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Original article

Intraoperative spinal cord monitoring: Lesional level diagnosis

M. Gavaret[a,b,*], S. Pesenti[b,c], M.S. Diop-Sene[a,b], E. Choufani[b,c], G. Bollini[b,c], J.-L. Jouve[b,c]

[a] AP–HM, service de neurophysiologie clinique, hôpital Timone, 264, rue Saint-Pierre, 13005 Marseille, France
[b] Aix-Marseille université, faculté de médecine, 13005 Marseille, France
[c] AP–HM, service d'orthopédie pédiatrique, hôpital Timone-Enfants, 264, rue Saint-Pierre, 13005 Marseille, France

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ABSTRACT

Background: In spinal deformity surgery, iatrogenic spinal cord injury is the most feared complication. Intraoperative monitoring (IOM) of the spinal cord assesses its functional integrity and allows significant reduction of the rate of spinal cord injury.
Hypothesis: In case of severe IOM alert, lesional level diagnosis constitutes supplementary and useful information.
Material and methods: This study was retrospective and monocentric. In our institution, 1062 pediatric spinal deformity surgeries have been monitored since 2004. We review the records of the six patients who presented a severe and prolonged IOM alert with lesional level determination. Somatosensory evoked potentials (SSEP), neurogenic mixed evoked potentials (NMEP) and D-waves were performed. In cases of IOM alert, sequentially moving an epidural electrode along the spinal cord allows lesional level determination, using this electrode either for stimulation or recording.
Results: Six patients, aged 12 to 17 years, characterized by severe IOM alerts during spinal deformity surgery are reported. Postoperative neurological examination was normal for five out of six cases. For patient 2, lesional level diagnosis allowed to determine a bi-laminar claw between T2 and T3 as the etiology of IOM alert. This IOM alert was delayed in time, being detectable only 30 minutes after the placement of this claw. Postoperative neurological examination was normal. For patient 6, a Stagnara wake-up test demonstrated paraplegia. Lesional level was established. Following corrective surgical maneuvers, postoperative neurologic deficit was limited to a pyramidal syndrome in one lower limb. Postoperative MRI demonstrated a spinal cord lesion at the determined lesional level.
Conclusion: During an IOM alert, lesional level determination allows localization of spinal cord dysfunction. This data, obtainable whatever the IOM device, constitutes supplementary information in order to rapidly identify the etiology of IOM alert and thus to react in the most appropriate way.
Level of evidence: IV, retrospective study.

1. Introduction

In spinal deformity surgery, the most feared complication is spinal cord injury. Spinal cord deficits constitute devastating complications for the spinal surgery patient and are to be avoided by all means [1]. A review of 1301 consecutive surgical cases was conducted using the prospective pediatric scoliosis study database [2]. The neural complication rate was 0.69% [2]. Factors associated with higher risks of neural complications include osteotomy, kyphosis correction, combined approach surgery, congenital scoliosis, curve magnitude (Cobb angle over 90°), revision procedures, distraction, sublaminar wire instrumentation and decreased spinal cord perfusion due to hypotension and/or significant hemorrhage [2–4].

Intraoperative monitoring (IOM) of the spinal cord assesses its functionality and allows reduction of the incidence of neurological complications resulting from spinal surgery [5]. Several techniques exist and are used in combination: somatosensory evoked potentials (SSEP), motor evoked potentials (MEP), D-waves and neurogenic mixed evoked potentials (NMEP) [6,7]. Early IOM alert detection allows the surgical team to perform rapid intervention in order to prevent injury progression or possibly to reverse (or minimize) impending neurologic deficit. Our study reports six

Abbreviations: IOM, intra-operative monitoring; MEP, motor evoked potentials; NMEP, neurogenic mixed evoked potentials; R, recordings; SSEP, somatosensory evoked potentials.

* Corresponding author at: AP–HM, service de neurophysiologie clinique, hôpital de la Timone, 264, rue Saint-Pierre, 13005 Marseille, France. Tel.: +33 4 91 38 49 90; fax: +33 4 91 38 58 26.
E-mail address: martine.gavaret@parisdescartes.fr (M. Gavaret).

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cases of severe IOM alerts during which the use of an epidural electrode allowed lesional level diagnosis. Lesional level did not always correspond to the apex of the deformity. IOM alert could occur with a delayed time-course with regards to the surgical injury. Diagnosis of the etiology is in this case rendered difficult, even with continuous evaluation of spinal cord functions. The purpose of this study was thus to highlight, through six severe IOM alerts (out of 1062 IOM), that lesional level determination constitutes supplementary information in order to react in the most appropriate way and thus to reverse (or minimize) impending neurologic sequelae.

2. Material and methods

In our institution, 1062 pediatric spinal deformity surgeries have been monitored since 2004 (age range: 4 months to 25 years, mean age: 12.6 years). We review the records of the six patients who presented a severe IOM alert with lesional level diagnosis (5 females, 1 male; age range: 12 to 17 years; four index surgeries, two revision procedures). Aetiologies for these six patients were: one congenital, one neurofibromatosis type I, one neuromuscular spinal deformity and three idiopathic scoliosis. IOM was explained to patients and their parents at the preoperative visit. Consent for monitored surgery was obtained from each patient, the parents or the legal guardian. Somatosensory evoked potentials (SSEP), neurogenic mixed evoked potentials (NMEP) and D-waves were performed. Characteristics, investigated pathways, advantages and limits of each IOM technique are synthesized in Table 1 [7–10].

2.1. Somatosensory evoked potentials (SSEP)

SSEP assess the integrity of spinal cord dorsal columns [8]. Tibial nerves SSEP were recorded before incision, allowing obtaining baseline latency and amplitude values of P39 cortical responses. SSEP were then recorded continuously throughout surgery. SSEP were elicited through percutaneous stimulation of the tibial nerves. SSEP were recorded over the popliteal fossae and over the scalp at Cz'/Fz (international 10–20 system), using subdermal needle electrodes. Stimulus parameters consisted of constant current stimulation (0.2 millisecond duration, 20 mA intensity and 3.3 Hz stimulation rate) [3].

2.2. Neurogenic mixed evoked potentials (NMEP)

NMEP are composed of both sensory and motor components [3,11,12]. The epidural electrode is guided into the epidural space, at the proximal end of the surgical site. In this study, Ad-Tech epidural electrode was used (Ad-Tech Medical Instrument Corp., Racine, WI, USA). This electrode is flexible, smooth, characterized by two platinum contacts with an inter-contact distance of 15 mm. For the insertion of the epidural electrode, the ligamentum flavum is incised (or already removed according to the type of instrumentation). Approximately two centimeters of the epidural electrode are cautiously guided in the epidural space. The epidural electrode is positioned above the T9 bony level in order to avoid stimulating lumbo-sacral nerve roots. Connectors are plugged to the IOM device. In order to record NMEP, a constant current is delivered between the two contacts of this electrode, in an ascending manner, to obtain consistent, reproducible NMEP responses (0.2 millisecond duration, intensity between 20 and 50 mA and 3.3 Hz stimulation rate). NMEP responses are recorded bilaterally using subdermal needle electrodes over the popliteal fossae.

2.3. D-waves

D (direct)-waves allow specific monitoring of motor pathways between the motor cortex and the epidural electrode location (Ad-Tech Medical Instrument Corp., Racine, WI, USA). Stimulation is delivered between C3 and C4 (international 10–20 system) (intensity, 80–100 mA; duration of stimulus, 0.5–1 millisecond and 0.8 Hz stimulation rate) [7]. D-wave monitoring is not used below the T10 bony level because of the small number of corticospinal tract fibers that remain below [13].

2.4. Anaesthesia

A total intravenous anaesthesia technique was used for all patients consisting of propofol and remifentanyl. Inhalation anaesthetic agents (sevoflurane, nitrous oxide) were rarely used during a few minutes for the initial induction. Boluses of neuromuscular blockade were administered. Arterial blood pressure, core temperature, diuresis, electrocardiogram and level of O_2 saturation were continuously monitored.

2.5. IOM alert and lesional level determination

An IOM alert was defined as a reduction in amplitude of at least 50% for SSEP and NMEP compared with baseline. When data met these warning criteria, all technical and anaesthetic variables were quickly checked before informing the surgeon. A severe alert was defined in this study by a complete loss of signals.

Moving the epidural electrode along the spinal cord, lesional level can be determined either with NMEP or D-waves.

Using D-waves, motor cortex is stimulated and recording is along the spinal cord (using the epidural electrode). At first, the epidural electrode has to be positioned at the T1–T2 bony level in order to assess D-wave characteristics. D-waves are then checked level by level, moving the epidural electrode caudally until their absence, thus defining the lesional level.

NMEP consist of spinal cord stimulations (using the epidural electrode) and popliteal sciatic nerves recordings. At first, the epidural electrode is positioned at the T8 bony level, in order to assess NMEP characteristics. NMEP are then checked level by level, moving the epidural electrode cranially until their absence, thus defining the lesional level.

IOM was performed using the device Keypoint 4-channel workstation (Alpine Biomed, Natus, CA, USA).

3. Results

In our hospital, since 2004, six out of 1062 patients presented a severe IOM alert with intraoperative neurophysiologic determination of the lesional level.

3.1. Patient 1

ES was a 17-year-old girl with congenital kyphoscoliosis (sagittal Cobb angle: 105°, proximal level: T2; distal level: T10). Preoperative spine MRI did not demonstrate any neural abnormality. Posterior Ponte osteotomies at the apex of the kyphoscoliosis and posterior instrumentation T1-L3 were conducted after preoperative halo-gravity traction during two weeks. IOM alert occurred during the kyphosis correction, characterized by an amplitude diminution and then a complete loss of SSEP. Lesional level was determined between T2 and T6 using D-waves (Fig. 1). Release of the correction between T2 and T6 was then performed. SSEP recovered after 30 minutes while D-waves recovered only after 50 minutes. A wake-up test was performed: movements of both legs were obtained. The surgical team thus decided to perform an instrumentation allowing stabilization, without correction of the kyphosis. Postoperative neurological examination was normal.

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