curarization
- Cannot be used < 4 years of age

D Waves
In EOS

Obtained after 4 Years of age

In our experience:
Unobtained in 4 very young child (21 M, 22 M, 30 M, 36 M)

Obtained in one child 25 months old

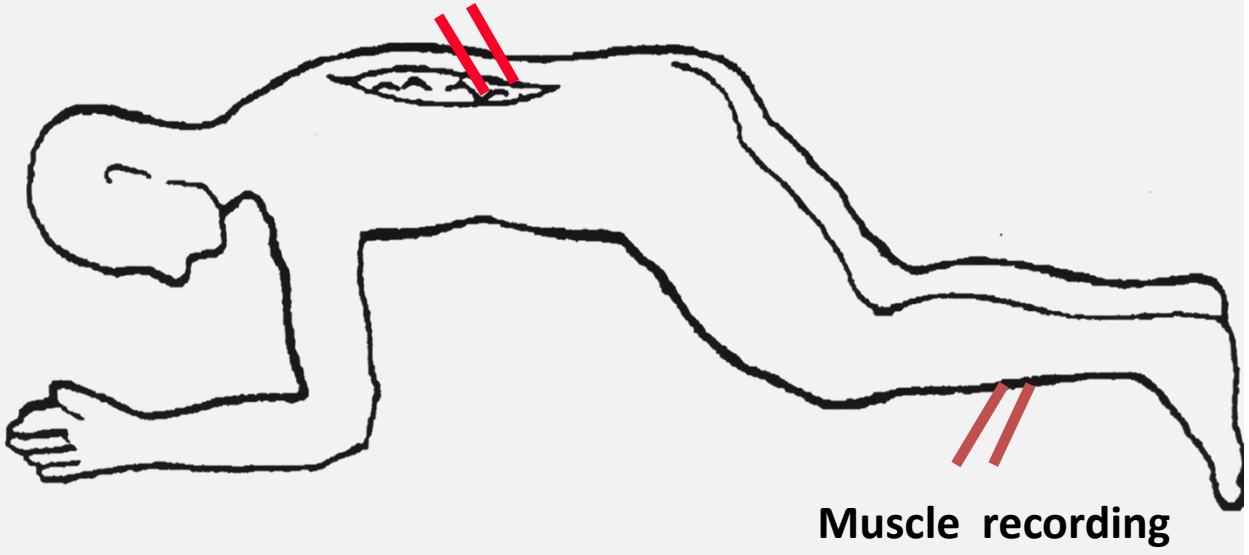
Maturation steps are variable

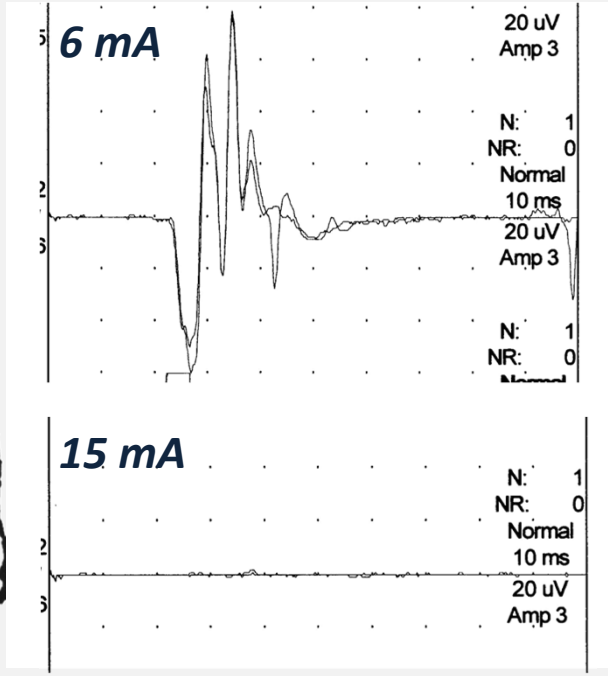
→ Difficult for the neurophysiologist to know before the surgery if he will be able to test selectively the motor pathways in a child before the age of 4 using D Waves (or using MEP, even with facilitation procedures).

Pedicle screws testing

Nerve root is the target

Stimulation : 5 à 30 mA, duration 0.2 ms, frequency 0.8 Hz
Recording: 20 Hz – 3 KHz, 5 ms/div, 50 µV/div
No averaging
Neuromuscular blockades are prohibited





Advantages
- Fast and easy to implement
- No curarization

Disadvantages
- Surgeon duty
- Sensitive to a large number of anesthetics
- Less sensitive for thoracic compare to lumbar pedicle screws

Pedicle screws testing

Stimulation of Pedicle Screw between 2 mA and 30 mA

< 5 mA = very likely screw contact with exiting root

5-10 mA = possible pedicle breach

>15 mA = no inferomedial breach (98% confidence level*)

**Glassman et al. 1995*

Pedicle screws testing
In EOS

No data before age 4

Values are certainly different

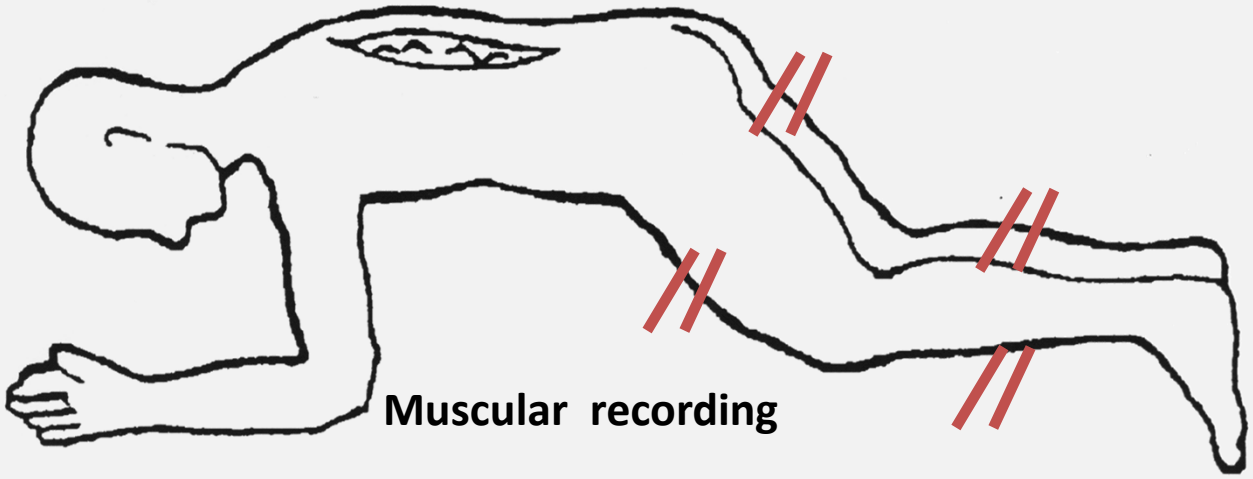
Bone conductivity values vary especially during chilhood

Gonçalvez and Al, 2003

Continuous Electromyography EMG

Nerve root is the target

No stimulation
Continuous recording : 20 Hz – 3 KHz, 5 ms/div, 50 µV/div,
Search for abnormal discharges of rhytmic motor unit potentials
No curarization



Advantages
- Multiple pathway recordings
- Immediate information

Disadvantages
- Poor Sensibility
- Poor Specificity
- Information not retroactive

Failure of Intra Operative Monitoring

False Negative

to Detect Post operative Neurologic Deficit

12,375 Patients

Multi modal Intra Operative Monitoring including:

SSEP	4	8.9%
Descending Neurogenic Evoked Potential (DNEP)	4	8.9%
Trans Cranial Motor Evoked Potential (MEP)		
Dermatomal somatosensory evoked potential (DSEP)	7	15.6%
Triggered EMG	9	20%
Spontaneous EMG	25	55.6%

45 / 12,375 i.e. 0.36% Post. Op. Deficits not Identified by IOM

37 Nerve Roots	6 Permanent Deficits
8 Spinal Cord	2 Permanent Deficits

Barry L Raynor and Al
48Th SRS Meeting Lyon 2013

Failure of Intra Operative Monitoring

False Positive

70 Patients

Mean Age: 4Y

	IOM alerts	
	Intra Op.	After I.O. Surg. And/Or Anesth. Measures
9 Neuromuscular	0	
27 Congenital	8	5
32 Idiopathic	4	0
32 cases monitored with SSEPs and MEPs	7	
38 cases monitored with SSEPs alone	5	

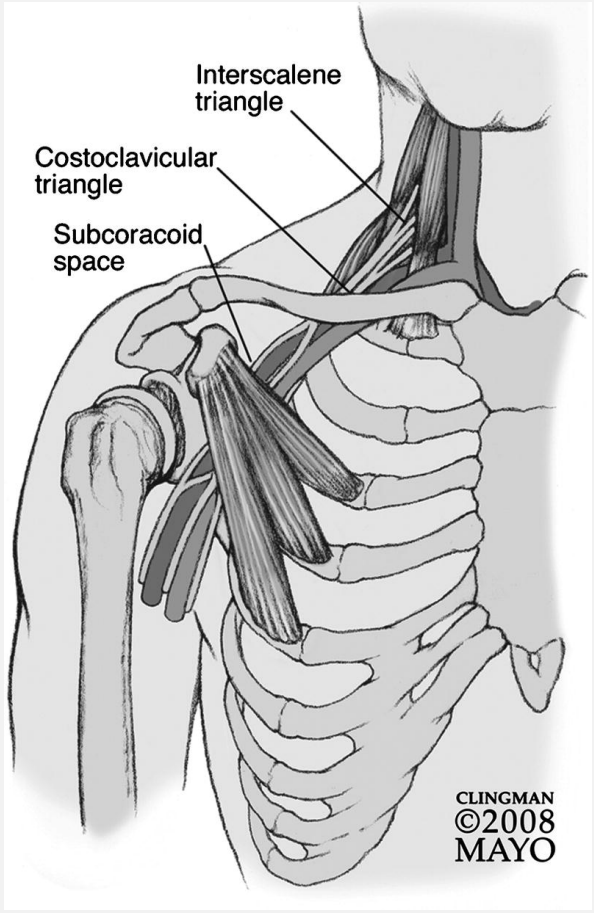
Olivier M. Stokes Incidence of False Positive Spinal Cord Monitoring Alerts in Surgery for EOS
ICEOS Meeting San Diego 2013

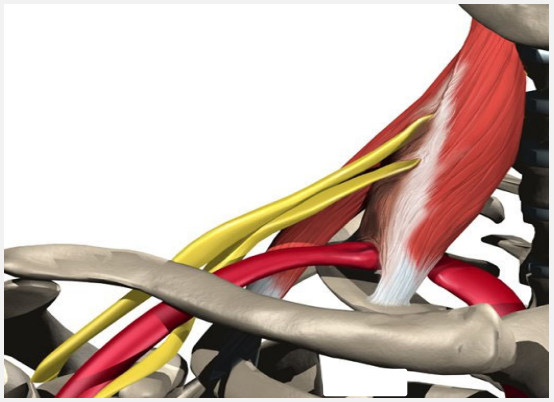
Rib Based Distraction and IOM

Methods

Simulated VEPTR procedure on 8 fresh cadaveric specimens

Manometric measurements in 3 anatomic regions

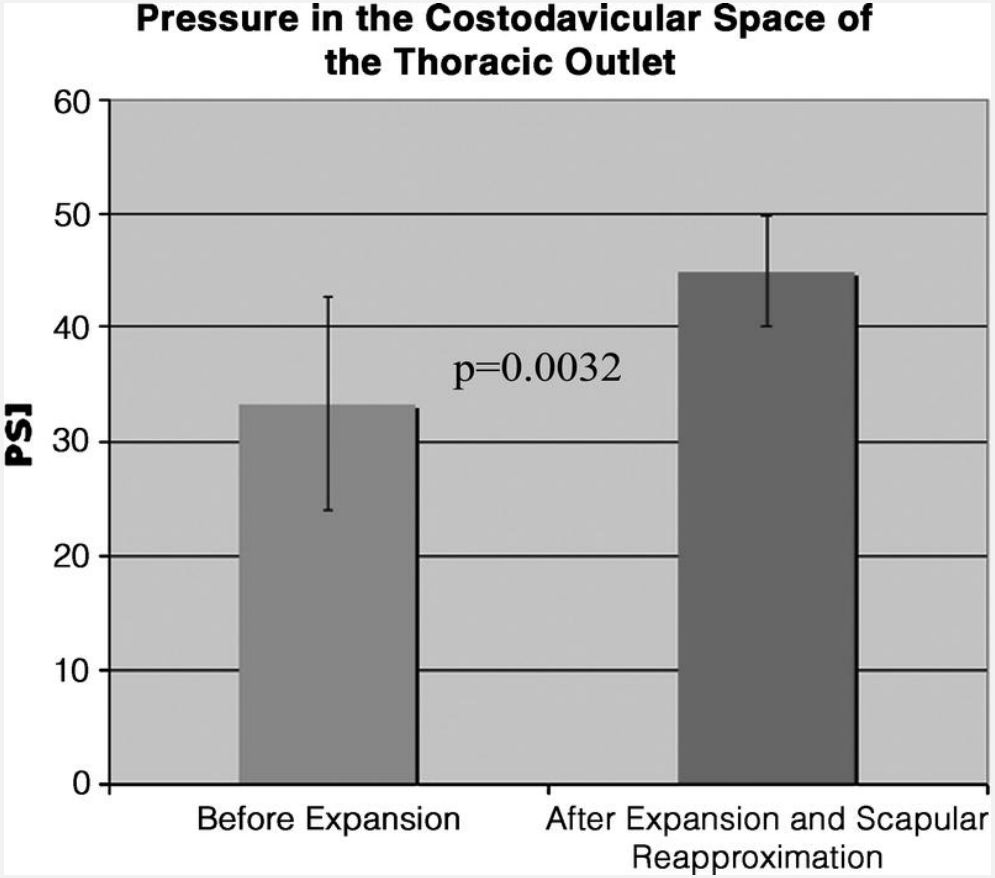


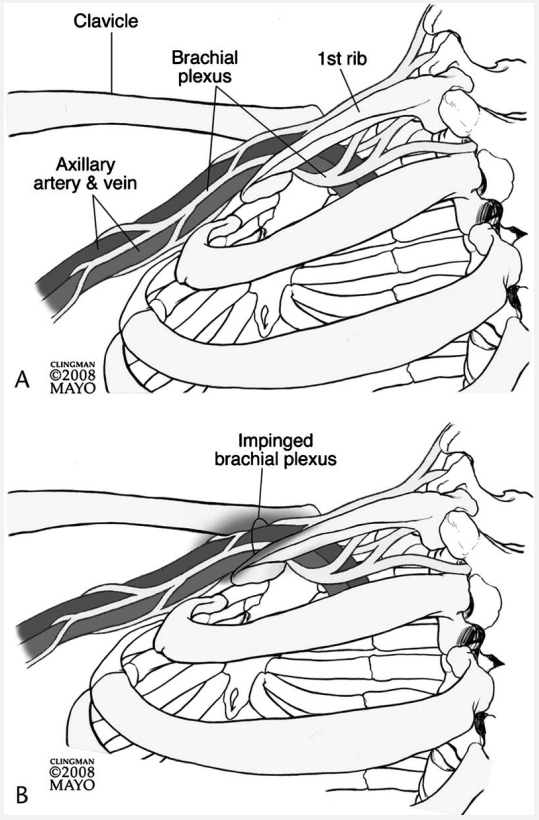


Nassr JPO 2009

Results

20% increase in pressure in the costoclavicular space of the thoracic outlet





Controversies

CWSDSG database from 2004-2013
524 Patients treated with rib based distraction
223 Congenital, 163 Neuromuscular, 67 Idiopathic, 63 Syndromic, 8 Unknown

9 Neurologic injuries = 1.7%
(7 congenital, 2 Idiopathic)

- 5 Brachial plexus injuries → 2 residual upper limb weakness
- 4 Partial Spinal Cord injuries → Full resolution

No injuries during routine lengthening surgery

Luke Gauthier And Al.

95 Patients underwent 635 rib based expansions and 90 exchange procedures

No neurologic deficit

Neuromonitoring may be not necessary in routine exchange and lengthening procedures

John T. Smith And Al.

Submitted as free papers at the ICEOS meeting San Diego 2013

Controversies

1736 consecutive VEPTR procedures

		Neurol. Inj.	IOM Changes	SSEP	MEP	Up	Low
327	Primary Device Implantation	5	5	3 1 1	 1	X X	X X X
224	Device Exchange	3	1 2 without IOM	1		X	
1736	Device Lengthening	0					

8 Neurologic Injuries

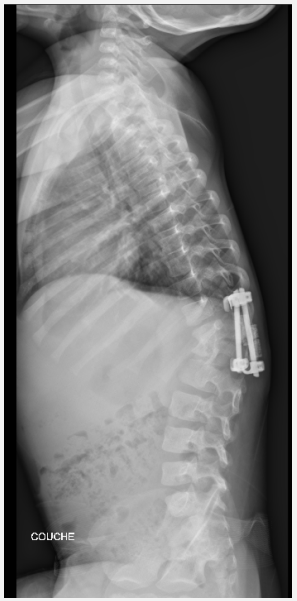
6 upper extremity → 1 permanent

2 lower extremity → resolved

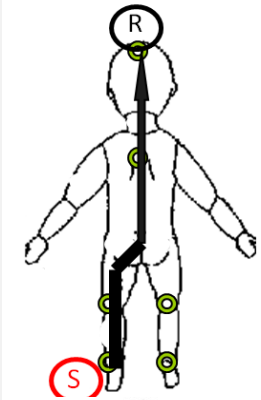
Upper and lower limbs neuromonitoring could be not mandatory during routine lengthening of a rib based construct but still mandatory during primary implantation as well as device exchange

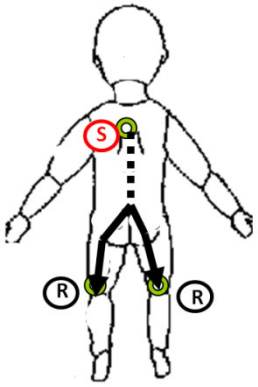
David L. Skaggs and Al. J Bone Joint Surg. 2009

NMEP alert, child 25 months-old
Thoraco-lombar kyphosis

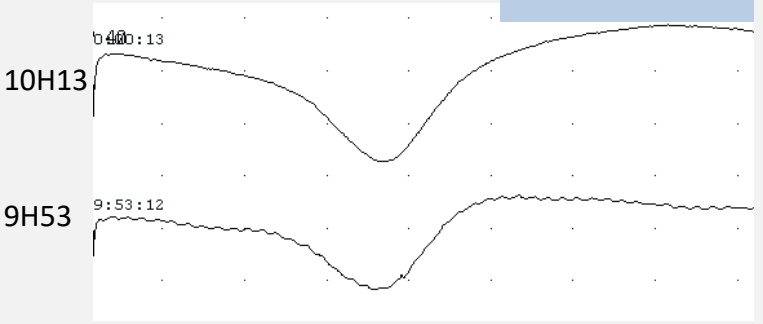


SSEP and NMEP with a spinal electrode at the level of T6

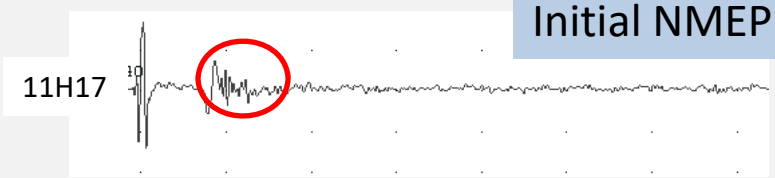




Initial SSEP



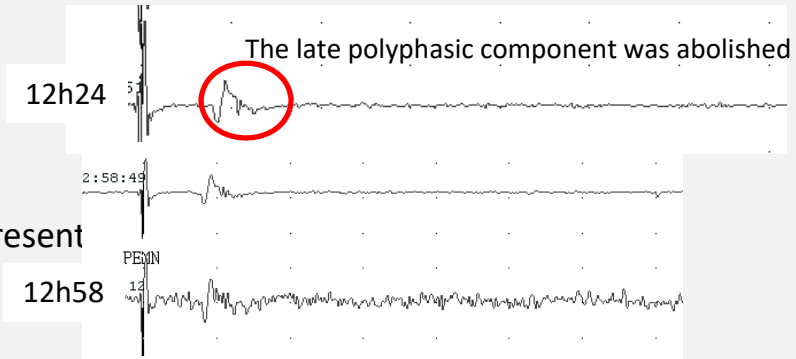
Initial NMEP



-D-wave was present

NMEP alert

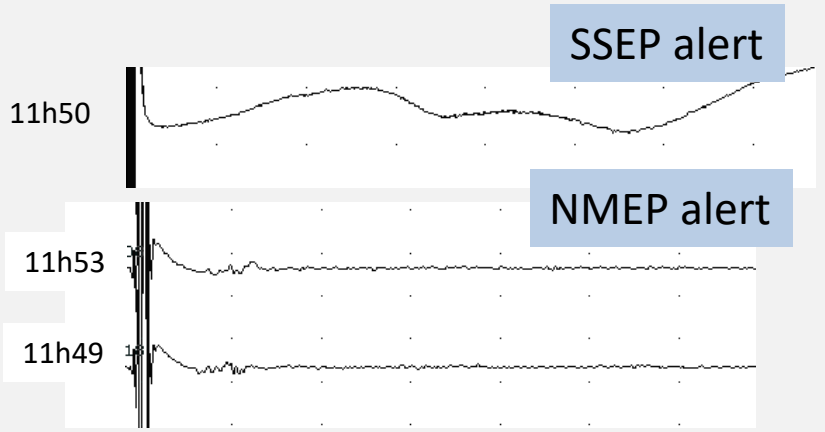
NMEP alert during the instrumentation while SSEP remain unchanged



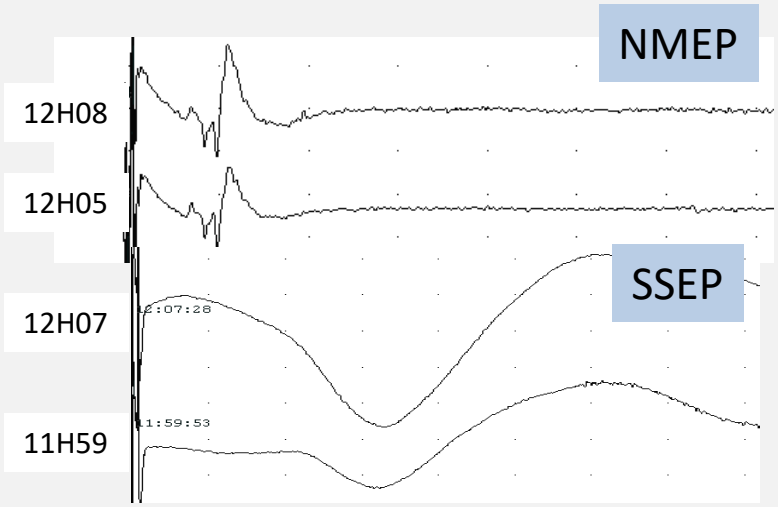
With a lesser correction, NMEP were re-establishe and D-waves were present

No neurologic deficit

NMEP & SSEP alerts / child 9 months-old
Congenital dislocation of the spine



11h50: Intra-operative NMEP & SSEP alert
Loss of amplitudes > 50%
Step of the surgery: dural traction



Release
→ Resolution of this monitoring alert
Normal post-operative neurologic examination

The multimodal intraoperative monitoring has to be adapted according to:

- the level of the surgery
- the structures at risk
- the age of the child
- the patient's medical history
- and the neurophysiologist's experience

Few data in the litterature before the age of 4 years
(Helmers & Hall, 1994; Wilson-Holden et al, 1999; Gavaret et al, 2011)

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REVIEW ARTICLE

Intraoperative neurophysiologic monitoring in spine surgery. Developments and state of the art in France in 2011

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Message to take home

Intra operative neuromonitoring in EOS patients

The motor pathways are difficult to selectively assess in young childs.

SSEP alone may have false negative

Question remains to use SSEP alone or associated with

MEP with facilitation procedures
or
NMEP associated with D waves