A North American Survey of Intravenous Regional Anesthesia

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One thousand questionnaires concerning the techniques and complications of intravenous regional anesthesia (IVRA) were sent to 900 American and 100 Canadian anesthesiologists. Of the 321 respondents, 86% perform IVRA regularly. A wide variation in device-related and clinical aspects was found, ranging from acceptable to falling outside published guidelines. Anesthesiologists perform a median of four upper-limb IVRA procedures per month, most often using 50 mL of lidocaine 0.5% at tourniquet pressures of 250 mm Hg or 100 mm Hg greater than the systolic blood pressure. Forearm, thigh, and calf IVRA are occasionally used. Complications, reported infrequently in the literature, were reported by respondents, including mistaken deflation of the cuff; dysphoria, dizziness, or facial tingling; seizures; cardiac arrests; and deaths. Although there was no correlation between complications and deviation from traditional practice, we recommend that IVRA be performed following recognized protocols by anesthesiologists who are familiar with the technique and trained to treat its potential complications. We recommend a protocol for IVRA. **Implications:** Intravenous regional anesthesia is a widely used anesthetic technique. A survey of 321 American and Canadian anesthesiologists indicates a wide variation in technique. Despite no correlation between complications and technique, the authors recommend that recognized protocols be used for this technique.

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Intravenous regional anesthesia (IVRA) is an effective method of providing anesthesia for extremity surgery, with published success rates ranging from 94% to 98% (1,2). IVRA is easy to perform, and the only necessary technical skill is inserting an intravenous (IV) cannula. Although there may be serious complications of local anesthetic toxicity associated with the technique, there are few reports of problems in the literature, especially since the use of bupivicaine for IVRA has declined (1).

Discussion with colleagues revealed a wide variation in techniques and complications despite published protocols for the administration of IVRA (1,2). The ASA Closed Claims Project Database relating to IVRA from 1977 to 1987 included claims for apnea, grand mal seizure, chronic vegetative state, cardiac arrest, and death (F. W. Cheney, MD, Director, ASA Closed Claims Project, personal communication, 1994). These unreported problems contradict the reputation of IVRA as a safe and foolproof method of anesthesia.

A survey of the techniques and complications was designed to evaluate the current practice of IVRA in North America.

Methods

One thousand questionnaires concerning techniques and complications of IVRA were sent to 900 alphabetically randomized members of the American Society of Anesthesiologists and 100 geographically randomized members of the Canadian Anaesthetists' Society.

Information for the study was obtained from a questionnaire containing 40 questions, which took less than 10 min to complete. Selected subjects received a cover letter, self-addressed stamped envelope, and questionnaire designed to be completed anonymously. Subjects were requested to return the questionnaire within 3 wk, and all information was collected within 6 wk. Responders who did not perform IVRA regularly stated the reason but did not complete the questionnaire; they were not included in the database.

Results

Of the 1000 questionnaires sent out, 321 were completed and returned (32%). Respondents were 29–78 yr of age (median 42 yr) and had been practicing 1–45 yr (median 11), mainly at private practice hospitals (60%) and university-based hospitals (35%). Of the 321 questionnaires returned, 276 were from anesthesiologists (86%) who perform IVRA regularly. Of those who do not use IVRA, 34% said it was not appropriate for their practice, 27% were no longer in practice, 23% preferred central or peripheral blocks, 7% felt that it was unsafe, 7% said surgeons preferred other techniques, and 2% were inadequately trained to perform IVRA.

Device-Related Aspects

A majority of anesthesiologists (97%) exsanguinate the upper limb before IVRA using an Esmarch bandage. Most anesthesiologists (95%) perform the exsanguination themselves or have their nurse anesthetist or their resident do so.

The tourniquet pressures most often used for upper-extremity IVRA are 250 mm Hg (40%) and 100 mm Hg greater than the systolic blood pressure (32%).

Most respondents (75%) never measure limb occlusion pressure (LOP), the minimal pressure required to occlude blood flow past the tourniquet cuff. Of those who measure LOP, 89% use a finger on the pulse, whereas 11% use either pulse oximetry or Doppler. Most respondents (90%) believe that cuff design could affect LOP.

Most anesthesiologists (91%) use a dual bladder cuff or two single bladder cuffs for upper-limb IVRA. Reasons offered for the use of two bladders included decreased cuff pain (99%), improved safety (30%), and decreased risk of accidental cuff deflation (21%). Dual bladder cuffs were believed to be unreliable by 9% of responders. Only 52% of responders recognized that dual bladder cuffs require higher pressures for occlusion than single bladder cuffs. Approximately half of the responding anesthesiologists inflate the distal cuff first after exsanguinating the limb, whereas half inflate the proximal cuff first.

Most respondents (80%) do not perform IVRA using forearm cuffs. Reasons given were: no experience (56%), cuffs unavailable (10%), preference for arm cuffs (8%), encroachment on surgical field (7%), unsafe (6%), unsuitable cases/no need (6%), and exsanguination difficult because of collaterals between the ulna and radius (5%).

Most responding anesthesiologists (83%) do not perform IVRA using thigh cuffs. Reasons given were: no experience (46%); unsafe/large doses of local anesthetic (22%); preference for spinal, epidural, or nerve blocks (11%); unsuitable cases/no need (10%); and cuffs unavailable (7%).

Most respondents (80%) do not perform IVRA using calf/ankle cuffs. Calf/ankle cuffs are rarely used for the following reasons: no experience (59%); preference for spinal, epidural, or nerve block (15%); unsuitable cases/no need (10%); and cuffs unavailable (5%).

Although 52% of the responding anesthesiologists regularly use an electronic tourniquet controller system, 29% use a mechanical or gas-powered system. A manual tourniquet or blood pressure manometer is used by 2% of responders.

Clinical Aspects

Lidocaine is the most often used local anesthetic for IVRA (98.5%), although 1.2% of respondents use bupivicaine and 0.4% add tetracaine to lidocaine. The median concentration of lidocaine used is 0.5% (range 0.33%–1.5%). Lidocaine concentrations greater than 0.5% are used by 14% of responding anesthesiologists. The median (range) of volumes of local anesthetic is as follows: forearm tourniquet 30 mL (20–50 mL), arm tourniquet 50 mL (20–62 mL), ankle tourniquet 45 mL (20–90 mL), and thigh tourniquet 60 mL (30–100 mL).

Other drugs are added to the local anesthetic for IVRA by 11% of the respondents. Reasons for adding other drugs are as follows: nondepolarizing muscle relaxants improve muscle relaxation; fentanyl and sufentanil improve block; bicarbonate decreases pain on injection, gives more rapid onset of block, and improves block; ketorolac improves block and postdeflation analgesia; bretylium and guanethidine improve reflex sympathetic dystrophy; and heparin decreases clot formation.

Adjunctive parenteral drugs are given by 98%, most often benzodiazepines (92%) and narcotics (84%).

The local anesthetic is injected over 60–90 s by 44% of the responding anesthesiologists. Almost half (47%) of the respondents inject the local anesthetic over 30 s or less, and 6% believe that the injection time is not clinically relevant. Most respondents (94%) wait a minimum of 20 min after injection of local anesthetic before deflating the cuff. The cuff is reinflated by 57% of the responding anesthesiologists, most often after 10 s (range 0–90), and repeated a median of three times (range 0–13). The most prevalent reason (94%) given for cuff reinflation was to decrease the systemic concentration of local anesthetic and to decrease the risk of toxicity.

The maximal time allowed for IVRA procedures ranged from 20 to 180 min (median 60 min). Reasons given for a maximal time of inflation included: cuff pain increases over time (83%), damage to tissue increases over time (61%), and anesthesia decreases over time (23%).

The responding anesthesiologists provide a median of four anesthetics per month (range 0–90) using upper-limb IVRA. Carpal tunnel release and ganglion

Table 1. Respondents Who Have Experienced Difficulties/Complications with IVRA at Some Time During Their Career

	Personal experience	Institutional experience
Incomplete anesthesia	258 (92.7)	253 (97.3)
Incomplete exsanguination	243 (93.1)	245 (95.8)
Severe pain on injection of local anesthetic	90 (36.3)	128 (52.7)
Severe cuff pain	232 (84.1)	236 (92.9)
Dysphoria, dizziness, and/or facial tingling	165 (66)	197 (80.1)
Mistaken deflation or cuff	89 (35.5)	152 (62.2)
Seizures	34 (13.5)	80 (35.4)
Cardiac arrest	3 (1.2)	15 (6.1)
Neurological damage	4 (1.6)	14 (5.7)
Death	1 (0.4)	3 (1.2)
Injection of the wrong drug[a]	3	

Data are presented as n (%).
IVRA = intravenous regional anesthesia.
[a] Percentage not available because information was volunteered by three respondents.

excision are often or always performed using IVRA by 70% of respondents. Dupuytren's release, tendon repair, and K-wiring are also often performed using IVRA.

Complications

Respondents reported whether they had personally experienced any of the following difficulties at any point during their career and whether they knew of any of these problems occurring at the institution in which they worked: incomplete anesthesia; incomplete exsanguination; severe pain on injection of local anesthetic; severe cuff pain; dysphoria, dizziness, and/or facial tingling; mistaken deflation of cuff; seizures; cardiac arrest; neurological damage; and death (Table 1).

There were no risk factors identified for the development of complications of IVRA, and there were no significant differences in the age, degree, and duration of practice of those respondents who experienced complications.

Discussion

It is impossible to determine whether nonresponders practice IVRA differently than responders. With a 32% response rate, the results may contain a biased sample, and the data may not reflect the usual practice of IVRA in North America.

Although there is much in the literature concerning IVRA, including several protocols (1,2), our survey reveals that some anesthesiologists use techniques outside recommended guidelines and that complications related to IVRA occur.

Almost all responding anesthesiologists exsanguinate the operative limb before IVRA using an Esmarch bandage, the most effective method of exsanguination (3). Other techniques of exsanguination, such as gravity with or without brachial artery compression and

pneumatic splint, are less effective but may be necessary in cases of trauma or fracture.

The tourniquet pressures most often used for upper-extremity IVRA, 250 mm Hg and 100 mm Hg greater than systolic blood pressure, are frequently cited in the literature as appropriate, despite little scientific evidence to support this. LOP has been recommended as the most appropriate method for determining the optimal tourniquet pressure, making evaluation of LOP for every patient an important prerequisite to choosing the tourniquet inflation pressure (4). LOP is the minimal pressure required in the selected tourniquet cuff to occlude arterial blood flow past the cuff in an individual patient, and it is affected by cuff width, design, application, and the patient's blood pressure and arm shape. Most anesthesiologists recognize that cuff design can affect LOP; therefore, the LOP may be greater than, less than, or equal to systolic blood pressure. Methods of determining LOP include the simple and most often used method of placing one's finger on the pulse, as well as pulse oximetry and Doppler. The pressure in the tourniquet must exceed LOP sufficiently to allow for increases in systolic blood pressure during the procedure. For a standard dual bladder IVRA cuff, a tourniquet pressure of LOP plus 100 mm Hg is usually sufficient to prevent the problem of vascular congestion in the arm (4). Local anesthetic toxicity, including significant serum bupivacaine level, and grand mal seizure have been related to congestion of the arm as a result of inadequate tourniquet pressure when LOP was not measured (4).

Most anesthesiologists use a dual bladder cuff or two single bladder cuffs for upper-limb IVRA. A dual bladder tourniquet is more effective than EMLA cream or nerve block by subcutaneous ring in minimizing cuff pain (5). However, a second bladder cuff increases the risk of equipment-related problems, particularly when inflation of the distal and proximal cuffs is interchanged, because there are twice as many

bladders, tubings, and connections. Only 52% of respondents recognize that dual bladder cuffs require higher pressure for occlusion than single bladder cuffs, which are normally wider (4). This makes dual bladder cuffs more likely to allow local anesthetic leakage than single bladder cuffs at the same tourniquet pressure (3). The distal cuff should be inflated first to aid in exsanguination of the tissue under the cuff, followed by the proximal cuff. Both cuffs should be left inflated during the injection of local anesthetic to minimize leakage. The distal cuff is deflated after the injection of local anesthetic to allow anesthesia under the cuff to develop should tourniquet pain become a problem.

Although infrequently used, forearm IVRA is effective in reducing the total dose of local anesthetic required (6), because satisfactory anesthesia may be obtained with 1.5 mg/kg of 0.5% lidocaine. Plourde et al. (6) have reported more than 100 cases of forearm IVRA with 100% satisfactory analgesia, no toxic reactions, and no limb congestion. The plasma lidocaine concentrations measured by Chan et al. (7) revealed only minimal leakage of lidocaine during forearm IVRA, confirming adequate venous occlusion.

IVRA with a thigh cuff has been performed using 3 mg/kg of 0.25% lidocaine, resulting in satisfactory anesthesia in 94% of patients and systemic lidocaine levels below the toxic range (8). IVRA with a single calf or ankle cuff can be used for procedures on the foot or ankle using 40 mL of 0.5% lidocaine (9). A calf tourniquet is more comfortable than a thigh tourniquet and seems to be safe as long as it is positioned at least 3 inches below the fibular head to avoid peroneal nerve injury (9).

Only 52% of the responding anesthesiologists consistently use an electronic tourniquet controller system, most of which incorporate audio-visual alarms to automatically warn the operator of hazardous over- or underpressurization of the cuff and excessive duration of cuff inflation (10). Mechanical or gas-powered systems require maintenance of the gas tank, and they do not incorporate cuff pressure alarms or elapsed time alarms due to inherent design limitations. Manual tourniquets and blood pressure manometers, although very unreliable, are still used.

Although most anesthesiologists use lidocaine for IVRA, 1.6% of respondents use bupivicaine and tetracaine, drugs considered too toxic for IV use. Prilocaine, the safest local anesthetic for IVRA (11), is no longer available in North America in a form suitable for IVRA because of concern about methemoglobinemia, although significant methemoglobinemia does not occur in the doses used for IVRA (2,11). Lidocaine concentrations greater than 0.5%, which predispose to toxic systemic levels even with the same total dose (12), are used by 14% of respondents. The maximal dose of IV lidocaine for IVRA is 3 mg/kg (2,6,13).

Muscle relaxants are added to local anesthetics to provide better muscle relaxation, and although effective (14), muscle relaxation may not be necessary or desirable in many hand procedures (7). No significant differences in sensory or motor function were found when fentanyl was added to lidocaine for IVRA (15). There is no evidence in the literature to support the addition of sufentanil or bicarbonate. Ketorolac improves mild to moderate tourniquet pain and prolonged postoperative analgesia in IVRA (16). Bretylium and guanethidine for IVRA are effective in treating reflex sympathetic dystrophy. Heparin has been added, theoretically to reduce clot formation; however, thrombosis has not been associated with IVRA, and IV lidocaine has been shown to have an antithrombotic effect because of its inhibition of platelet aggregation (17).

Most responding anesthesiologists give adjunctive parenteral drugs: benzodiazepines to raise the threshold of central nervous system effects of local anesthetic toxicity and to produce sedation, and narcotics to decrease tourniquet pain.

Leakage under the cuff may be minimized by the distal injection of local anesthetics over a minimum of 90 seconds (3). Local anesthetic is injected over 60 to 90 seconds by only 44% of respondents. Shorter injection times, used by almost half of respondents, predispose to systemic local anesthetic toxicity because the pressure in the veins under the cuff may exceed the pressure in the tourniquet (3,18). The antecubital vein should not be used for injection because this also increases the risk of local anesthetic leakage under the cuff, and has resulted in grand mal seizures (3,18). Most respondents wait the recommended 20 minutes after the injection of local anesthetic before deflating the cuff (1) to allow binding of local anesthetic to tissues.

Although 57% of respondents reinflate the cuff after deflation, there is no change in peak serum lidocaine level with reinflation, only in the time to reach it (19). If reinflation is performed to increase the time to reach peak plasma lidocaine levels, a 10-second deflation interval is optimal, because peak arterial serum levels of lidocaine occur at 15 seconds (19). Reinflation times of less than 10 seconds are associated with venous congestion, patient discomfort, and higher levels of local anesthetic with the second deflation (19).

A wide range of maximal times for IVRA was reported by survey respondents. According to animal studies in the orthopedic literature, tourniquet time should be limited to 90 minutes to avoid most ischemic injury to muscle (20). There is no evidence in the literature to suggest that anesthesia decreases over time with a properly functioning tourniquet.

From 1977 to 1987, the ASA Closed Claims Project database for IVRA received claims for pain on injection of local anesthetic ($n = 1$), circumoral numbness

and tingling related to tourniquet failure ($n = 1$), skin reaction after administration of lidocaine to a patient with a history of lidocaine allergy ($n = 1$), failed block followed by petechiae ($n = 1$), accidental administration of pentothal for IVRA ($n = 1$), peripheral nerve injury ($n = 2$), loss of ulnar nerve function in an anticoagulated patient undergoing IVRA for ulnar nerve transposition ($n = 1$), grand mal seizure without sequelae ($n = 1$), cardiac arrest resulting in chronic vegetative state ($n = 1$), and grand mal seizure resulting in death after receiving the wrong concentration of lidocaine ($n = 1$) (F. W. Cheney, personal communication).

Dunbar and Mazze (2) reported 16 episodes (2.1%) of mild central nervous system toxicity, including dizziness, blurred vision, facial numbness, and difficulty speaking in a series of 779 patients, 778 of whom had received lidocaine. More serious complications reported in the literature include numerous seizures (3,4,18) and three cardiopulmonary arrests after IVRA with lidocaine, bupivacaine, and chloroprocaine (21–23). Seizures, cardiac arrests, and deaths related to IVRA were reported by survey respondents (Table 1). IVRA has been associated with at least seven reported deaths in the United Kingdom from 1979 to 1983 (24). Details for all of the cases are not known, but common factors in five of the deaths were that the patients were healthy, automatic tourniquets were used, bupivacaine was the drug, and a resident in emergency medicine performed the block and then went on to carry out the surgical procedure without a second person to supervise the use of the tourniquet (24). In three cases, the equipment was examined and found to be satisfactory, but the cuff had been deflated at an inappropriate time (24). After this, Heath (24) recommended that IVRA be performed using a drug other than bupivacaine and by an anaesthetist trained in IVRA and possessing resuscitative skills, who would supervise the use of the tourniquet during the operation.

Although the survey results represent only a sample of anesthesiologists practicing in North America, the questionnaire revealed a wide variation in technical and clinical aspects ranging from acceptable to falling outside published guidelines. This survey indicates that serious complications related to IVRA can and do occur in the clinical setting.

No correlation was found between complications and deviation from traditional practice. However, we recommend that IVRA be carried out following current, recognized protocols; using suitable tourniquet cuffs and instrumentation; with appropriate drugs, concentrations, and volumes; in a monitored setting; with immediate access to resuscitative equipment; by anesthetists familiar with the technique and fully trained to treat its potential complications.

Appendix 1

Recommended Protocol for IVRA

1. Check equipment—use an electronic tourniquet controller system.
2. Perform IVRA in an area with immediate access to resuscitative drugs and equipment.
3. Ensure that the patient has no contraindications to IVRA.
4. Start an IV cannula in the nonsurgical limb.
5. Apply standard monitors, including electrocardiogram, noninvasive blood pressure, and pulse oximeter.
6. Insert an IV cannula in the hand of the operative limb and flush the cannula with saline before capping. Do not use an antecubital vein.
7. Apply stockinette to the operative arm.
8. Apply the tourniquet snugly over the padding.
9. Measure LOP.
10. Exsanguinate the extremity using an Esmarch bandage.
11. Inflate the tourniquet to LOP plus 100 mm Hg. If using a double cuff tourniquet, inflate the distal cuff first, followed by the proximal cuff. Check for inflation by palpation of the tourniquet cuff.
12. Remove the Esmarch bandage.
13. Palpate the radial artery to ensure absence of pulsation.
14. Inject a maximum of 3 mg/kg preservative-free 0.5% lidocaine steadily over 90 s.
15. If using a double cuff tourniquet, the distal cuff should be deflated. If required for tourniquet pain control, the distal cuff may be inflated, followed by deflation of the proximal cuff. Check for inflation by palpation of the tourniquet cuff.
16. The cuff may be deflated in one step after waiting a minimum of 20 min after the injection of lidocaine.
17. Maximal duration of tourniquet inflation should not exceed 90 min.

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