COMBINATION OF HIGH-RESOLUTION ULTRASOUND-GUIDED PERIVASCULAR REGIONAL ANESTHESIA OF THE INTERNAL CAROTID ARTERY AND INTERMEDIATE CERVICAL PLEXUS BLOCK FOR CAROTID SURGERY

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INTRODUCTION

Although it has been 50 years since the first carotid endarterectomy was performed, there is still no consensus on the optimal anesthetic protocol for this procedure (Tangkanakul et al. 2000). In Germany, 20% of carotid endarterectomies are performed under regional anesthesia (Bundesgeschäftsstelle für Qualitätssicherung 2007). The major advantage of regional anesthesia is simple and quick neurological monitoring, which results in high sensitivity and high specificity for neurological events. The most common regional anesthetic techniques are superficial and deep cervical blocks and inter-scalene cervical plexus blocks (Moore 1975; Winnie et al. 1975). These traditional peripheral nerve blocks rely on external landmarks and are performed with or without electrical nerve stimulation for the identification of target nerves (Mehta and Juneja 1992). Because of the complex innervation of the lateral neck region, especially in the region of the carotid bifurcation and the internal carotid artery, all previously documented regional anesthesia procedures during carotid artery surgery have required local or systemic supplementation of the regional

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anesthesia (Davies et al. 1997). However, intra-operative supplementation has several possible shortcomings. Cerebral convulsions have been reported in cases of intra-operative supplementation of regional anesthesia with local anesthesia, and systemic administration of opiates or analgesics can make it impossible to properly monitor neurological symptoms. Another disadvantage is the severity of puncture-related complications, such as brain stem anesthesia, accidental intra-vascular local anesthetic application and laryngeal or phrenic nerve palsy (Passannante 1996; Stoneham and Bree 1999; Stoneham and Wakefield 1998; Urmey and McDonald 1992). Therefore, in our institution, ultrasound-guided inter-scalene cervical block is preferred for carotid surgery. The major advantages of ultrasound-guided regional anesthesia are visualization of the target structure, observation of the spread of the local anesthetic and reduction of puncture-related complications. In a previous study, we showed improved block success by local anesthetic spread close to the internal carotid artery (Rössel et al. 2007). For this reason, we evaluated a combination of high-resolution ultrasound-guided perivascular regional anesthesia of the internal carotid artery and intermediate cervical plexus block for carotid endarterectomy. More precisely, this type of cervical plexus block avoids the deep local spread of the anesthetic that occurs with superficial cervical plexus block (Pandit et al. 2003; Telford and Stoneham 2004). The aim was to evaluate a method to achieve complete anesthesia of the entire surgical site including the "neurovascular sheath." We assumed that a combination of ultrasound-guided perivascular regional anesthesia of the internal carotid artery and intermediate cervical plexus block might accomplish this goal.

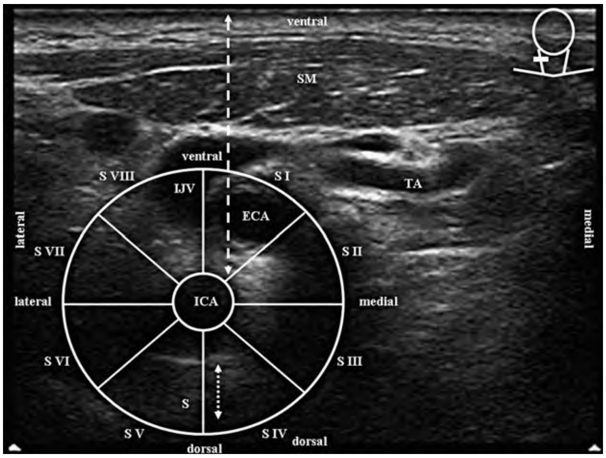

Fig. 1. In this position, we examined the relationship of the external carotid artery (ECA) and the internal jugular vein (IJV) to the internal carotid artery (ICA). Furthermore, the distances between the skin and the ICA (—) and between the ICA and the spine (···) were marked. Locations of the sternocleidomastoid muscle (SM), compressed IJV, ECA, ICA, thyroid artery (TA) and spine (S) are marked. SI–SVIII = sections I–VIII.

METHODS

After institutional review board approval by the ethics committee of the Medical Faculty Carl Gustav Carus, Dresden (No. 97052006) and written informed consent, we recruited 34 subjects for carotid endarterectomy who received combined perivascular regional anesthesia of the internal carotid artery and intermediate cervical plexus block. Exclusion criteria included a history of anaphylactic reaction to local anesthetics and presumed limitations to the patients' compliance for regional anesthesia. The evening before surgery, patients received 25 mg of clorazepate (Tranxilium, Aventis GmbH, Bernburg, Germany) orally. No oral pre-medication was administered on the day of surgery. In the operating room, peripheral venous access was attained and an arterial line for continuous monitoring of arterial blood pressure was inserted. A five-lead electrocardiogram including ST-segmental analysis and pulse oximetry (Philips IntelliVue MP50, Philips Medicine Systems GmbH, Hamburg, Germany) was obtained. Patients were placed in the supine position with their heads turned 30° to the opposite side. Before ultrasound examination, the anatomical landmarks of the cricoid cartilage, the clavicle, the sternocleidomastoid muscle, the mastoid process and the transverse process from C-2 to C-6, if possible, were identified and marked. All ultrasound exams and anesthetic blocks were performed by the same two anesthesiologists (T.R. and A.R.H.). Prior to the block, the anatomic conditions of the neck region were visualized using a 12.5-MHz linear ultrasound transducer (Philips HD 11, Philips Medicine Systems GmbH, Hamburg, Germany). The examination was started caudal and lateral to the larynx with the transducer in the transverse position. With this alignment, the typical shape of the transverse process of C-7, the common carotid artery and the internal jugular vein were visualized. After these structures were identified, the transducer was shifted cranially along the common carotid artery until the internal carotid artery could be identified. In this position, the distance between the skin and the internal carotid artery, as well as the distance between the internal carotid artery and the spine, was recorded. Furthermore, we noted the relationship of the external carotid artery and the internal jugular vein to the internal carotid artery (Fig. 1). The transducer was then moved in a slightly lateral direction until the nerves of the cervical plexus directly below the sternocleidomastoid muscle could be identified (Fig. 2). For the patients' comfort we administered 50–150 μg of fentanyl (Janssen-Cilag GmbH, Neuss, Germany) before puncture. After the skin was disinfected and sterile covers (CIV-Flex

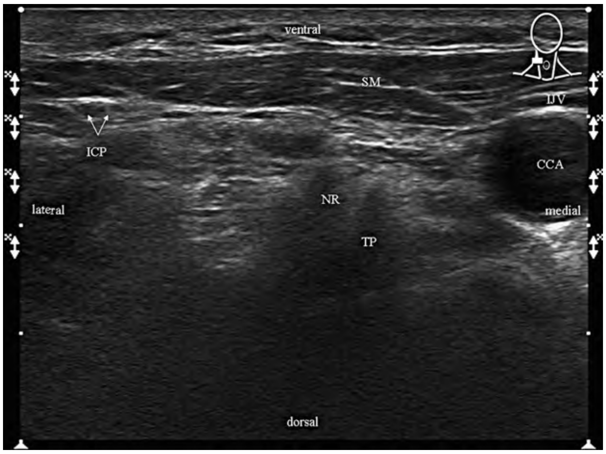

Fig. 2. Nerves of the intermediate cervical plexus directly below the sternocleidomastoid muscle and the nerve root of C-5 before regional anesthesia. Locations of the sternocleidomastoid muscle (SM), compressed internal jugular vein (IJV), common carotid artery (CCA), intermediate cervical plexus (ICP), nerve root (NR) and transverse process (TP) are marked.

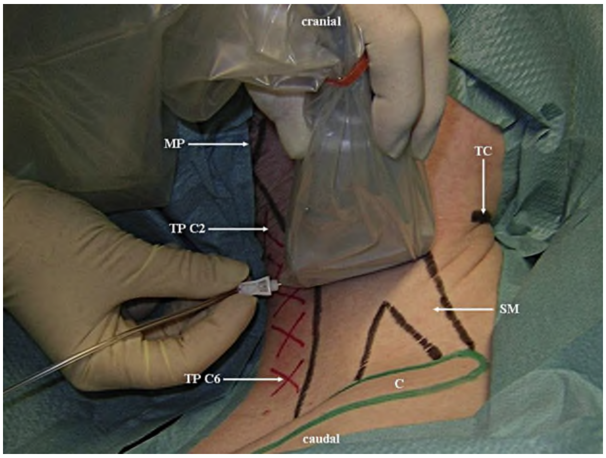

Fig. 3. Congruent positioning of the transducer and insertion needle during regional anesthesia. The anatomical landmarks of the thyroid cartilage (TC), clavicle (C), sternocleidomastoid muscle (SM), mastoid process (MP) and transverse process (TP) from C-2 to C-6 are marked.

Transducer Cover, CIVCO, Kalona, IA) applied to the transducer and puncture site, the transducer was positioned in the previously described manner to identify the internal carotid artery. We applied a skin pad with 2 mL of 1% prilocaine (Xylonest, AstraZeneca, Wedel, Germany) at the lateral edge of the transducer. Without electrical nerve stimulation, a 50-mm short bevel needle (Stimuplex A, Braun Melsungen AG, Melsungen, Germany) was inserted lateral to the transducer near the posterior border of the sternocleidomastoid muscle (Fig. 3). Under ultrasound visualization, the needle was advanced in line with the transducer dorsally to the internal carotid artery and was directed cranially above the bifurcation of the common carotid artery. After an aspiration test, 3–5 mL of 0.5% ropivacaine (Naropin, AstraZeneca, Wedel, Germany) was administered perivascularly (Fig. 4). In correct injection, the local anesthetic spreads in a half-moon figure within the carotid sheath around the vessels and is easily recognized in the ultrasound image.

For the intermediate cervical plexus block, the transducer was moved in a slightly more lateral position. Ultrasound guidance was used to redirect the needle beneath the sternocleidomastoid muscle, close to the cervical plexus nerves. For orientation, the transverse process of C-7 was identified as reported previously (Martinoli et al. 2002) and the transverse processes were counted backward to ensure correct injection. Ten to twenty milliliters of 0.5% ropivacaine was injected. During the injection, spread of the local anesthetic was visually assessed on the ultrasound image (Fig. 5). The desired spread around the carotid artery was ensured by corresponding needle adjustments under direct sonographic vision. The success of the blockade was confirmed with a pin-prick test along the neck (C2–4 segment). Loss of differentiation between sharp and blunt when pricked with a needle or its backside within the region of surgery (C-3, in parts also C-2 and C-4 dermatomes) was considered evidence of sufficient spread of the block. A moderate increase in blood pressure was also a sign of successful blockade. Time was recorded from the beginning of the first ultrasound exam to final removal of the needle used for local anesthesia.

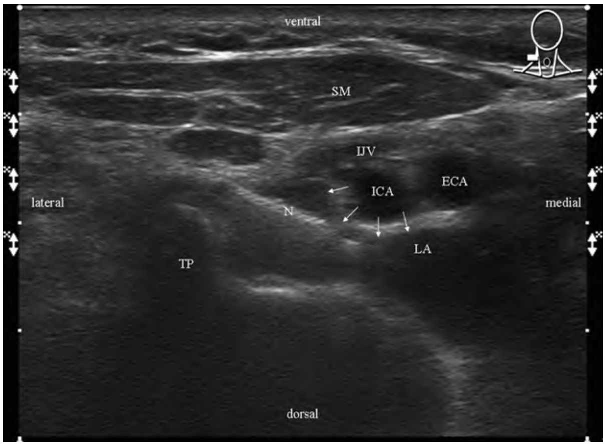

Fig. 4. During perivascular blockade, the insertion needle (N) is introduced under visualization congruent with the transducer toward the internal carotid artery (ICA) and external carotid artery (ECA), directly above the bifurcation. Furthermore, the sternocleidomastoid muscle (SM), transverse process (TP), compressed internal jugular vein (IJV) and half-moon-shaped configuration of local anesthetic (LA) spread are marked. We administered 3–5 mL of 0.5% ropivacaine (Naropin, AstraZeneca, Wedel, Germany).

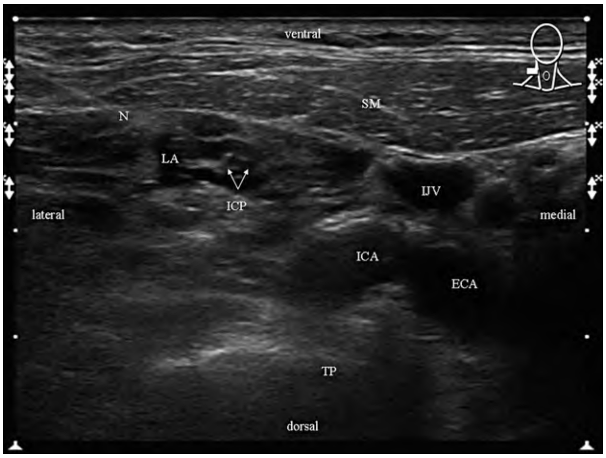

Fig. 5. To achieve intermediate cervical nerve block, the transducer was moved in a slightly lateral position. The insertion needle (N), sternocleidomastoid muscle (SM), internal jugular vein (IJV), internal carotid artery (ICA), external carotid artery (ECA) and local anesthetic (LA) spread are marked. We administered 10–20 mL of 0.5% ropivacaine (Naropin, AstraZeneca, Wedel, Germany).

Surgery was initiated when the surgical site had been sufficiently anesthetized and the patient did not report pain when the skin was pricked with a needle. Surgery was performed as reported before (Stötzel et al. 2012). Pain during surgery was evaluated according to the Numeric Analgesia Scale (NAS) from 0 = no pain to 10 = worst pain (Hjermstad et al. 2011). If patients complained of intra-operative pain NAS ≥ 3, additional 1% prilocaine was infiltrated locally by the surgeon. The amount of additional local anesthetic was recorded as was use of additional sedatives or opioids or conversion to general surgery.

Neurological function was continuously monitored by the anesthesiologist by controlling the level of consciousness and the response to verbal commands. During cross-clamping, the patient was challenged to squeeze a squeaking rubber toy with the contralateral hand every 10–15 s and to answer simple questions for close judgment of neurological function. A shunt was placed if any signs of neurological dysfunction occurred during cross-clamping. After surgery, patients were observed for 4 h under cardiovascular and neurological monitoring in the post-anesthesia care unit. All patients underwent follow-up visits on post-operative days 1 and 3. Complications (*e.g.,* wound infection, bleeding and neurological disorders such as facial paresis, hypoglossal paresis and stroke) were recorded using a standardized follow-up form and compared with pre-operative findings. All patients were seen by a neurologist on the third post-operative day. Demographic and clinical data (age, sex, body mass index, side of stenosis, nicotine abuse, history of previous stroke, asymptomatic or symptomatic stenosis. *etc.*) were prospectively recorded in a computerized database.

Table 1. Patients' pre-operative risk factors

Risk factor	Number of patients
Hypertension	34
Chronic obstructive pulmonary disease	9
Coronary artery disease	25
Diabetes mellitus	13

RESULTS

Over a period of 8 mo, carotid endarterectomy was performed in 34 consecutive patients (ratio of male/female: 24/10, median height: 169 $\pm$ 10 cm, median weight: 77 $\pm$ 12 kg, body mass index: 27 $\pm$ 3). Median age was 68 $\pm$ 4 y. Pre-operative risk factors and indications for surgery are outlined in Tables 1 and 2. Identification of the bifurcation and internal jugular vein using ultrasound was successful in all patients. The bifurcation was localized at the C-4 level in 28 patients. Three patients had a bifurcation at level C-3 and one had a bifurcation at C-5. In two cases, we localized the bifurcation between C-2 and C-3. The distance between the skin and the internal carotid artery was 1.6 $\pm$ 0.4 cm. Figure 6 shows the position of the external carotid artery and the internal jugular vein relative to the internal carotid artery. The time required to perform the block was 25 $\pm$ 8 min. Spread of the local anesthetic under the sternocleidomastoid muscle was observed in all cases. We observed the typical half-moon shape spread of the local anesthetic at the lateral and dorsal border of the internal carotid artery in 29 patients. Spread of anesthetic toward the transverse process was observed in two cases. In three patients, local anesthetic spread mainly in the lateral direction. Vascular puncture did not occur in any cases, and we observed no signs of local anesthetic intoxication. Three cases had a short period of hoarseness after puncture. In addition to the hoarseness, one patient showed Horner syndrome for 12 h. Five patients complained of pain during surgery that was assessed as NAS > 2. One patient showed a deep internal carotid artery location, with 2.5 cm between the skin and internal carotid artery. In two cases, the puncture was difficult because the internal jugular vein was located in section II and covered the internal carotid artery. We observed a high bifurcation

Table 2. Indications for carotid endarterectomy

Indications for surgery	Number of patients
No symptoms	22
Transient ischemic attack	10
Stroke	2

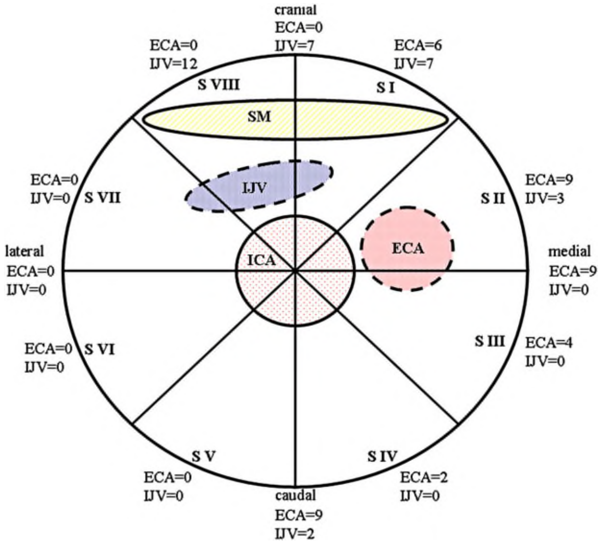

Fig. 6. Position of the external carotid artery (ECA) and internal jugular vein (IJV) in relationship to the internal carotid artery (ICA) in 34 patients. Percentages of patients are given in parentheses.

in two patients. These patients had otalgia during preparation of the internal carotid artery. In these five cases, the surgeon locally administered additional (2–6 mL) 1% prilocaine. No conversion to general anesthesia because of an incomplete block was necessary. The duration of surgery was 113 ± 22 min, and the cross-clamping time was 37 ± 10 min. Shunt placement was not necessary in any cases. No patient suffered intra- or post-operative neurological deficits. The average post-operative hospital stay was 5 days.

DISCUSSION

Regional versus general surgery

The optimal anesthetic procedure for carotid endarterectomy continues to be unclear and so remains controversial (Rössel et al. 2008). On the basis of the literature, regional anesthesia appears to offer benefits with respect to hemodynamic complications and sensitivity and specificity of patient neurological monitoring (Stötzel et al. 2012) . The possibility of bypassing post-operative intensive care and the tendency toward shorter hospital stays can be considered to be benefits of regional anesthesia (McCarthy et al. 2001).

Different methods for regional anesthesia

Winnie's inter-scalene cervical block technique and cervical epidural anesthesia are used in addition to classic cervical block techniques. Considering the effectiveness of blocks, no differences have been found between the various techniques used for regional anesthesia for carotid endarterectomy (Merle et al. 1999; Pandit et al. 2000). Despite the benefits of regional anesthesia in carotid artery surgery, possible complications continue to be highlighted. Possible complications of regional anesthesia in the neck region are vascular puncture followed by epileptic seizures, impairment of pulmonary function and injury or inadvertent block of the nerve structures including spinal anesthesia (Pandit et al. 2007; Passannante 1996; Stoneham and Bree 1999; Stoneham and Wakefield 1998; Urmey and McDonald 1992). Because of the close relationship between the needle and the nerve roots of the cervical plexus, deep cervical block is prone to the latter complications. In addition to the low depth of puncture, the major advantage of superficial block over intermediate blockade of the cervical plexus is the safe distance of the needle tip from vital structures. Despite the low incidence of true puncture complications, local anesthetic spread toward the deep plexus may cause difficulties (Pandit et al. 2003; Telford and Stoneham 2004). Dorsomedial spread may be followed by blockade of the stellate ganglion. In addition, because of the close anatomic relationship and complex neural inter-connections, there is a risk of transient cranial nerve (glossopharyngeal, hypoglossal or vagal) palsy. Thus, further research in this area is required to assess the safety of such procedures.

Ultrasound-guided application of regional anesthesia to avoid functional impairment of adjacent structures

One of the developments in management of such risks and improvement of block success was the introduction of ultrasound into regional anesthesia, enabling visualization of anatomic structures, needle advancement and distribution of local anesthetic solutions. Furthermore, reductions in local anesthetic dose and puncture-related complications were achieved (Rössel et al. 2007). However, the common problems previously documented for regional anesthesia techniques for carotid endarterectomy, particularly insufficient anesthesia in the neurovascular sheath region, are not solved by using ultrasound. The reason for this almost regular insufficient anesthesia is the complex innervation of the cervical "neurovascular sheath" covering the internal carotid artery target structure, thereby complicating complete regional anesthetic block. The tissues attached to the internal carotid artery are innervated not only by the cervical plexus, but also by branches of the vagus and glossopharyngeal nerves. However, direct block of these nerves has not been achieved with any of the previously documented block techniques for carotid artery surgery, and complete block was not desired. For instance, complete block of the glossopharyngeal nerve is associated with considerable discomfort for patients because they are then unable to detect or swallow sputum that accumulates in the pharynx. Alternative methods that can be used to achieve full analgesia include supplementation with local anesthetics and systemic administration of sedatives and opioids during preparation of the carotid artery. The protocols for intra-operative supplementation with local anesthetics, opioids and sedatives appear to vary considerably. In a prospective trial of 1000 patients, Davies et al. (1997) found the rate of supplementation with regional anesthetics to be 53%.

Disadvantages of intra-operative supplementation of regional blocks

The aforementioned method of intra-operative supplementation can cause serious problems. Convulsions have been reported when local anesthetics have been used intra-operatively, and systemic administration of opioids and benzodiazepines can render neurological monitoring difficult or impossible or, in the worst-case scenario, can even induce respiratory complications. The perivascular technique might result in analgesia without additional supplementation during preparation of the neurovascular sheath because it shuts off the sensory afferents of the glossopharyngeal and vagus nerves from the site of surgery. However, this technique is possible only with the use of ultrasound because close alignment between the needle and internal carotid artery is necessary for optimal blockade. Visualization and selective blockade of the nerves and the perivascular sheath have enabled a 50% reduction in the amount of local anesthetics required and avoidance of systemic opioids, in contrast to the technique described by Kefalianakis et al. (2005).

Ultrasound-guided regional anesthesia renders cervical blocks safer

In summary, the technique described in this study improves regional anesthesia for carotid endarterectomy. In contrast to the current literature, the advantage of our technique is that additional use of sedatives, opioids and intra-operative local anesthetic supplementation is not necessary, rendering the cervical regional anesthesia more effective and safer for the patient. However, further randomized controlled trials with larger patient populations are necessary to demonstrate that our method generally leads to improvement in patient comfort and safety and results in a higher rate of successful blocks. With respect to the complex anatomic environment and the potential severe side effects, the described technique requires substantial experience in sonoanatomy and ultrasound-guided regional anesthesia.

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