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Comparison of intermediate *vs* subcutaneous cervical plexus block for carotid endarterectomy

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Editor's key points

- Local anaesthetic techniques for carotid endarterectomy include local infiltration and superficial, intermediate, and deep cervical plexus block.
- Superficial and intermediate cervical plexus block may result in a similar distribution of local anaesthetic in the tissues if the investing fascia of the neck is not complete.
- No difference was demonstrated between intermediate and superficial cervical plexus block with regard to local anaesthetic supplementation, patient satisfaction, or surgeon satisfaction.
- This study supports use of superficial blocks for carotid endarterectomy.
- The results support the proposal that the investing fascia of the neck is incomplete and allows the spread of local anaesthetic to deep tissues.

Background. Carotid endarterectomy surgery can be performed under regional anaesthesia alone or under general anaesthesia. However, there are several types of regional block available and reported complication rates after superficial cervical plexus blocks are significantly lower than deep blocks. It is not known if subcutaneous and intermediate blocks are equally effective, although anatomical evidence suggests that the latter (where the injectate diffuses below the deep cervical fascia) might provide superior quality of intraoperative anaesthesia.

Methods. Forty-four patients were randomized to receive either subcutaneous or intermediate cervical plexus blocks for carotid endarterectomy. The primary endpoint was supplemental lidocaine requirement during surgery. Secondary outcome measures included: total amount of fentanyl administered during surgery, recall of pain scores during surgery, complications, and patient and surgeon satisfaction.

Results. There was no statistically significant difference for median (range) lidocaine supplementation between the subcutaneous and intermediate groups 65 (20–170) mg *vs* 85 (30–345) mg, respectively; $P=0.31$. There were no statistical differences in the secondary outcome measures and no major complications during the study.

Conclusions. Intermediate and subcutaneous cervical plexus blocks are equally effective for carotid endarterectomy. This study adds to the body of evidence supporting the safe use of superficial blocks for this type of surgery.

Keywords: anaesthesia, local; anaesthesia, nerve block; cervical plexus; endarterectomy carotid

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Carotid endarterectomy is a well-established surgical treatment for significant carotid stenosis[1] for which both general and regional anaesthetic techniques have been shown to be effective.[2] Although regional anaesthesia has been preferred in high-risk patients as it avoids the systemic complications of general anaesthetic techniques,[3] the recent international, multicentre GALA (General Anaesthesia *vs* Local Anaesthesia) trial[4] failed to demonstrate superiority of the regional technique. Among several possible reasons for this failure to meet expectations[5] was the possibility that the precise technique of regional anaesthesia used was not tightly controlled.[6] If regional techniques differ in their efficacy or safety, and if (as was the case) several types of regional methods were used in the trial, then the inclusion of some methods that offer poorer analgesia or yield more complications may have adversely influenced the 'local anaesthetic limb' of that GALA trial.[6] Previous studies have established that the superficial and deep blocks are equally effective[7 8] as are combined intermediate and deep blocks,[8] but superficial and intermediate blocks have a significantly lower incidence of complications than do deep blocks.[3]

Recent anatomical research is relevant. Pandit and colleagues[9] showed that injections placed below the investing fascia of the neck diffuse into the deep space, whereas injections placed s.c. did not. In other words, the subfascial or intermediate and deep blocks appeared anatomically (functionally) equivalent but different from subcutaneous block. Figure 1 clarifies the relevant structures. Nash and colleagues[10] demonstrated that the investing layer of fascia was either lacking or incomplete on histological examination of neck tissues. This seeming dichotomy of findings permits a specific testable hypothesis which we proposed in correspondence.[11] Namely, if Nash and colleagues are correct and the investing fascial layer is incomplete, then we would expect subcutaneous cervical plexus block to be as clinically effective as an intermediate block placed deep into the putative investing fascial layer (i.e. s.c. injection may penetrate

deeper *in vivo* than it does in cadavers). If, on the other hand, the earlier study of Pandit and colleagues is correct and the investing fascia is complete, then we would expect it to act as a barrier to subcutaneous spread and therefore, an s.c. injection would be clinically less effective than an intermediate (putative subfascial) injection.

Telford and Stoneham[12] declared that 'a randomized controlled trial comparing superficial and intermediate cervical plexus blocks as the sole method for providing local anaesthesia for carotid endarterectomy is essential.' Our current study was designed to address this question.

Methods

This study was approved by the Institutional Review Board (IRB) of the University of Michigan. After written informed consent, 46 patients undergoing elective carotid endarterectomy were randomized by means of computer-generated random numbers into two groups: subcutaneous and intermediate injections (Fig. 2). Exclusion criteria were patients with known bleeding diathesis, history of allergy to local anaesthetics, local sepsis, or known diaphragmatic motion abnormalities.

After peripheral venous access, standard monitoring included invasive blood pressure (via 20G catheter in radial artery of the arm ipsilateral to the operation), five-lead electrocardiography, and pulse oximetry. The cervical plexus blocks were performed by one of four anaesthetists experienced in the technique. Anaesthetists were not blinded to the block they were performing; however, surgeons and postanaesthetic care unit (PACU) staff were blinded. During the block and monitoring line insertion, anxiolysis was achieved with midazolam in incremental doses of 1 mg i.v. For both blocks, patients were positioned supine with gentle head-up tilt. The head was turned to the opposite side and the skin was cleaned with chlorhexidine. A small intradermal wheal was raised with 1% lidocaine at the posterior border of the sternocleidomastoid at the mid-level of the neck and a blunt end 22 gauge 50 mm Stimuquik© needle (Arrow International, Reading, PA, USA) was used for the blocks. This needle was chosen because of its blunt end and ability to inject with minimal movement of needle tip, but no electrical stimulation was used. For the subcutaneous block, the needle was inserted alongside the posterior border of the sternocleidomastoid no deeper than 5 mm and injection was performed along the entire length of muscle border along this plane, caudally and rostrally, after confirming absence of blood during aspiration. With the volumes of local anaesthetic used, a large 'skin weal' was evident that spread along the length of the sternocleidomastoid muscle and encompassed both its posterior and anterior borders. For the intermediate block, the needle was inserted in a perpendicular plane at the midpoint of the posterior border of the sternocleidomastoid muscle until a 'loss of resistance' or 'pop' was felt as the needle passed the investing layer of the cervical fascia (at ~1–2 cm depth). Injection in this plane was performed with a fixed needle position using a technique similar to that of Pandit and colleagues' cadaver study, where the needle was placed immediately below the dissected fascial plane under direct vision. We planned a fixed dose of 1.4 mg kg^{-1} bupivacaine (i.e. ~25 ml of 0.375% bupivacaine) for both blocks. As the endpoints for

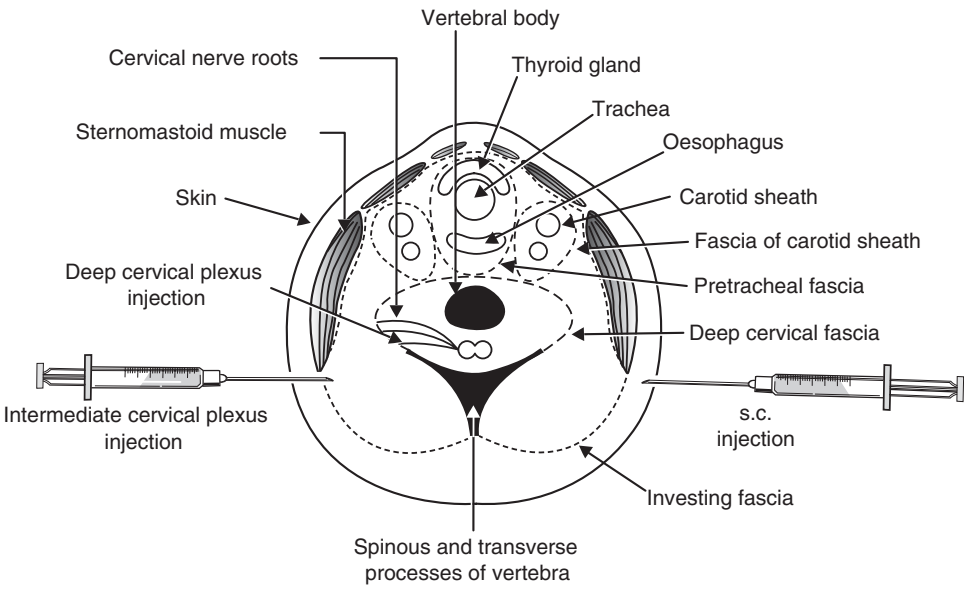

Fig 1 Diagrammatic cross section of the neck at C4 level showing the site of injection of the cervical plexus blocks: deep, intermediate, and subcutaneous. Note the investing layer of cervical fascia that putatively acts as a barrier to deep spread of s.c. injection. It is this anatomical layer whose existence is questioned by the studies of Nash and colleagues.

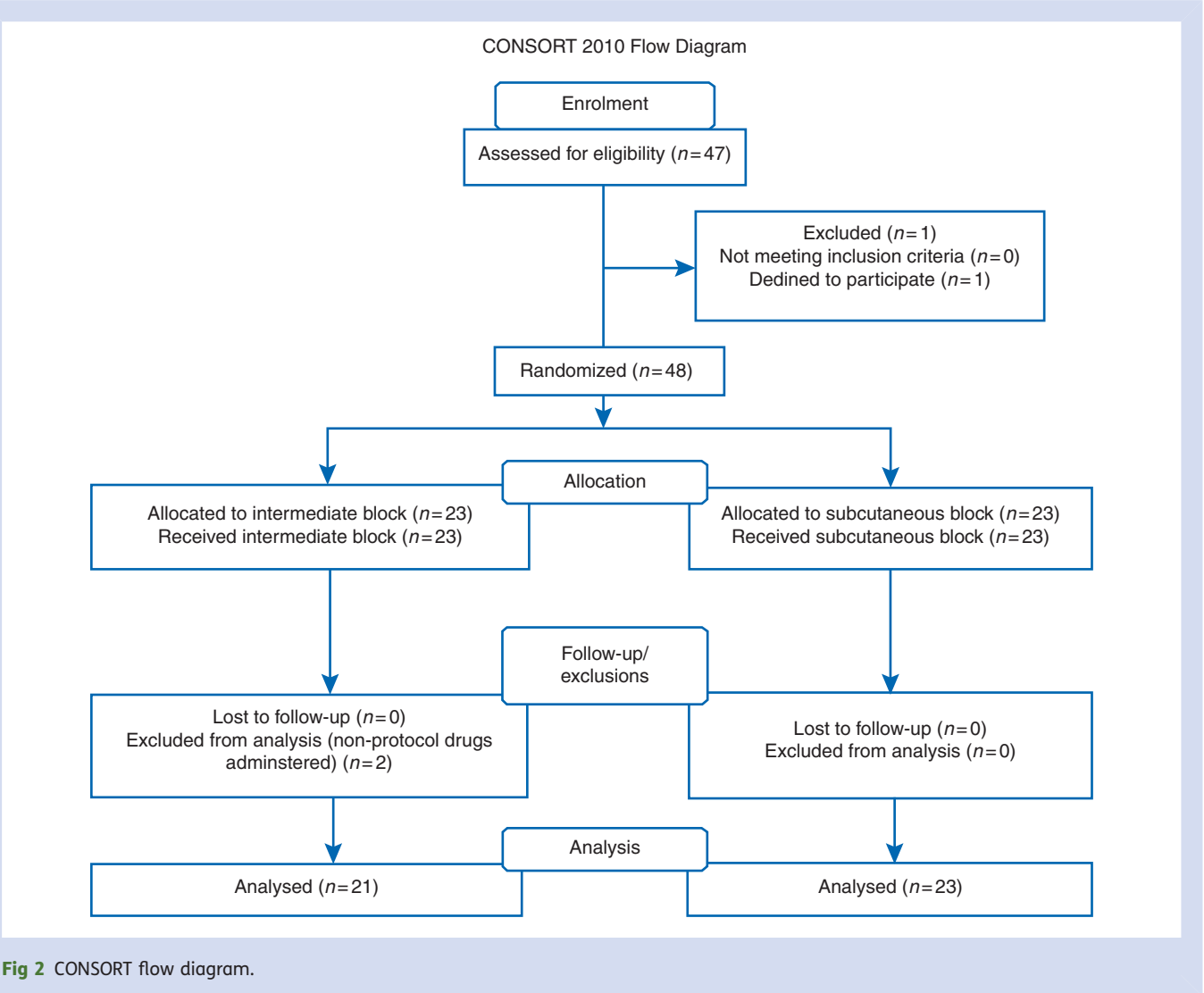

Fig 2 CONSORT flow diagram.

correct placement of the needle were judged clinically in both the blocks, 'fanning' of the injectate was avoided to reduce the chance of inadvertently injecting the local anaesthetic below or above the investing fascia.

Surgery was performed by two surgeons who used the same surgical technique. Briefly, a linear incision along the anterior border of the sternocleidomastoid muscles was always used. This may extend as low as the suprasternal notch and as high as the retroaural region, depending on the level of the bifurcation (although in this study there were no unusually high or low bifurcations of the carotid artery). The skin and subcutaneous tissues were divided to the level of the platysma, which was also divided. Self-retaining retractors were then placed, and the underlying fat dissected to identify the anterior edge of the sternocleidomastoid muscle. Retractors were left superficial at all times on the medial side to prevent retraction injury to the laryngeal nerves but, laterally, were occasionally more deeply placed. Dissection proceeded in the mid-portion of the wound down the sternocleidomastoid muscle until the jugular vein was identified and then, along the medial jugular border. The underlying carotid artery was identified after the jugular was retracted. The carotid complex was completely exposed, and posterior dissection was more extensive in the region of the internal carotid artery.

Before the first incision, the block was formally assessed in the operating theatre using pin-prick response to ensure lack of sensation to the first incision. Additional 1% lidocaine was administered by the surgeons during surgery in 1–2 ml boluses as needed in response to patient discomfort. An episode of discomfort was defined as pain or discomfort to surgical manipulation that disappeared with treatment. For each episode of discomfort, local anaesthetic was used first and if pain was not controlled well, additional doses of fentanyl 25 μg was administered as needed. No additional sedative was administered to patients in the operating theatre. On arrival to the PACU, the patients were asked (by staff blinded to the type of block used) to recall how much pain they experienced during surgery. A 11-point verbal pain scale was administered by a research assistant blinded to

the type of block used (0, no pain; 10, worst pain imaginable).[13] Immediately after surgery, the surgeons were questioned by the same blinded staff as to their satisfaction with the operating conditions (i.e. 'very satisfied', 'satisfied', 'average', 'poor', and 'very poor').[14 15] Postoperative analgesia was administered at the discretion of the PACU or ward nurses who were blinded to the type of block. We planned to record any perioperative complication under the following three categories.[3]

(a) block-related serious complications, defined as any potential threat to life arising directly from block placement, e.g. intravascular or intrathecal injection of local anaesthetic, local anaesthetic toxicity, local trauma, or haematoma caused by the injecting needle of a severity that led to the cancellation of surgery, airway obstruction, or respiratory distress after placement of block but before surgery (e.g. owing to diaphragmatic or vocal cord paralysis);
(b) conversion to general anaesthesia after placement of the block for any reason (including any block-related serious complication as defined above) or owing to failure of adequate analgesia, lack of patient co-operation after insertion of the block or extreme patient anxiety;
(c) serious systemic complications such as death owing to any cause during surgery or in the immediate postoperative period; cardiovascular complications (e.g. myocardial infarction, angina, circulatory collapse); central nervous system complications (cerebrovascular accident/stroke, transient ischaemic attack, unconsciousness owing to any or unspecified cause); airway or respiratory complications during or after surgery (i.e. excluding those related to placement of the block itself); significant wound haematoma during or after surgery.

The primary outcome measure of this study was the amount of supplemental lidocaine used by the surgeon during the procedure for adequate analgesia. Secondary measures included total amount of fentanyl administered during surgery, recall of pain scores during surgery, complications, and patient and surgeon satisfaction.

Previous work has suggested a mean (SD) supplemental lidocaine requirement of ~100 (50) mg.[8] Study size estimation was based on the minimum clinically important difference between the blocks being 40 mg of supplemental lidocaine. To achieve a power of 0.8, a minimum of 20 patients were required in each group. We planned to recruit 23 patients in each group to allow for any drop-outs.

PASW version 18 (SPSS Inc., Chicago, IL, USA) was used for all analyses. Groups were compared using the Mann–Whitney *U* test for continuous non-parametric data and Pearson's chi-square test for categorical data. A *P*-value of <0.05 was considered statistically significant. Data are presented as medians (range [inter-quartile range]) for continuous data and number (percentage) for categorical data.

Results

Of the 46 patients randomized to the study, two patients randomized to intermediate group were excluded from analysis because of protocol violations as drugs not recommended (propofol, morphine) were inadvertently administered before surgical incision by anaesthesia providers who were not aware of the study protocol (Fig. 2). The remaining 44 patients who were recruited for the study underwent successful carotid endarterectomy with no conversions to general anaesthesia. There were no differences in patient characteristics between the two groups (Table 1) and the amount of bupivacaine used was similar.

There was no difference between lidocaine supplementation requirements in the intermediate and subcutaneous groups (Table 2; $P=0.31$), with median supplementation requirements of 6.5–8.5 ml of 1% lidocaine. The additional fentanyl requirements were not significantly different between the groups (Table 2; $P=0.80$).

The secondary measures—pain scores, patient, and surgeon satisfaction scores were equally distributed across both groups (Table 3). None of the patients required placement of an intraoperative shunt, and there were no postoperative complications. All patients recovered well.

Discussion

The main finding of this study is that intermediate and subcutaneous cervical plexus blocks are equally effective for carotid endarterectomy. In the context of our initial hypothesis, this seems a surprising result because the intermediate injection is known to penetrate to the deep cervical space and therefore block nerves at their roots, which presumably results in denser, more reliable analgesia. Subcutaneous infiltration on the other hand, would need to block each nerve branch of the superficial cervical plexus to achieve the same effect and this seems less likely as discussed below. This result is more consistent with the suggestion of Nash and colleagues that a complete impermeable investing fascia does not exist and therefore a subcutaneous injectate may easily penetrate deeper into tissues, than it is with the proposal of Pandit and co-workers that the investing fascial layer acts as a barrier to the spread of subcutaneous injectate.

Table 1 Characteristics of patients. Age and BMI data are presented as median [range]

Variable	Subcutaneous ($n=23$)	Intermediate ($n=21$)
Age	69.0 [62–77]	73.0 [68–78]
Male gender, *n* (%)	17 (73.9%)	13 (71.4%)
BMI (kg m^{-2})	26.0 [23.8–28.3]	28.2 [22.7–30.1]

Applied anatomy of superficial cervical plexus nerves

Although the superficial branches of the cervical plexus are located deep into the superficial fascia in the vicinity of the mid-point of the posterior border of sternocleidomastoid, they pierce the fascia to emerge superficially elsewhere.[16] Figure 3 displays the relevant nerves in the neck. The *cutaneous cervical nerves* turn around the middle of the posterior border of sternocleidomastoid and passes beneath the external jugular vein to the anterior border of the muscle, where they perforate the deep cervical fascia and supply the antero-lateral parts of the neck through the *ascending and descending branches*. The *supraclavicular nerves* emerge beneath the posterior border of the sternocleidomastoid and descend in the posterior triangle of the neck beneath the platysma and deep cervical fascia. Near the clavicle, they perforate the fascia and the platysma to supply the skin over the lower sternocleidomastoid and clavicle, pectoralis major, deltoid, and upper and posterior shoulder. There may also be innervation from the contralateral side, face, chest, and deep innervation from cranial nerves, which have all been suggested reasons for the need for local anaesthetic supplementation during surgery, even if the ipsilateral cervical plexus is well-blocked.

Table 2 Characteristics of block and rescue analgesia. All data are presented as median (range)

Variable	Subcutaneous ($n=23$)	Intermediate ($n=21$)
Bupivacaine 0.375% volume used (ml)	25.0 [17–28]	25.0 [20–25]
Preoperative midazolam (mg)	1.0 [0–4.0]	1.0 [0–3.0]
Lidocaine 1% supplementation (ml)	65 [20–170]	85 [30–345]
Supplemental fentanyl (μg)	25.0 [0–300]	25.0 [0–250]
Supplemental midazolam (mg)	1.0 [0–6]	1.0 [0–6]

Table 3 Secondary measures of block quality. Patient and surgeon satisfaction score was measured on a 5-point scale (1, very satisfied; 2, satisfied; 3, average; 4, poor; and 5, very poor). All data are presented as median (range). None of these comparisons reached statistical significance

Quality measure	Subcutaneous ($n=23$)	Intermediate ($n=21$)
Pain score	2.0 [2–4]	2.0 [1–4]
Patient satisfaction score	2.0 [1–4]	1.0 [1–2]
Surgeon satisfaction score	1.0 [1–2]	2.0 [1–3]

There are several options for regional anaesthesia in carotid endarterectomy. The surgeon may infiltrate local anaesthetic during dissection or the anaesthetic may be administered preoperatively as a block. A proposed nomenclature for these blocks is as follows.[12] A subcutaneous block consists of local anaesthetic infiltration just under the skin.[17] Next is what is termed an 'intermediate' or 'subfascial' block, which is a somewhat deeper injection with the intention to pierce the investing fascia of the neck.[9] The deep cervical plexus block is the deepest injection, designed to deposit local anaesthetic beneath the deep cervical fascia (i.e. close to the lateral processes of the cervical vertebrae), and it can be performed either as a single[18] or a multiple injection technique.[19]

Limitations and strengths of the study

While we successfully blinded the surgeons and scorers to the block, we did not blind the anaesthetist. This might have been possible (in part) if one anaesthetist had placed the block but another had conducted the remainder of the anaesthesia. However, staffing levels precluded this.

There may be minor details of some of our block techniques that differ from anaesthetic practice elsewhere. For example, our s.c. injection was made at the posterior border of sternocleidomastoid but some practitioners may place the injection at the anterior border. It was of course intended that the depth of injection differed between the two techniques, but the extent of injection was also different: the subcutaneous injectate was injected along the length of the sternocleidomastoid, while the intermediate injectate was placed essentially at a single point and may have influenced the efficacy of each block.

The efficacy of both subcutaneous and intermediate blocks is specific to the surgical technique used. While this was 'standard',[20] variations in the incision site, or retraction methods are described for which efficacy of these blocks is not confirmed.[21] Our study did not examine the actual spread of local anaesthetic and so we need to consider some possible alternative explanations for our results. First, it is possible that the number of superficial cervical plexus branches blocked by s.c. injection is, very simply, sufficient to conduct the operation. Any other block which is more sophisticated by comparison is, in a sense, unnecessary because a good result is obtained by simple infiltration anaesthesia. An analogy would be that a brachial plexus block probably provides no better analgesia for finger pain than local infiltration. However, counter to this argument is the fact that surgeons often desire a degree of muscle relaxation for a carotid endarterectomy and (albeit difficult to measure objectively) their subjective satisfaction scores were equal for the two techniques (Table 3). Also, the operation involved dissection of deep tissues and it is surprising that a s.c. injection provides a suitable analgesia for these surgical planes without deep penetration.

The second possibility is that, because both techniques (subcutaneous and intermediate) are essentially 'blind',

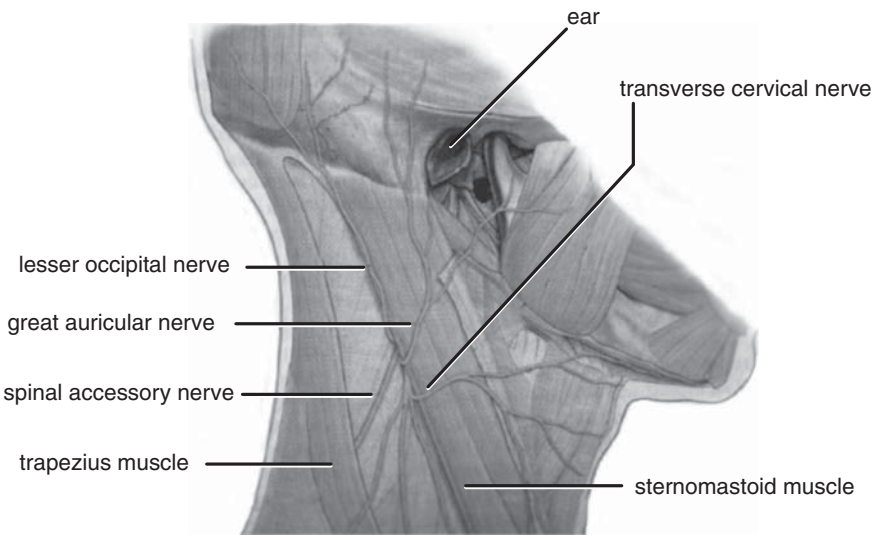

Fig 3 Outline of the superficial branches of the relevant cervical nerves; with the skin, subcutaneous tissues, and investing fascia 'removed'. Note that although they wind around the posterior border of sternocleidomastoid (i.e. where we made the s.c. injection), they only pierce the fascial layers and become more superficial at their terminal branches. Adapted from Khan and colleagues.[16]

then it is possible that some s.c. injections were actually made deeper than intended (and therefore actually sited intermediate) or vice versa (i.e. some intended intermediate injections were in fact subcutaneous). We feel this unlikely as all practitioners were very experienced (several having published and taught on regional techniques for endarterectomy) but nonetheless, using ultrasound-guided nerve blockade may have eliminated this confounding factor as injectate may then have been placed more reliably within the intended anatomical plane or space. Additionally, ultrasound-guided methods for the placement of these blocks are in their infancy and appear suitable for placing the block below the deep fascia.[22] It is interesting to note that the 'loss of resistance' or 'pop' was felt by all providers during the intermediate block placement, but not during s.c. injection. If Nash's hypothesis is correct, then this 'pop' could be the passage of the needle through the aponeurosis of sternocleidomastoid muscle. Although not (according to Nash's results) indicative of placement below an investing fascia, this does place the injection at least at the correct anatomical depth.

Previous studies have described techniques that involved routine administration of lidocaine immediately before surgical incision to supplement the block. In our current study, we restricted lidocaine supplementation only to those episodes of discomfort and this therefore served as a more robust measure of block efficacy. A further strength of our study was that that the doses of midazolam and fentanyl used were modest and unlikely to influence the results.

Implications for research and clinical practice

Our work has several implications for both future research and clinical practice. Pandit and colleagues' result in cadavers indicated that s.c. injection does not penetrate deeper tissues owing to the barrier imposed by the investing fascia. Yet, our result that s.c. injection is clinically effective supports Nash's finding of an incomplete investing fascial layer. Nash and colleagues used sophisticated methods, including ultrastructural histology and although their results appear persuasive, it would be important to assess the spread of s.c. injectate directly *in vivo* to confirm an absence of any barrier. Winnie and colleagues used radiological monitoring to assess the spread of the deep cervical block (which they found confined to the deep cervical space)[18] and their approach could be repeated or modified (e.g. using computed tomography or magnetic resonance imaging) to assess the spread of an s.c. injection. Finally, the results have a logical implication for the deep block. Although we did not examine this block in this study, the fact that either subcutaneous or intermediate blocks when used alone are suitable techniques for carotid endarterectomy implies few remaining indications for the deep injection, especially as the former methods appear safer.

In conclusion, this study demonstrates that intermediate and subcutaneous cervical plexus blocks are equally effective for carotid endarterectomy. This study adds to the body of evidence supporting the safe use of superficial blocks for this type of surgery.

Conflict of interest

None declared.

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