Intravenous regional conduction anesthesia: A technique and literature review—Part II

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In Part I of this two-part series, the author reviewed the development of the Bier Block technique and discussed the use of tourniquets and the site and mode of action of intravenous regional anesthesia (IVRA). In the second part, he focuses on the various local anesthetic agents and principles of pharmacokinetics.

Essential to the successful practice of IVRA is a comprehensive understanding of the pharmacology and pharmacokinetics of intravenously injected local anesthetic agents. Although a plethora of data has accumulated making succinct analysis difficult, it must be remembered that the technique was practiced successfully for more than half a century before scientific information confirming even the site of action was available. Similarly, research methods and technology have only recently allowed a precise understanding of many aspects of the technique.

The effectiveness of various agents is dependent upon the total dose administered, concentration of the drug used, anatomical placement and certain chemical characteristics of the agent itself. A general review of various agents reported for use in IVRA is given in this article, followed by a discussion of the pharmacokinetics of intravenously injected local anesthetics.

Pharmacology

Cocaine hydrochloride: Although it was the first local anesthetic agent used extensively for other forms of regional anesthesia, cocaine apparently never became popular for use in IVRA. Bier did not mention it in his original work and Hitzrot wrote of its use in only one case before abandoning it for procaine. In this isolated case, he reported a "marked constitutional reaction" following release of the tourniquet, apparently a toxic systemic reaction severe enough to preclude its further use.

Procaine hydrochloride (Novocain®): Discovered by Einhorn in 1904 and popularized for regional anesthesia by Braun, dilute procaine solutions for use in IVRA were first described by Bier. He suggested up to 100 cc of 0.25% solution for short procedures of the arm. For more prolonged or traumatic surgery he chose 50 cc of 0.5% solution. It should be considered, however, that during this era the degree of surgical intervention was largely limited by the anesthesia care available. As a result, extensive surgery was seldom considered with regional anesthesia techniques. Indeed, Bier's original report consisted only of manipulation of tuberculin ankylosic joints, debridements and limb amputations.

Other authors of the day, given little alternative, reported varying degrees of success with doses similar to Bier's. Morrison, however, did not report success with low volumes (10-12 cc) of very concentrated (2%) solutions.

It is interesting to note that, during a time in which the need for safe short duration anesthetic techniques was so important, IVRA did...
not gain wide popularity. Advances in specific peripheral nerve (plexus) block techniques, the cumbersome manipulations of IVRA, procaine's inability to provide consistently adequate anesthesia and its relative CNS toxicity no doubt contributed heavily to IVRA's lack of acceptance.

Procaine was still mentioned as late as 1946, however references in recent literature are generally only comparative.6

Tetracaine (Pontocaine®): Synthesized by Eisleb in 1931 and introduced into clinical practice by Kless in 1939, tetracaine was never popular for use in IVRA.6 This was presumably due to its toxicity, as only one isolated report of its use can be found.6

Lidocaine hydrochloride (Xylocaine®): Following its general introduction by Löfgren in 1943, lidocaine quickly became the favored local anesthetic agent for all forms of regional anesthesia.8 It naturally follows that lidocaine would be considered when Holmes "reintroduced" IVRA. To date, lidocaine remains the favorite of most anesthetists. This is no doubt due to its effectiveness at reasonably low concentrations (0.5%) and relative safety when given in large volumes.

While it has been suggested that the traditional method of recommending dosages based on body weight (mg/kg) fails to make rational allowances for patients at the extremes of body habitus, such ratios are presented in this article to provide a basis on which to make judicious adjustments.10 Whatever the method, however, common sense must prevail.

A number of concentrations and volumes have been studied; 3 mg/kg (lean) body weight of 0.5%, solution is the most often suggested. Bell found this dose to produce a maximum mixed venous plasma level of 1.2 mcg/cc.11 Bell and Harris suggested that this could be reduced to 1.5 mg/kg if 20 min of tourniquet ischemia were produced prior to injection of the agent.11,12 Using this technique, Harris found mixed venous plasma levels following tourniquet release of only 0.9 mcg/cc.

In light of Foldes report that sustained venous plasma levels of 5.29 mcg/cc were needed to produce toxic symptoms, it would seem counterproductive to consume valuable tourniquet time with the 15-20 min "pre-injection ischemia" modification.18

Prilocaine hydrochloride (Citanest®): Developed in the early 1950s by Löfgren, prilocaine was not introduced clinically until 1960.14 Hooper, in 1964, was the first to suggest its use in IVRA; it has subsequently enjoyed considerable popularity for this purpose, as reported particularly in Canadian and European literature.15

Initial studies reported that in equipotent local anesthetic doses, prilocaine was 40% less toxic than lidocaine.19 This was believed to be the result of rapid destruction of the agent by liver enzymes.

Manthey noted that the resolution of block following tourniquet release was longer with prilocaine than with lidocaine, presumably due to slower release from tissues of the arm.17

Acquired methemoglobinemia, a condition in which the iron of heme is in the ferric form and is incapable of reversibly binding molecular oxygen, has been noted following the use of prilocaine.18 A breakdown product of prilocaine, orthotoluidine, has been implicated in this regard as causing the irreversibility.

Darling found that prilocaine-induced methemoglobinemia created a shift of the oxygen dissociation curve to the left, decreasing the normal release of oxygen to tissues with low partial pressures of oxygen.19 Asymptomatic cyanosis has been noted when 10-15% of methemoglobin is present while symptomatic anoxia may appear at levels of 20-25%.18

Several authors have studied the formation of methemoglobin and have demonstrated average peak levels of 4-6% following the use of total doses of 600 mg.20-22 Doses of 900 mg resulted in levels of 7-10% with occasional unsustained levels of 15-20%. Asymptomatic cyanosis has been reported with the latter dose. In deference to these values, it should be noted that normal values of methemoglobin are 2±.06%.

Mazee found that following the use of 3 mg/kg of 0.5% prilocaine for IVRA, average peak methemoglobin levels ranged from 2.2% to 2.8%; the highest single value was 7.4%.18 Using 4 mg/kg with a pre-injection ischemia (15 min) modification, Harris noted peak methemoglobin levels of only 0.5-1% at 160 min following tourniquet release.23

As with classical methemoglobinemia, the cyanosis and hypoxic symptoms may be reversed with intravenous injection of methylene blue, 1 mg/kg body weight.28 Caution is advised however, as the action of methylene blue is transient and should not be repeated as it may act as a hemoglobin oxidant, thus worsening the situation.

Mepivacaine (Carbocaine®): Developed by Ekenstam in 1956, mepivacaine was introduced clinically in 1957 by Dhuner.24, 25 It was first suggested for use in IVRA by Cox in 1964.5 Costley and Fujita have conducted the most extensive work with this agent, the latter finding no signifi-
cant variance in onset or resolution of anesthesia with mepivacaine when compared with several other agents.26, 27

Mepivacaine is considered to be less toxic because of its high degree of tissue and protein binding properties, however, this factor appears too insignificant to advocate its use in deference to other available agents.

Chloroprocaine (Nesacaine®): Chloroprocaine, a halogenated derivative of procaine, was developed in 1943 by Marks but was not considered for IVRA until 1965.28, 29

The high degree of safety and the rapid hydrolysis (plasma half life is less than 30 sec) of this agent by plasma enzymes would seem to make this an ideal agent for IVRA. A number of authors, however, have reported an unacceptable incidence (3-10%) of thrombophlebitis following its use.23, 29, 30 The low pH (5.09) necessary for solubility and stability along with the use of additives such as benzyl alcohol or sodium bisulfate have been incriminated in causing this complication, therefore, the suggestion has been made that the drug not be considered further for use in IVRA.31

Bupivacaine hydrochloride (Marcaine®): Introduced clinically by Widman in 1966, bupivacaine has rapidly gained in popularity for peripheral nerve and epidural blocks because of its systemic safety.32 This safety is apparently due to its high degree of lipid solubility and protein binding.

In 1975, Ware first investigated bupivacaine for use in IVRA and suggested that 1.5 mg/kg of 0.2% solution gave the most satisfactory results.33 Katz has reported favorable results with a 0.25% solution.34

Watson found that bupivacaine provided a delayed onset of analgesia (average 10.9 min) and a slow sensory return (average 23.6 min) after the tourniquet was deflated.35 This was highly variable but was considered favorable when it was desirable to remove the tourniquet prior to final closure of the wound. He also found a significant prolongation in the time from tourniquet release to the

Figure 1
At present Astra Pharmaceutical's single dose vial of Xylocaine HCl 0.5% containing no preservatives is the only preparation of local anesthetic approved for use in Intravenous Regional Anesthesia.
patient's request for systemic analgesics (average 163 min).

Work by Evans suggests that residual analgesia may last as long as 344 minutes. It is not clear, however, if this was sufficient to allow continued surgical manipulation or was merely cutaneous analgesia.

As is common with bupivacaine when used in other forms of regional anesthesia, muscle relaxation is poor when low concentrations (0.25%) are used in IVRA. At present, bupivacaine is not approved for use in IVRA. Infiltration of the surgical site, however, with this agent will allow continued surgical time and postoperative analgesia following resolution of IVRA.

Etidocaine hydrochloride (Durane®): Popularized by Adams for peripheral and epidural anesthesia, etidocaine HCl apparently never gained wide acceptance for use in IVRA.

Covino suggests that etidocaine's relative safety is due to its high degree of protein binding and lipid solubility. Evans feels these same characteristics contribute to etidocaine's residual analgesia following release of the tourniquet when used for IVRA. Full sensory return is generally complete in four minutes while motor paresis may persist for more than two hours. This residual motor loss offers no clinical advantage and may be a source of unnecessary annoyance to patients.

At present, only one product is approved by the U.S. Federal Drug Administration for use in IVRA. This drug, lidocaine hydrochloride (Astra Pharmaceuticals nde-0186-0137-01) is prepared as a single dose 50 ml vial containing no preservatives. This vial is designed to be used only once and the remaining solution discarded (Figure 1).

Pharmacokinetics

Not surprisingly, the pharmacokinetic properties of local anesthetic agents utilized in IVRA are strikingly similar to those of other agents injected directly into the systemic circulation.

With only rare exception, virtually all early reports on IVRA pharmacokinetics presented discussions and made judgments based on quantitative mixed venous data obtained from the contralateral extremity. One needs only an elementary understanding of intravenous kinetics to appreciate that these values reflect minimal useful information on the systemic toxicity of the agents studied. It is perhaps the arterial level of agent which should be considered because it ultimately interfaces with susceptible target organs such as the brain or heart.

Due care should be taken even with arterial data, however. Tucker showed that peak levels taken from the peripheral (radial) artery were but 30% of those derived from the pulmonary artery. This suggests that a significant degree of drug may be extracted by the lung.

This is not to imply that all venous data is insignificant. Evans showed that in blood taken from an anesthetised arm, lidocaine yielded higher residual levels (40 mcg/ml) after tourniquet release than did prilocaine (12 mcg/ml). As prilocaine is less protein bound than lidocaine, this data suggests that prilocaine has a greater affinity for muscle tissue than lidocaine, thereby making equipotent doses of prilocaine less likely to result in CNS toxicity. Eriksson reached a similar conclusion.

Hargrove, however, suggests that no clinical correlation can be drawn between absolute blood levels, venous or arterial, and symptoms of toxicity. He considers the establishment of maximum allowable blood concentrations to be less important than the rate at which these levels are achieved as well as the duration over which they are maintained.

Covino has proposed a three-compartment, time-based model to illustrate the disappearance kinetics of intravenously injected amide-type local anesthetic agents (Figure 2). While the curve depicted is characteristic of the amide agents presently used in IVRA, absolute values vary widely and are directly influenced by: (1) pharmacologic characteristics of redistribution and metabolism of the specific agents used, (2) duration of vascular occlusion (tourniquet time), (3) technique of tourniquet deflation, and (4) volume and concentration of agent used.

Redistribution and metabolism: The initial (alpha) phase of IVRA reflects the rapid redistribution of drug from blood to highly perfused tissues (the brain, heart, lung, kidney). The second (beta) phase represents the continued slower redistribution of drug into lesser perfused tissues such as muscle or fat. The third (gamma) phase depicts the elimination of drugs by metabolism or excretion.

The duration of each phase is defined as the time needed for a 50% reduction in blood concentration (plasma half-life). While the shape of the disappearance curve is similar for all the amide type local anesthetic agents, the actual half-life values vary widely. Table I lists values for various drugs commonly used in IVRA.

As Hargrove suggested, it would seem that the safe agents would be those with a rapid alpha phase. Prilocaine possesses such a characteristic...
Figure 2
Three compartment model depicting theoretical disappearance of amide local anesthetic agents from plasma following intravenous injection. (From Covino, B. G. 1979 "Pharmacokinetics of Intravenous Regional Anesthesia" Regional Anesthesia 4(1): 5-8. With permission.)

Table I
Disappearance properties of intravenously injected amide-type local anesthetic agents. (Modified from Covino, B. G. 1979 "Pharmacokinetics of Intravenous Regional Anesthesia" Regional Anesthesia 4(1): 5-8)

<table>
<thead>
<tr>
<th></th>
<th>Lidocaine HCl</th>
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<td>57</td>
<td>43</td>
<td>29</td>
<td>162</td>
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<td>Alpha Half Life (Seconds)</td>
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<td>T 1/2 β</td>
<td>96</td>
<td>114</td>
<td>93</td>
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<td>Beta Half Life (Minutes)</td>
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and is widely accepted as the safest agent for IVRA, particularly as reported in European literature.

The alpha values for mepivacaine and lidocaine are similar, however, the beta phase for mepivacaine is longer than that of lidocaine. This suggests slower metabolism and elimination of mepivacaine.

As would be expected, the clinically longer acting agents such as bupivacaine and etidocaine show prolonged alpha and beta values.

Duration of vascular occlusion: Numerous technical modifications have been suggested to prevent elevated systemic levels of local anesthetic agents when performing IVRA. Several authors have stressed the importance of the injection-tourniquet-release interval. Bier suggested that the tourniquet be maintained in place for 20 minutes following injection. Morrison observed fewer symptoms if the tourniquet was left inflated for 10 minutes or more following administration of a local anesthetic agent. He subsequently suggested a minimum of 30 minutes be allowed prior to deflation of the tourniquet. Adams recommends a minimum of 60 minutes.

Tucker provided experimental data to demonstrate an inverse relationship between peak arterial plasma drug levels and the duration of vascular occlusion. The shape of the disappearance curve parallels that of direct intravenous injection regardless of the duration of vascular occlusion. However, absolute arterial plasma levels are significantly less as the tourniquet time is increased (Figure 3).

The injection of 3mg/kg lidocaine combined with 10 min of tourniquet occlusion yielded peak arterial levels of 10.3 ±2.9 mcg/ml. The same dose restrained for 20 min did not vary widely from the earlier sample, however, occlusion for 45 min yielded significantly lower peak levels of 2.3± 0.6 mcg/ml. This suggests that as tourniquet time is increased, local anesthetic agents diffuse from the intravascular space and enter the extracellular fluid of muscles and skin. Raj’s radiographic evidence closely parallels these findings.

Other authors have clouded this issue by suggesting that regardless of the injection-tourniquet interval, a significant amount (25%-30%) of local anesthetic agent remains intact within the occluded vasculature and enters the systemic circulation immediately upon release of the tourniquet. With the popular technique using 40 cc of 0.5% lidocaine, this would be equivalent to a very rapid 50 mg bolus of lidocaine which is certainly capable of producing symptoms of central nervous system toxicity. The agent remaining in the extracellular fluid (70%-75%) is removed from the extremity more slowly in accordance with Covino’s theoretical model.

Cycled tourniquet deflation: Hargrove and Eriksson found that in arterial blood, maximum plasma concentrations were found 1-1.5 min following tourniquet deflation. Considering this, several authors suggest that the tourniquet be deflated for approximately 5-30 sec and then reinflated to above systolic pressure. This reinflation should be maintained for 2-3 min to allow for redistribution of the initial bolus. Following this the tourniquet may be safely removed. A number of variations of this routine have been advanced—all with the idea of decreasing circulating levels of local anesthetic agents.

Volume of injectate: The total volume of injectate must also be considered as a variable in the success of IVRA. Adams has found that the exsanguinated upper extremity contains approximately 170 cc of blood. Therefore, very small volumes, regardless of their concentration, are not adequate to fill the superficial vessels sufficiently to cause flow to the small intraneural vessels, the theoretical site of action. Colbern has suggested...
that the onset of block may be hastened by following
the injection of local anesthetic agent with a
5-10 ml "chaser" of normal saline solution. This
is thought to force the agent from the superficial
vessels into the intraneural vasculature.

Haas has described a "second wrap" technique
modification in which the arm is rewrapped with
an elastic bandage immediately after injection of
the local anesthetic agent; the premise again is
better redistribution of drug. In this instance,
the attempt is to expose the nerves beneath the
distal tourniquet so that when it is subsequently
inflated it will compress well-anesthetized tissues.

In another attempt to enhance the effective-
ness of small volumes, Fleming suggested that the
tourniquet be placed distal to the elbow and
20 cc of agent be injected. Present experience has
found this to be unnecessary and potentially harm-
ful to nerves of the forearm.

Concentration of injectate: Tucker's work
suggested that lower arterial levels of drug could
be attained by decreasing the concentration of
agent used. Rupp found that very high volumes
(60-70 ml in the upper extremity and 70-90 ml in
the lower) of very dilute (0.15-0.20%) lidocaine
would provide satisfactory results. This further
supports the concept that the agents work at the
intraneural level, as such dilute solutions applied
to the exterior of peripheral nerves would fail to
provide surgical levels of analgesia.

Possible complications

Although the technical aspects of IVRA are
decievously simple, the anesthetist must be ever
aware of potential complications arising from its
use. Most complications are related to deflation of
the tourniquet, purposeful or otherwise, with re-
sultant rapid entry of large volumes of anesthetic
agents into general systemic circulation.

Various methods of limiting the amount and
rate at which the agent is allowed to reenter cir-
culation have been discussed previously in this
article and in Part I. They are helpful in avoiding
the following symptoms of toxicity:

Neurologic complications: Neurologic symp-
toms are generated by local anesthetic agents' ability to depress subcortical cerebral cortex and
medullary centers. This active activity is respon-
sible for the subjective symptoms of excitement,
vertigo, or tinnitus and may progress to tonic/}
convulsive activity.

Much controversy exists as to the method best
suited for treating these symptoms, especially the
seizure activity. DeJong found that small doses of
diazepam (2.5-5.0 mg in adults) would double the

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plasma level of the local anesthetic agent at which
symptoms developed. He recommends its pro-
phylactic use as a preanesthesia medication as well
as intravenously to attenuate neurologic symptoms
of toxicity should they develop. Tatum has re-
ported similar results with intravenous bar-
biturates.

Moore suggests that one need only assist
patients who manifest these symptoms with high
inspired concentrations of oxygen because the
central nervous system excitement is transient and
is followed by general depression resulting in
various degrees of drowsiness, occasionally to the
point of unconsciousness.

Unfortunately, some have advocated the intra-
venous administration of depolarizing muscle re-
 laxants to decrease the muscular activity accom-
pnying a seizure. As such drugs play no role in
the reduction of central nervous system activity
and may further complicate an already unfortunate
situation by requiring artificial management of
the patient's airway, this practice is to be con-
demned.

Neurologic complications of peripheral nerves
resulting from use of a tourniquet have been dis-
cussed in Part I and should be considered any time
IVRA is contemplated.

Cardiovascular complications—pulse: Following
release of the tourniquet, there is an acute
vascular shunt of arterial circulation (approxim-
ately 170 cc in the upper extremity). In addition,
due to sustained acidosis of the tissues, there may
be a reactive hyperemia which may account for an
additional shunt. This may result in a transient
increase in pulse as the heart attempts to modify
cardiac output in response to these changes. This
phenomenon should not be considered a complica-
tion.

Local anesthetic agents, particularly when
given as a bolus, are known to decrease myocardial
conduction. Bradycardia, including at least one
case of asystole, has been reported following release
of a local anesthetic agent into general circulation
following IVRA. This bradycardia is generally
temporary and most commonly of little significance.
If such activity is prolonged and results in hypo-
tension, it should be treated with intravenous ad-
ministration of a sympathomimetic drug such as
atropine sulfate and supplemental oxygen by mask.

Blood pressure: The most common modifica-
tion in systemic blood pressure is hypotension.
Steinhaus feels this is due to medullary center
stimulation by local anesthetic agents. The
decrease in cardiac preload resulting from arterial
shunt and a decrease in myocardial contractility
resulting from circulation of acidotic blood from the anesthetized extremity have been cited as well.

Electrocardiogram: A myriad of dysrhythmias have been reported including ventricular extrasystole, arterial extrasystole, S-T segment depression, nodal rhythm and sinus bradycardia. Modig has suggested the modification of serum electrolytes from the isolated extremity. He states that release of a tourniquet following 30 min of occlusion will increase serum potassium by more than 1.0 mEq/L.

Hypersensitivity: A complete medical history, including existence of known drug allergies, must be obtained from all patients for whom IVRA is considered. True hypersensitivity or "allergy" to local anesthetic agents is extremely rare. Aldrete suggests that very few reactions involving local anesthetics are of a true allergic nature. Unfortunately, a large number of patients have been labeled as allergic to these drugs when, most commonly, their reactions have been the result of syncopal vasovagal responses or inadvertent intravascular injection of drug.

The ester-linked agents such as procaine HCl have been found to be most prone to produce allergic reactions, particularly with repeated exposures. It is for this reason that the amide-linked agents such as lidocaine HCl have gained wide popularity as they are virtually free of documented hypersensitivity reports. DeJong has suggested that the preservative methylparaben, which is added to multiple dose vials to prevent fungal growth, is structurally related to procaine and is responsible for the majority of cutaneous reactions reported. (At least one company, Astra, has addressed this potential problem by marketing a preservative-free preparation of lidocaine expressly for use in IVRA.) (See Figure 1.)

While anaphylactoid reactions and angioneurotic edema have been reported, the majority of reports indicate skin eruptions such as urticaria or wheals. Treatment is symptomatic and may include administration of diphenhydramine HCl or epinephrine in extreme cases.

Costley has suggested that another preservative, benzyl alcohol, contributes to a high incidence of thrombophlebitis following the use of agents to which it has been added. In addition, the extremes of pH at which some drugs are prepared undoubtedly play a role in the manifestation of this complication.

Contraindications
As with all techniques of anesthesia, patient refusal constitutes the primary absolute contraindication to IVRA. An informative preanesthesia visit will often allay any doubts a nervous patient may have.

Other anesthetic techniques should be considered in patients suspected of having diseases which would preclude the use of an occlusive tourniquet such as sickle cell disease or advanced peripheral vascular disease (i.e., diabetic neuropathy).

Serious consideration should also be given before administering IVRA to patients with major systemic disease such as severe hepatic disorders, malnutrition or debilitation with severe protein loss, or myasthenia gravis. As local anesthetics exert a quinidine-like effect on the heart, large volume techniques such as IVRA should not be used for decompensated or digitalized patients.

In cases of severe extremity trauma, unrecognized disruption of major venous channels may preclude adequate distribution of injected agent. The use of local anesthetics is not contraindicated in patients with a history of psychomotor epilepsy.

Additionally, IVRA should not be considered in cases where a totally "bloodless field" (i.e., microsurgery) is mandatory. Even with high tourniquet pressures blood continues to pass through the noncompressible medullary cavities of long bones and into soft tissue vessels distal to the tourniquet. This, combined with the volume (40-50 cc) of local anesthetic injected may cause oozing into the surgical field, obstructing the surgeon's view. This is present to a lesser degree with other anesthetic techniques such as brachial plexus block.

Additional considerations
A number of modifications to Bier's original technique have been advanced. While most are but minor technical changes, some deserve further delineation. Among these are the use of IVRA for the lower extremity, its use in pediatrics, and the use of a continuous IVRA technique.

Use of IVRA on the lower extremity: Bier mentioned the use of IVRA for manipulation and amputation in the lower extremities in his earliest works. That he did not report significant toxic complications is remarkable. The rapid removal of the extremity and the subsequent loss of intravascular local anesthetic agent no doubt limited the systemic uptake of drug following release of the tourniquet.

With his reintroduction of IVRA, Holmes suggested 100 cc of 0.5% lidocaine with the tourniquet placed at the thigh. Others suggested
that a lesser concentration (0.25%) could be utilized if the tourniquet was placed three inches below the head of the fibula. This position is important to avoid compression of the peroneal nerve as it crosses the fibula.

The author has found IVRA of the lower extremity variable and more often than not, unsatisfactory for all but the shortest procedures. Concern for neurological deficits following the use of a pneumatic tourniquet below the knee and the ready availability of peripheral nerve blocks to isolate the extremity raise considerable doubt as to continued use of the technique. Intrathecal or peridural techniques should also be considered when desirable.

**Use of IVRA in pediatrics:** Several authors have reported the use of IVRA in children, apparently with good results. Careful consideration must be given to the determination of the appropriate volume of local anesthetic injected in this patient population. No general guidelines, other than the mg/kg body weight ratio previously discussed, are provided for IVRA in children.

**Continuous technique:** Brown has described a “continuous technique” by which he is able to prolong the surgical time using IVRA. He simply leaves the intravenous cannula intact and secures it for later use. Following the allowable tourniquet occlusion time, the tourniquet is deflated for 5-10 minutes. The arm is again exsanguinated, the tourniquet reinflated and checked, and one-half the original volume of local anesthetic agent is injected.

This technique generally extends the usable time by approximately one hour. Thus, it would seem difficult to justify this technique when other regional anesthetic techniques using long acting agents such as Pontocaine (tetracaine) and bupivacaine are readily available.

**Summary**

Used successfully for more than three-quarters of a century, intravenous regional anesthesia—the “Bier Block”—has withstood the proverbial test of time. While deceptively simple to perform, its careless use can be devastating. Careful attention to detail is mandatory. When used properly, however, IVRA offers an important addition to the clinical anesthetist’s armamentarium of care.

**REFERENCES**


(30) Colbern EC. 1970. The Bier Block for Intravenous Re-
Appendix I

Technique of Intravenous Regional Anesthesia

Patient Evaluation
- Personal interview and informed consent
- Medical history (including drug allergies)
- Vital signs (including Blood Pressure)

Premedication (as indicated)
- Diazepam
  - Orally: 0.15 Mg/Kg with antacid (Aluminum Hydroxide) 30-60 minutes before block
  - Intravenous: 0.05 Mg/Kg slowly immediately prior to block

Intravenous Fluid Access Line
- Contralateral extremity
- Plastic cannula of appropriate size

Equipment Check (Prior to each use)
- Check tourniquet gauge against mercury manometer for correct reading
- Check patency of connections and lines

Support Equipment (at scene of block technique)
- Oxygen and positive pressure equipment
- Injectable diazepam or barbiturate drawn and ready for use
- Airway and endotracheal equipment checked and ready for use
- Suction apparatus and cannulae checked and ready for use

Tourniquet Padding
- Cotton wool (Webri®)
- Roll single layer overlapping each roll to one inch either side of tourniquet

Tourniquet
- Specially designed two compartment cuff (do not use Riva-Rocca cuffs)
- Two stage valving system designed for Intravenous regional anesthesia
  - Two separate pressure sources may be substituted if valving system is not available.
- Continuous pressure source (Compressed Air, Oxygen, CO2, etc.)
- Continuous read pressure indicator (CM H2O or MM Hg)
- Place tourniquet at point of maximum circumference

Intravenous Injection Device
- Plastic cannulae (22-25 Gauge)
- Place in superficial antecubital vessel and direct proximally
- Connect to sterile injection path (syringe and extension set, Heparin Lock®, or cannula obturator)

Exsanguinate Extremity
- Esmarch bandage, ACE® wrap, or crepe bandage tightly rolled distal to proximal
- Air splint if extremity is painful
- Elevate arm for three to five minutes for gravity drainage if too severely traumatized

Inflate Tourniquet
- Inflate proximal tourniquet bladder first
- Inflate to Minimum Effective Pressure (100 MM Hg above systolic pressure)
- Check for lack of peripheral pulse or vascular filling (if present, increase tourniquet pressure until eliminated)

Inject Agent
- Slowly inject agent (noting area for extravasation of agent into soft tissues)
- Approximately 40-50 cc Total Dose:
  - Xylocaine hydrochloride (without preservatives—NDC# 0186-0137-01)
  - 0.5% (to maximum dose of 3 Mg/Kg body weight)
  - May add 0.1% Mg/CC d-tubocurarine to solution if total flaccidity is desired
- Remove cannula and hold pressure two to three minutes

Rotate Tourniquet
- Approximately 30-45 minutes after initial inflation
- Inflate distal tourniquet bladder to M.E.P.
  - Check for complete and secure inflation of the distal bladder
- Deflate proximal tourniquet bladder

After Completion of Surgery

Cycle Deflation of Tourniquet
- Deflate tourniquet bladder
- Wait 30-45 seconds
- Reinflated tourniquet to M.E.P.
- Wait 2-3 minutes for systemic circulation of local anesthetic from extremity
- Repeat 1-3 times as indicated
- Deflate and remove tourniquet

Observe for systemic indications of local anesthetic toxicity
- If present:
  - Oxygen by mask or positive pressure if necessary
  - Intravenous diazepam (titrated to maximum of 0.2 Mg/Kg)
  - Supportive treatment as indicated
Appendix II
Technique Review—Site of action of IVRA (From Part I—August, 1981 AANA Journal)

In our discussion of the various local anesthetic agents and their pharmacological properties, it is important that we review the mechanism of IVRA (Figure 1). How can relatively small volumes of very dilute agents produce such profound sensory loss?

The site of action of IVRA has been clarified in numerous experiments. It has been shown that the fibers which serve the distal extremities are located in the core of major nerve trunks while those which serve the proximal tissues are around the mantle or periphery of the trunk (Figure 12). The microvascularity of such a peripheral nerve trunk is demonstrated in Figures 13 & 14.

Immediately following injection of the local anesthetic agent into the exsanguinated and isolated vessels of the extremity, these vascular channels carry the agent into the intraneural vessels near the core of the trunk. The fluid diffuses into the nerve fibrils due to a concentration gradient. Ten to 15 minutes later, diffusion of the local anesthetic agent into the extracellular fluid of muscle tissue ensues, continuing until an equilibrium with the intravascular drug is approached. Sensory perception returns in a similar pattern, proximal to distal.

Figure 1
August Bier’s original technique of Intravenous Regional Anesthesia. Placement of a metal cannula required a surgical procedure which no doubt deterred from its ready acceptance. Of interest is the use of both a distal and proximal tourniquet to isolate the surgical site and to lessen the total volume of injectate.


Figure 12
Axons located in the nerve’s “mantle” innervate proximal regions, those in the “core” distal regions. Onset of anesthesia is related to the distribution of nerve exposed to local anesthesia agents.

Nerve trunk
- Mantle bundle
- Core bundle

Figure 13
Cross section of ulnar nerve. Note abundance of blood vessels in the “core” region of the nerve and the large “nutrient” vessel in the perineurium.

(From Raj, P.P., et al 1972 “the Site of Action of Intravenous Regional Anesthesia,” Anesthesia and Analgesia 51:776-786, With permission)
Appendix II (continued)

Figure 14
Photomicrographs of injected peripheral nerves. Note the "nutrient" arteriole which enters the nerve substance to give rise to an intraneural vascular plexus extending the length of the nerve. (B) Extreme close-up of above.
(From Sunderland, S. Nerves and Nerve Injuries, Churchill Livingstone, New York, 1978, With permission)

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(38) Adams HJ, Kronberg GH, Takman BG. 1972. Local Anesthetic Activity and Acute Toxicity of (±) 2-(N-ethylpro-


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