Surgical stimulation increases median nerve somatosensory evoked responses during isoflurane-nitrous oxide anaesthesia

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Summary

Median nerve somatosensory evoked responses (MnSSER) were recorded in 15 healthy adult patients, ASA I–II, before and during orthopaedic surgery. After induction of anaesthesia with fentanyl 0.1–0.15 mg, etomidate 0.3 mg kg\(^{-1}\) and vecuronium 0.1 mg kg\(^{-1}\), anaesthesia was maintained with 0.6 % isoflurane (end-tidal) and 66 % nitrous oxide in oxygen. MnSSER were recorded after establishment of steady-state anaesthesia at baseline, during preparation (n = 11) and continuously after the start of surgery. For the last measurement period, four patients were excluded from analysis because additional fentanyl was required. MnSSER were recorded at Erb’s point, at C6 (neck) and at the respective contralateral primary somatosensory projection area (C3 or C4). All MnSSER waveform components remained recordable and easily identifiable during anaesthesia. During intense surgical stimulation (e.g. periosteal stimulation) the peak-to-peak amplitude N20P25 increased significantly by more than 45 % (P < 0.05), whereas latencies of all components did not change over time. These data indicate that MnSSER may be reliably monitored in the intraoperative period during steady-state isoflurane–nitrous oxide anaesthesia. In addition, concurrent changes in haemodynamic variables during nociceptive stimulation support the hypothesis that reversal of isoflurane–nitrous oxide-induced suppression of MnSSER may indicate increased nociceptive input when depth of anaesthesia is inadequate. (Br. J. Anaesth. 1995; 75: 598–602)

Key words


Recording of spontaneous and evoked brain electrical activity has been advocated for intraoperative monitoring when neural tracts are at risk during orthopaedic, neurosurgical and cardiovascular surgery [1]. In addition, it has been pointed out recently that monitoring of somatosensory evoked responses may be useful for assessment of depth of anaesthesia [2]. The effects of anaesthetic agents and other drugs on somatosensory evoked potentials have been studied extensively [2–4]. However, few data are available on the effects of surgical procedures on median nerve somatosensory evoked responses (MnSSER). Sebel and colleagues [5] reported a decrease in latency and an increase in amplitude of the first negative peak of the early cortical MnSSER component induced by skin incision in anaesthetized patients. In contrast, no MnSSER changes were observed, during the stimulation induced by tracheal intubation. It is unclear if the type of surgery plays a role in the MnSSER response to nociceptive stimulation. In the present study, we investigated 15 patients during steady-state isoflurane–nitrous oxide anaesthesia before and during surgery to determine if the surgical procedure per se resulted in significant changes in latencies and amplitudes of MnSSER.

Patients and methods

After obtaining approval from the Institutional Ethics Committee and written informed consent, we studied 15 patients (aged 38 (range 18–54) yr, body weight 70 (SD 13) kg), ASA I–II, undergoing elective orthopaedic surgery (e.g. femoral osteosynthesis, lumbar disc operations. Patients were devoid of any neurological or psychiatric disorders and had not taken any centrally acting drugs for at least 3 months before surgery.

Premedication comprised midazolam 7.5 mg orally, 30–60 min before the study. Anaesthesia was induced with fentanyl 0.1–0.15 mg and etomidate 0.3 mg kg\(^{-1}\). Tracheal intubation was facilitated by vecuronium 0.1 mg kg\(^{-1}\). Anaesthesia was maintained with 0.6 % isoflurane (end-tidal) and 66 % nitrous oxide in oxygen. Mechanical ventilation was set to maintain end-expiratory carbon dioxide tensions (\(P_{\text{ET CO}_2}\)) at 4.2–4.5 kPa. Rectal temperature was kept constant within the physiological range using heating blankets. The arm used for eliciting MnSSER was also covered by blankets. The following variables were recorded after an equilibration period of 30 min (baseline), during positioning and preparation before the start of surgery and following skin incision: MnSSER, heart rate (HR), mean arterial pressure (MAP) \(P_{\text{ET CO}_2}\), \(P_{\text{ET CO}_2}\) arterial haemoglobin oxygen saturation (\(\text{S}_\text{O}_2\)) and rectal body temperature.

MnSSER were recorded using an Evomatic 400 system (Dantec, Copenhagen, Denmark). MnSSER waveforms were recorded simultaneously on three amplifier channels using sterile platinum needle...
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EvoPC, Müller, Hamburg, Germany). The following latencies were evaluated: N12 at Erb; N13 and P17 at C6; N20, P25 and N35 at the scalp. Furthermore, the peak-to-peak amplitudes N13P17, N20P25 and P25N35, and the central conduction time (CCT) (difference in latencies: N20 − N13) were calculated. For statistical analysis all variables were evaluated at the following times: baseline (BL), during positioning and preparation before surgery (prep), 5 min after skin incision (surg1), during maximal surgical stimulation, for example periosteal irritation (surg2) and after maximal stimulation (surg3). Data are given as mean (sd). Data were analysed by the Friedman test. Post-hoc comparisons were made by the Mann–Whitney U test corrected for multiple comparisons. The null hypothesis of no changes in evaluated variables was rejected at \( P < 0.05 \).

Results

During positioning and preparation, MnSSER recording was possible in only 11 patients because of complicated positioning procedures. In four patients, recordings at surg3 were excluded from statistical analysis, because fentanyl was given when HR and MAP increased by more than 30 % from baseline after surgical stimulation. In general, surg3 recordings were made between 10 and 20 min after maximal surgical stimulation (for example during suturing of subcutaneous tissue).

Representative MnSSER recordings of one patient are shown in figure 1. At baseline, the amplitudes of N20P25 and P25N35 were 1.7 (0.8) \( \mu \text{V} \) and 1.5 (0.6) \( \mu \text{V} \), respectively (fig. 2). The increase in N20P25 during positioning (prep) and skin incision (surg1) was not significant. Very intense surgical stimulation at the periosteum resulted in a significant increase in N20P25 or about 45 % to 2.5 (0.9) \( \mu \text{V} \), which returned to baseline values 10–20 min later (surg3). Whereas N20P25 increased in all patients, P25N35 increased in only 12 of 15 patients. Table 1 summarizes MnSSER latencies. Latencies, including CCT and the amplitude N13P17, did not change over time.
Whereas MAP was already increased significantly after skin incision, heart rate increased significantly during strong stimulation (n = 15), Surg2 = without manipulation during surgery (10–20 min after Surg2, n = 11).

Discussion

In agreement with previous reports, the present study has demonstrated that MnSSER can be recorded reliably during inhalation anaesthesia [6]. In addition, these data indicate that increases in early cortical MnSSER may be related to surgical stimulation during steady state anaesthesia with 0.6% isoflurane and 66% nitrous oxide. Latencies and amplitudes of all subcortical components did not change over time. During weak sensory stimulation, such as positioning and preparation procedures, and skin incision there was a trend for an increase in MnSSER amplitudes of cortical components which was not significant. Intense noxious stimulation (periosteal irritation) resulted in significant increases in peak-to-peak amplitudes of the early cortical responses N20P25, and P25N35.

These data indicate that increases in cortical amplitudes are most likely caused by intraoperative nociceptive stimulation because MnSSER were recorded during steady-state anaesthesia and with the exception of haemodynamic variables all other variables did not change with time. It is unlikely that the moderate increases in HR and MAP resulted in changes in MnSSER because of significant changes in cerebral blood flow as MAP was not increased above the upper limit of cerebral autoregulation, [7, 8]. However, it cannot be excluded that other sensory stimulation (i.e. touch, warm or cold sensation) may also affect MnSSER amplitudes. Although not significant, N20P25 and P25N35 were increased slightly during positioning. This may indicate that MnSSER do not only assess nociceptive signal transmission but also the summed effects of anaesthesia and global somatosensory input.

The effects of sensory stimulation on evoked responses in anaesthetized patients have been studied previously. Sebel and colleagues [5] reported on a decrease in latency and an increase in the amplitude of the early cortical MnSSER component N20 with skin incision, whereas tracheal intubation did not affect MnSSER. The difference in latencies in our study may be caused partly by the different anaesthetic techniques used. In the study of Sebel and colleagues [5], MnSSER recordings at baseline and after tracheal intubation were performed after administration of a “sleep dose” of thiopentone, whereas fentanyl (1.5 μg kg⁻¹) was given before incision. At this time the thiopentone concentration in blood and brain may have already decreased substantially so that the anaesthetic level was not controlled during MnSSER recordings [9]. The effects of thiopentone on MnSSER have been studied previously. Koth and colleagues observed no significant effects on N20 amplitudes induced by thiopentone (5 mg kg⁻¹ bolus followed by an infusion of 2 mg kg⁻¹ h⁻¹) [10]. However, latencies and the CCT were significantly increased. In this study, additional administration of fentanyl (10 μg kg⁻¹) did have an additional depressant effect on cortical amplitudes. According to this, the decrease in latency reported by Sebel and colleagues may rather reflect a decrease in thiopentone brain and plasma concentrations rather than an effect of surgical stimulation. However, if the increases in MnSSER amplitudes were related to noxious stimulation the additional administration of fentanyl may have counteracted the enhancing effects of surgical stimulation on MnSSER amplitudes.

Further evidence for the usefulness of MnSSER monitoring for assessment of inadequate depth of anaesthesia during surgery has been given by Freye,
Hartung and Schenk [11]. A significant reduction in the amplitude of the late cortical MnSSER response N100 was observed using an anaesthetic technique with propofol (2-mg kg\(^{-1}\) bolus, 100 µg kg\(^{-1}\) min\(^{-1}\) infusion) and 66 % nitrous oxide in oxygen. During surgery (tract of the mesentery) the amplitude was increased again towards baseline values. From these findings it may be concluded that the offset of the anaesthetic-induced depressant effects on MnSSER are most likely related to noxious stimulation when analgesia is inadequate for the surgical stimulus.

The mechanisms for an increase in early cortical MnSSER amplitudes after noxious stimulation are unclear. In awake patients amplitudes of evoked responses of all modalities change in relation to stimulus intensity. The MnSSER component N20 has its origin in the thalamocortical radiation and in the primary sensory cortex reflecting the synchronized postsynaptic activity of pyramid cells in area 3 (for review see [12]), P25 and N35 are probably generated in area 1, which receives input from thin axons of the thalamus. These MnSSER components mostly probably reflect corticocortical activity in the sensory cortex. Increases in amplitudes of N20P25 in combination with reduction of N35P45 and increases in latencies have been reported after bolus injection of etomidate 0.3 mg kg\(^{-1}\) [13]. Several studies have reported increases in MnSSER amplitudes when enflurane (> 2.0 %) was used in combination with 50–66 % nitrous oxide [14, 15]. These increases have been interpreted as enflurane-induced cortical excitatory or disinhibitory effects.

In patients with unilateral disc protrusions causing sciatica, increases in amplitudes of the N150P220 component were observed after sural nerve stimulation, when on the affected side intense neurological pain was induced by Lasègue manoeuvre [16]. The Lasègue manoeuvre performed on the non-affected side, being totally painless, resulted in a decrease in amplitude of N150P220. These data indicate that increases in evoked cortical responses may be related to increases in pain sensation.

In contrast, in gynaecological patients studied 48 h after surgery, an increased pain threshold to electrical stimulation in the corresponding dermatome to the surgical wound was found [17]. The amplitudes of P1 (at 23 ms), N1 (at 31 ms) and P2 (46 ms) decreased while subjective pain ratings increased [17]. However, the intensity of surgical pain at the time when recordings were performed was not assessed. A difference between acute pain induced by the surgical stimulus and subacute pain 48 h after operation may contribute to the different findings. In addition, no data exist on the combined effects of tonic (surgical pain) and phasic (electrical stimulation) pain.

Electrical stimulation of a large mixed nerve is the most widely used method for MnSSER recordings in the operating room. In clinical studies, it has been emphasized that subjective sensation after electrical stimulation is unnatural and non-specific, thus reducing their potential usefulness. Stimulation of a large mixed nerve is known to activate not only cutaneous afferents, but joint, deep tissue and muscle afferent and antidromically motor efferent neurones (for review see [18]). Differences in conduction velocities and response properties, various excitatory and inhibitory interactions among different classes of fibres contribute to difficulties in interpreting their role in nociception. From pain research it is known that amplitudes of late cerebral components (more than 100 ms) of evoked responses caused by specific noxious stimuli are correlated with subjective pain sensation and can be depressed by several drugs, but early and middle cortical components have not been studied in detail [19].

The decrease in temperature (from 36.5 (0.5) to 36.1 (0.5) °C) is unlikely to have affected our results. Lam and colleagues observed no statistically significant changes in human MnSSER with mild hypothermia [20]. But a decrease in nasopharyngeal temperature of more than 1.2 °C resulted in a significant increase in latencies and a decrease in amplitudes of N10 and N13, whereas the prolongation of latency of 0.4 ms and a decrease of amplitudes of 23 % of N20 were not statistically significant. From these findings it can be concluded that a temperature effect would even counteract the MnSSER changes observed in the present study. In addition, MnSSER returned to baseline values after surgical stimulation had stopped in the presence of decreased body temperature.

This study provides more information for the usefulness of MnSSER monitoring during anaesthesia. The increases in early cortical MnSSER components most probably originate at the supraspinal level, because spinal potentials and CCT did not change. These data indicate that MnSSER amplitude changes may be related to inadequate depth of anaesthesia when strong surgical stimuli are applied. From this it may be concluded that MnSSER at least assess modulation of nociceptive input. However, the neural mechanisms underlying the changes in MnSSER amplitudes after noxious stimulation are poorly understood. Further studies are required to elucidate if our data may be explained by physiological mechanisms which have been demonstrated in awake patients and how they are modulated by anaesthetics [2].

References
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