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Relationship between clamping of the unilateral internal carotid artery and transient slowing of electrical activity in the bilateral hemisphere

KAZUO IRITA, TADASHI KANDABASHI, TAKAKO MATSUKADO, CHIE SAKIHARA, MASAMUNE TOMINAGA, and SHOSUKE TAKAHASHI

Department of Anesthesiology and Critical Care Medicine, Faculty of Medicine, Kyushu University, 3-1-1 Maidashi, Higashi-ku, Fukuoka, 812-82 Japan

Introduction

Ligation of the internal carotid artery (ICA) is performed for the radical resection of neck tumors as well as for the treatment of giant cerebral aneurysm and carotid-cavernous fistula. Manual compression or a balloon occlusion of the cervical carotid artery is done preoperatively to predict neurological deterioration after ligation of the ICA. Intraoperative neurological monitoring is also important for the prevention, detection, and intervention of iatrogenic brain ischemia. Monitoring of the adequacy of cerebral blood flow after ligation of the ICA, however, is difficult in patients under general anesthesia. Computer-processed electroencephalography (EEG) has enabled anesthesiologists to identify changes in brain activity in the operating theater [1]. Monitoring of jugular venous oxygen saturation (Sjo_2) has been suggested as a useful way to estimate the relationship between oxygen supply and oxygen uptake in the brain [2].

We present a patient who underwent left superficial temporal artery-middle cerebral artery anastomosis followed by a ligation of the ipsilateral ICA under general anesthesia. Just after occlusion of the left ICA, transient low-amplitude delta activity occurred in the bilateral hemisphere. The associated changes in the continuously monitored Sjo_2 are also presented.

Case report

A 47-year-old woman (155 cm, 47 kg) developed diplopia and was diagnosed as having a large aneurysm of the left ICA in the cavernous portion. She had no history of hypertension, and her preoperative mean blood pressure was 73-105 mmHg. The Matas balloon test showed that a 20-min occlusion of the left ICA did not induce any changes in her EEG readings nor any neurological abnormality.

Anesthesia was induced with droperidol 5 mg, fentanyl 0.3 mg, and sevoflurane (up to 2.5%). Tracheal intubation was facilitated by vecuronium 6 mg. Anesthesia was maintained with droperidol (total 5 mg), fentanyl (total 0.6 mg), nitrous oxide (50%), and supplemental isoflurane (0.3%–1.0%). EEG recording electrodes were placed on the C3, C4, and Fz, according to the international 10–20 system. The compressed spectral arrays of the EEG were monitored using an OEE-7102 electroencephalograph (Nihon Kohden, Tokyo, Japan). A 4F fiberoptic catheter (Opticath, Oximetrix, Mountain View, CA, USA) was introduced in the surgical field via a branch of the left internal jugular vein in the cephalad direction. Sjo_2 was monitored continuously using an Oximetrix-3 (Abbot, North Chicago, IL, USA).

Before the clamping of the left ICA, left superficial temporal artery-middle cerebral artery anastomosis was done. Neither the EEG readings nor Sjo_2 changed during this procedure. The left ICA was then clamped. The patient's mean blood pressure was maintained at around 70 mmHg before clamping of the left ICA. The isoflurane concentration was decreased from 1.0% to 0.7% 7 min before the clamping of the left ICA, and her mean blood pressure was increased gradually to 93 mmHg. Her heart rate increased from 68 to 72 bpm after clamping of the left ICA, and then decreased gradually to 60 bpm. $Paco_2$ was maintained between 35 and 40 mmHg. Her rectal temperature remained at 36.3°–36.5°C. The baseline 6 Hz theta activity diminished in amplitude immediately, and was replaced by lower amplitude delta activity (Fig. 1). This change occurred in the right hemisphere as well as in the left hemisphere. Although the Oximetrix-3 indicated that Sjo_2 decreased from 65% to 47%, Sjo_2 measured by

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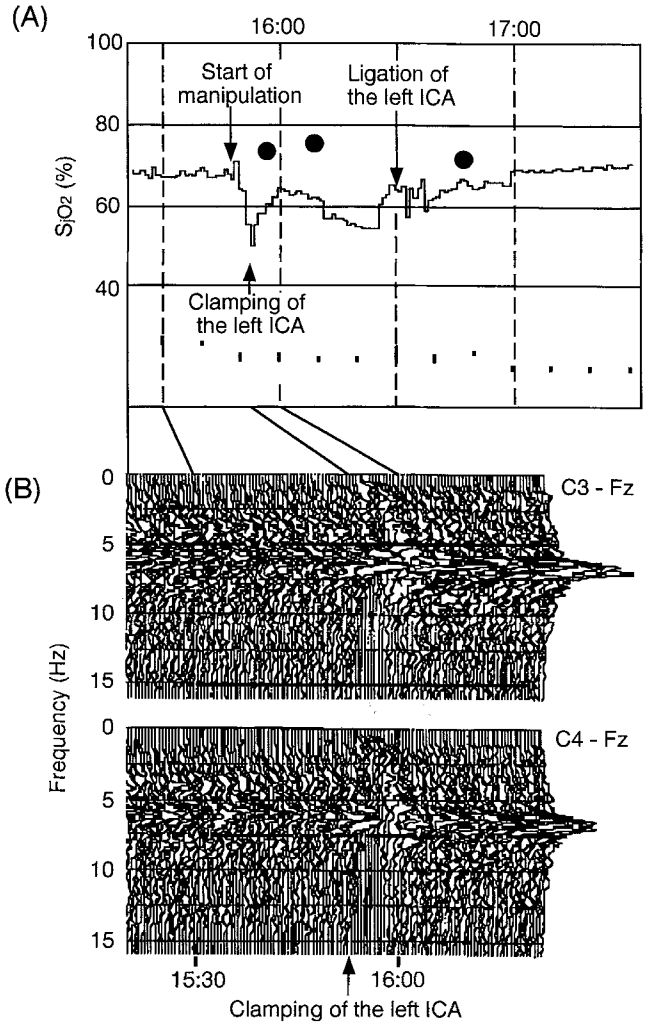

Fig. 1. **A** Continuous Sjo_2 monitoring of a 47-year-old woman with a giant aneurysm in the cavernous portion of the left ICA. Note that Sjo_2 started to change prior to the clamping of the left ICA. The dots indicate Sjo_2 determined by blood gas analysis. **B** Compressed spectral arrays from the EEG of the same patient. Data are Fourier-processed in 30-sec epochs to produce power spectra of 0.25 Hz resolution from 0 to 16 Hz

blood gas analysis (1312 BGM, Instrumentation Laboratory, Lexington, MA, USA) showed 73.8% 5 min after clamping of the left ICA. Furthermore, the decrease in Sjo_2 recorded by the Oximetrix-3 was found to have started before clamping of the left ICA. The EEG readings improved spontaneously within 10 min. We judged that blood flow to the left hemisphere was maintained, and the left ICA was permanently ligated 38 min after the application of the clamp. Six months after the operation, no neurological dysfunction was observed.

Discussion

Manual compression or balloon occlusion of the cervical carotid artery is done preoperatively to confirm the patency of Willis' ring and to assess the possibility of neurological deterioration after ligation of the ICA. These procedures, however, cannot assess the probability of postoperative cerebral infarction in some patients, because the tests do not cause complete cessation of blood flow. In our patient, we monitored EEG and Sjo_2 to evaluate the adequacy of cerebral blood flow after clamping the ICA. Although the slowing of brain activity after carotid occlusion has been reported to be followed by neurological deterioration [3], the maintenance of Sjo_2 made us think that blood flow to the left hemisphere was maintained even after clamping of the left ICA. This was confirmed by the spontaneous recovery of EEG readings within 10 min and by the absence of neurological deficit after the operation. During the ICA ligation procedure, EEG monitoring is essential, and Sjo_2 monitoring is helpful to confirm the adequacy of the oxygen supply/demand relationship in the ipsilateral hemisphere.

A slowing of electrical activity after clamping the unilateral ICA occurred in the ipsilateral hemisphere as well as in the contralateral hemisphere. Morioka et al. also reported some patients who developed bilateral slowing during the Matas balloon test, which was always accompanied by some neurological abnormalities [3]. It seems possible that these EEG changes are caused by changes in the distribution of blood flow in the contralateral hemisphere induced by occlusion of the contralateral ICA. For example, when the blood supply from the contralateral ICA is not sufficient for perfusion of the bilateral hemisphere, a deficit in the blood supply and a slowing of brain activity in the contralateral hemisphere can develop. The pathophysiological significance of the bilateral slowing should be further elucidated. Determining whether slowing is temporary or progressive might be important for predicting the probability of a neurological deficit occurring [3].

Sjo_2 represents the overall balance between oxygen demand and supply in the hemisphere. Fiberoptic devices, which make it possible to measure Sjo_2 continuously, have been introduced for the management of unconscious patients [4] and of cardiopulmonary bypass [5]. However, continuous Sjo_2 monitoring is associated with more frequent artifacts than continuous monitoring of mixed venous hemoglobin saturation. These artifacts seem to be caused mainly by attachment of the catheter tip to the wall of blood vessels, which occurs more easily when the catheter is introduced in the surgical field: surgeons may manipulate the catheter unintentionally in a small surgical field. This implies that changes, especially abrupt ones, in continuously monitored Sjo_2 should be confirmed by blood gas analysis. The observed decrease in continuously monitored Sjo_2 in our patient is indeed an artifact. When surgeons started to manipulate the left ICA again after left super-

ficial temporal artery-middle cerebral artery anastomosis, Sjo_2 decreased concomitantly and continued to fluctuate until the completion of ligation of the left ICA. An attachment of the catheter tip to the wall of blood vessels was also suggested by an increase in the jugular venous pressure from 11–12 mmHg to 16 mmHg. Therefore, monitoring jugular venous pressure and its wave form would help to rule out artifacts detected by continuously monitored Sjo_2.

We present a patient who underwent ligation of the ipsilateral internal carotid artery (ICA) under general anesthesia. Just after clamping the left ICA, computer-processed EEG showed transient low-amplitude delta activity occurring in the bilateral hemisphere. The transient activity coincided with a drop in Sjo_2 in the left jugular vein, which was being monitored by a fiberoptic catheter. However, Sjo_2 determined by blood gas analysis did not show any change. This suggests that the observed drop in continuously monitored Sjo_2 was an artifact caused by manipulation of the catheter. The patient was discharged uneventfully. Because temporary occlusion of the unilateral ICA has been reported to cause bilateral slowing of electrical activity and neurological deficits, intraoperative monitoring of the patient's brain activity is essential. Although continuous Sjo_2 monitoring is also helpful to estimate the adequacy of blood flow in the ipsilateral hemisphere, its changes should be interpreted carefully.

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