

# An update on intravenous regional anaesthesia of the arm

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**Abstract.** – Intravenous Regional Anaesthesia (IVRA) has been first described in 1908 by the German surgeon August KG Bier. Although the technique was easy to perform and effective in giving surgical anaesthesia, the newer plexus block techniques largely replaced in a short time the "Bier block", because of time limitations of IVRA and safety considerations.

Throughout the years modifications in procedure and new pharmacologic adjuvants have been shown to prevent toxic reactions to anaesthetics and mitigate limitations of IVRA.

This paper reviews the technique itself, its historical background, procedural modifications to improve its safety and efficiency, pharmacologic adjuvants acting on onset time of anaesthesia and on tourniquet pain, and drugs improving postoperative analgesia and muscle relaxation. The economic side of IVRA is also discussed.

*Key Words:*

Regional anaesthesia, Intravenous, IVRA.

Nevertheless Intravenous Regional Anaesthesia (IVRA) has not been completely abandoned (e.g., Herreros recommended in 1946 the use of IVRA on the battlefield<sup>3</sup> and international symposia on IVRA have been held in 1966 and 1979), and throughout the years new procedures and pharmacologic adjuvants have been shown to prevent toxic reactions to the anaesthetic solution and mitigate limitations of IVRA.

Since intravenous blocks of the lower limb have not achieved the popularity and clinical application of the upper limb block technique, the Authors of this paper will refer to the upper extremity Bier block.

The paper will review, keeping in mind the historical background, the technique itself, its traditional limitations and pharmacologic and procedural modifications improving its safety and efficiency, making IVRA profitable on the economic side too.

## Introduction

In 1908 August, KG Bier<sup>1</sup>, Professor of Surgery at Berlin, first described a technique in which a local anaesthetic solution (procaine) was administered intravenously into a limb with the arterial blood supply occluded by a tourniquet. Although the technique was easy to perform, providing a quite rapid onset of surgical anaesthesia and an acceptable muscular relaxation, time limitations and safety considerations remained paramount, and the more reliable and safe plexus block techniques, introduced in clinical practice few years later, largely replaced the "Bier block" (the now famous eponym has been suggested by Colberne in 1970<sup>2</sup>) some years after the description of the method.

## Clinical Applications and Contraindications

IVRA is easy to administer, its overall cost is low, it is applicable to all age groups, the onset of surgical anaesthesia is quite rapid, and after the tourniquet (a device introduced for limb amputation by war surgeons<sup>4</sup>) is released normal sensation and motor power return rapidly.

Short elective surgical procedures (< 90 min) can be performed on the hand and the forearm, usually on soft tissues, but in case of an emergency bone fractures can be treated, even in children<sup>5,6</sup>.

IVRA contraindications include allergy to local anaesthetic, infection, a personal history

of seizures, peripheral neurologic diseases, cardiac arrhythmias, conditions precluding exsanguination and/or the use of an ischaemic tourniquet, e.g. scleroderma, Raynaud's disease, tumours, increased intracranial pressure, sickle cell disease (possible), deep vein thrombosis or thrombophlebitis, vascular insufficiency.

### IVRA Procedure

An intravenous cannula 18-20 Gauge is inserted in the affected arm as distally as possible; a second one is inserted in the contralateral one for injection of drugs (sedative or resuscitative) if needed.

A double pneumatic tourniquet, a procedural modification introduced by Holmes in 1963<sup>7</sup>, with a proximal and distal chamber that can be inflated separately, connected to a control apparatus and fitted with a reliable pressure gauge is placed on the operative side. The use of a factory double cuff tourniquet has been first described in 1964<sup>8</sup> and the device has been commercially available from 1967. The arm is then exsanguinated.

Three possibilities exist. It can be done by wrapping the extremity tightly using an Esmarch's bandage (a rubber bandage expressly studied for a purpose other than an amputation developed in 1873), but it may cause excessive pain to a fractured patient or if large soft tissues lacerations exist. Another method is getting exsanguination by extremity elevation for several minutes plus arterial occlusion by compression of the brachial artery: quality of surgical anaesthesia does not differ, but an excess of blood might remain on surgical field<sup>9</sup>. A third method is a combination of the two previously described, and this is generally accepted as the most effective. In older studies following exsanguination the proximal tourniquet cuff is inflated to approximately 50 to 150 mmHg pressure higher than the patient's systolic pressure. An adequate tourniquet pressure is confirmed by the absence of the radial pulse. Nevertheless most of Authors now agree that 300 mmHg is the most reliable inflation pressure.

Some difficulties may be encountered performing IVRA with double tourniquet on obese patients or patients with large arms. In

fact this device does not properly wrap around the arm, and the use of two individual tourniquets may be more successful.

Wider single-cuffed tourniquets working at a lower inflation pressure may have an advantage over double tourniquets, decreasing the risk of neurologic injury<sup>10</sup>. A single child-sized cuff may be used in small children, being a double tourniquet usually too large.

A local anaesthetic, usually 0.5% lidocaine or prilocaine is injected slowly over a period of 180 sec. The calculated dose is about 3 mg/kg up to a 40 ml of local anaesthetic solution volume. The use of long-acting anaesthetics will be briefly discussed later.

The cannula is then removed, a gauze sponge is placed on the puncture site and the arm elevated to prevent leakage during the development of anaesthesia. After a 2-3 min time the arm can be placed on the operating table.

If the patient complains of tourniquet pain (it happens usually before 30 min of exsanguination) the distal tourniquet, placed on anaesthetized skin, is inflated and the proximal one carefully deflated.

Keeping the tourniquet inflated at least 20-25 min after the injection of local anaesthetic is mandatory, even if the surgical procedure is much shorter. Moreover, deflation should occur by a series of deflations and inflations to avoid a massive washout of anaesthetic solution in the circulation<sup>11</sup>.

IVRA with a forearm tourniquet could be recommended for distal surgery below the elbow. In this way up to 50% less of anaesthetic solution can be used, thus toxicity risks are lower; tourniquet pain is delayed in onset and of lesser severity; according to Reuben et al<sup>12</sup> increased risk of nerve injury or anaesthetic solution leakage have not been really demonstrate in any study.

This recently published material meets head on with older studies. In a paper by Chan et al<sup>13</sup>, despite slow injection of lidocaine over 120 sec, leakage occurred in more than 50% of patients. Kalso et al<sup>14</sup> reported earlier a leakage rate of more than 67%. These reports stated that a complete occlusion can not never be achieved, because blood continues to run in the vessels between radius and ulna. Bernstein and Rosenberg<sup>15</sup> advised in 1993 to avoid forearm tourniquets.

## Side Effects and Complications

IVRA is a simple and almost always very effective technique, but during the years a number of side effects and complications have been reported. Essentially all complications have been related to the systemic pharmacologic effects of the local agent used; Bier himself recognized the potential toxicity of local anaesthetics recommending to keep the tourniquet inflated for at least 20 min and restore blood flow gradually.

During the '80s, Grice et al<sup>16</sup> associated with the technique seven deaths, two cardiac arrests and several cases of seizures. Radiocontrast studies demonstrated anaesthetic solution leakage even under a correctly positioned and inflated tourniquets, since venous pressure during injection exceeded tourniquet pressure causing passage of drug into the general circulation. Placement of intravenous cannula as distally as possible, slow injection and an appropriate tourniquet pressure of inflation are likely to minimize serious complications. Rawal et al<sup>17</sup> recommended re-exsanguination with an Esmarch's bandage following institution of IVRA, with a brief deflation and reinflation of the tourniquet; they called this procedure re-IVRA, a technique that would result in minimal leakage of local anaesthetic.

The correct choice of local anaesthetic drugs might be important in prevent severe systemic complications: toxic reactions and even death cases have been reported using long acting drugs (e.g., bupivacaine)<sup>18</sup>.

Early and/or massive deflation of the tourniquet or accidental loss of its pressure before the anaesthetic has had time to fix to the tissues may lead to a toxic reaction as well (see the IVRA procedure section of this paper for correct placement and release of tourniquet at the end of surgery, and time of injection of anaesthetic solution).

The relationship between toxic reactions and excessive doses of local anaesthetic is intuitive.

Pneumatic compression of tourniquet can lead to tissue damage. Nerve is more susceptible to mechanical pressure<sup>19</sup> (thus tourniquet has to be carefully positioned and checked), whereas muscle is more vulnerable to ischaemia<sup>20</sup> (the time of tourniquet inflation must be checked with attention). Really

problems specifically related to the use of ischaemic tourniquets in an IVRA context have been seldom recorded, e.g. development of compartment syndrome<sup>21</sup>, or the loss of the limb<sup>22</sup>. In this particular case, Authors suggested three mechanisms: cannulation and injection of the radial artery; idiosyncrasic allergic reaction to the anaesthetic agent or the preservative; erroneous injection of a foreign substance (the most likely cause).

It is not the aim of this paper to go deep into side effects and complications related to the use itself of ischaemic tourniquets, as postoperative oedema, damage to the vessels in patients with atherosclerotic disease, skin damage, effects on patients with increased intracranial pressure, effects on body temperature especially in children, effects on asthmatics, metabolic changes. For more details see Bernstein and Rosenberg<sup>23</sup>.

Tourniquet pain is a traditional limitation of IVRA. It manifests itself as a dull and aching pain sensation increasing in severity with duration of inflation despite an adequate regional anaesthesia<sup>24</sup>. Even with double tourniquets pain is typically present by 40 min after initial inflation. Deflation of the tourniquet is followed by resolution of the subjective symptoms.

Theories regarding aethiology of tourniquet pain support that nerve ischaemia and compression are the main causes of pain. Unmyelinated C fibers (not active before tourniquet inflation and not affected by movement or anaesthesia) have been recognized as representing the major pathway of pain<sup>25-27</sup>. Furthermore, activity from other small diameter pain fibers (A-delta) can not be excluded<sup>27,28</sup>.

One more limitation of IVRA is the lack of postoperative pain relief after tourniquet deflation, because of the rapid washout of anaesthetic solution in general circulation. From this point of view brachial plexus analgesia has been traditionally considered to be superior compared to IVRA.

## What is New With IVRA

Most of technique adjustments improving IVRA efficiency and safety have been already listed in this paper: distal i.v. cannula,

slow injection, use of double cuff tourniquets and appropriate inflation pressure, careful deflation procedure.

One more procedural adjustment, this time intended to reduce discomfort of injection, is the use of warm anaesthetic solutions (37° C), although there is no difference in the quality and the rate of development of the block if a colder solution is injected<sup>29</sup>.

As stated recently by Viscomi<sup>30</sup>, three limitations of IVRA can be defined “traditional”: relatively slow onset time, tourniquet pain, lack of postoperative analgesia.

It is quite natural that the development of regional anaesthesia has been paralleled by the development of drugs both producing local anaesthesia and/or acting as adjuvants. In the following sub-sections pharmacologic adjuvants and new local anaesthetics introduced in clinical practice with the aim to ameliorate IVRA efficiency are discussed.

Beside the sub-sections on IVRA’s “traditional limitations” ameliorating tools, a few words are spent on drugs acting on muscle relaxation, a must for fracture reduction or tendon repair.

#### ***Pharmacologic Adjuvants Acting on Anaesthesia Onset time***

At the time when Bier described and introduced in clinical practice IVRA, the latter was described, among other things, to be rapid in its onset. This assertion is likely to have been true in the first decade of 20<sup>th</sup> century when the economic side of clinical practice was not probably a primary concern.

Now, at the beginning of 21<sup>st</sup> century, even a delay of few minutes in a surgical procedure may have a cost: shortening IVRA onset time may result in shorter operating room times, thus a greater number of operations can be performed, with an evident economic advantage. Several adjuvants have been proposed to decrease IVRA onset time.

Looking at recent published data, neostigmine seems to be the most effective<sup>31</sup>, being more or less involved in more than one crucial aspects of IVRA, reducing onset time of anaesthesia, intraoperative discomfort, request of postoperative analgesic rescue medications, and increasing motor block during surgery. The effectiveness of neostigmine in decreasing block onset time has been demonstrated adding 0.5 mg of the drug to a stan-

dard dose of prilocaine, reducing onset time of surgical anaesthesia by 60%.

Neostigmine is a drug that has been used in anaesthesiological practice to antagonize non-depolarising muscle relaxants at the end of surgery. It has been shown that intrathecal administration of neostigmine causes analgesia by inhibition of the breakdown of acetylcholine in the spinal chord. It has also been shown that there are acetylcholine receptors in peripheral nerves, responsible for the action of neostigmine in peripheral analgesia. Really, in the opinion of Turan et al<sup>31</sup>, IVRA is a quite different kind of regional block, with its own different mechanism of action: local anaesthetics and adjuvants are injected very near the surgical site but, above all, there is tourniquet ischaemia, which affects blood-nerve barrier and distorts nerve penetration by oxidative stress.

Much less important is the role of alkalisation of anaesthetic solutions in reducing the time between injection and commencement of surgery. In a 1990 study, Armstrong et al<sup>32</sup> did not find any significant difference in anaesthesia onset time between a group of patients receiving an alkalised prilocaine solution and a control group, nor studies involving lidocaine have been able to demonstrate any advantage of sodium bicarbonate use in IVRA.

Several opioids have been studied as adjuvants in IVRA<sup>33</sup>, but their ability in reducing onset time of surgical anaesthesia has not never been completely defined. Furthermore, emetic symptoms and dizziness have been reported after tourniquet deflation.

On the contrary, long acting local anaesthetic as levo-bupivacaine or ropivacaine seem to reduce significantly onset time of IVRA if compared to lidocaine or prilocaine<sup>34,35</sup>.

#### ***Pharmacologic Adjuvants Acting on Tourniquet Pain***

Tourniquet pain is typically present when surgical procedures last too long, even if a double cuff device is used. Infiltrating local anaesthetic in a subcutaneous ring beneath the tourniquet<sup>36</sup> has led to controversial results, and TENS has failed<sup>37</sup> as the use of a stellate ganglion block<sup>38</sup>.

Some pharmacologic adjuncts have been more or less recently investigated in the context of IVRA.

Ketamine has been used with some success during the '80s as the sole agent for IVRA, but it has been abandoned after a short time, since patients tended to become too much frequently unconscious after tourniquet cuff deflation<sup>39</sup>; nevertheless its local anaesthetic efficacy, if added to bupivacaine for wound infiltration, has been confirmed by more recent studies<sup>40</sup>. A 2001 paper<sup>26</sup> shows that 0.1 mg/kg ketamine added to IVRA reduces significantly tourniquet pain, decreases the need of intraoperative rescue medications and does not affect awareness after tourniquet release. It is believed that the mechanism of ketamine ability to block nociception is antagonism of NMDA (N-methyl-D-aspartate) receptors, decreasing post synaptic depolarization of unmyelinated C-fibers.

One mg/kg clonidine interacts like ketamine with local anaesthetics to inhibit synergistically C-fiber action potentials, maybe also facilitating peripheral mobilization of endogenous opioids; nevertheless it is less effective than ketamine alone<sup>26,41,42</sup>. At our knowledge, studies on combination of ketamine and clonidine as adjuvants to IVRA are not yet available.

Ketorolac added to IVRA at a dose up to 20 mg reduces tourniquet pain<sup>43</sup>, but the potential of ketorolac in causing wound haematomas by localized platelet inhibition has not yet been examined by any published study.

Neostigmine not only seems to decrease dramatically onset time of IVRA, but also seems to reduce intraoperative discomfort lowering the need of rescue medications and increasing the quality of anaesthesia<sup>31</sup>. Whether a lower than a control group intraoperative patients heart rate (~10 bpm less) is subsequent to muscarinic effects of neostigmine or a better intraoperative pain control has to be investigated.

Several studies have been carried out to investigate the efficacy of topical anaesthesia under the cuff intended to control tourniquet pain. In the last few years the attention of investigators has been pointed to topical application of EMLA cream. EMLA (Eutectic Mixture of Local Anaesthetics) cream is a mixture of lidocaine and prilocaine<sup>44</sup>. This particular formulation allows local anaesthetics to penetrate up to 0.5 cm into intact skin and finds its main indications in intravenous

cannulation, making the procedure virtually pain free, and extended skin scarification in plastic surgery. Its action is time dependent and at least one hour rest after application should be allowed before performing scheduled procedures. Unfortunately, in several studies topical application of EMLA cream resulted to have a significant analgesic effect on tourniquet pain only if compared with a no treatment control group, having a limited effect, if not at all, if compared with a double cuff technique, and no advantages if compared with topical subcutaneous infiltration anaesthesia<sup>45-47</sup>.

The systemic route has also been tested with the aim to control or reduce tourniquet pain.

Short-acting intravenous agents that can be decreased just before tourniquet deflation are better than the ones having a persistent systemic effect after pain is gone. Therefore most of opioids are not indicated for tourniquet pain relief and not enough data are available on more recent molecules, e.g. EMO (Esterase Metabolised Opioids)<sup>48</sup>. Propofol by infusion or low-dose boluses may help to alleviate discomfort, nevertheless after tourniquet release the patient may remain very somnolent and even may require respiratory assistance<sup>49</sup>. More recently a study on a priming i.v. injection of 1 mg/kg of lidocaine has shown its effectiveness in reducing tourniquet pain in IVRA<sup>50</sup>. The dose has been chosen on the basis of reports showing that low doses of lidocaine could reduce hyperalgesia<sup>51</sup> and a delay of 5 min before IVRA is necessary to obtain peak plasma levels of lidocaine at the appropriate time<sup>52</sup>. Several mechanisms are plausible explanations for the anti-hyperalgesia action of lidocaine: a study using the isolated arm technique in humans supports a peripheral analgesic effect of lidocaine<sup>53</sup>.

#### ***Pharmacologic Adjuvants Improving Postoperative Analgesia***

Because of the rapid reperfusion of the limb after tourniquet deflation, IVRA typically provides minimal postoperative analgesia. From this point of view brachial plexus anaesthesia techniques have a major advantage if compared to IVRA.

Several drugs can improve postoperative analgesia after IVRA, first clonidine and ke-

torolac. Both, beside their action on tourniquet pain, improve significantly postoperative analgesia.

Profound postoperative analgesia is evident up to six hours after tourniquet deflation if 0.10-0.15 mg/kg clonidine are added to IVRA<sup>41,42</sup>.

Reuben et al<sup>43</sup> showed in a 1995 paper that ketorolac 60 mg added to IVRA may give up to 12-16 hours of postoperative analgesia. The same group later reported in a dose-ranging study using an upper arm tourniquet that the benefits of ketorolac incrementally increase up to 20 mg and no further benefits are evident with larger doses<sup>54</sup>.

Duration and quality of postoperative analgesia are increased with levo-bupivacaine and ropivacaine, but to a lesser degree compared to clonidine or ketorolac<sup>34,55</sup>.

The same is for neostigmine: it improves postoperative analgesia, but this effect is little important, prolonging the need for postoperative analgesic medications by 20 min only<sup>31</sup>.

Finally, the only opioid used as sole anaesthetic in IVRA has been meperidine, known to have weak local anaesthetic properties. It has been very recently proposed for IVRA again<sup>56</sup>: it can not be a first choice drug, but, when local anaesthetics are contraindicated, it may be an alternative drug. Unfortunately, duration of analgesia after 40 ml meperidine 0.25% IVRA is only a little longer if compared to lidocaine 0.5% IVRA.

#### ***Pharmacologic Adjuvants Improving Muscle Relaxation***

Muscle relaxation may be useful in improving operating conditions in situations as fracture reduction on the forearm or tendon repair.

Between other paralitics, atracurium besilate (approximately 2 mg in a 70 kg adult) has been recommended when motor blockade is necessary, remembering nevertheless that after tourniquet release the return to normal extremity muscle strenght might be consistently delayed and muscle weakness can last several hours<sup>33</sup>.

A weak increased muscle block using neostigmine has been demonstrated by Turan et al<sup>31</sup>. In this case residual weakness lasts for only few minutes.

In conclusion, in a 1990 historical review celebrating 80 years from the first use of Bier's block, Hilgenhurst<sup>57</sup> has shown as the

technique has survived the test of time: never completely accepted, but never completely abandoned, and debate continues about the safest drugs and how to best control tourniquet pain. Technical modifications and the use of pharmacologic adjuvants acting synergically with the anaesthetic solution have improved without any doubt safety and efficiency of IVRA and future research will certainly include further studies on appropriate dosage of drugs, on synergic effects of co-administration of adjuvants, and on the most beneficial pharmacologic combinations.

But the true modern side of this "old dog" (the nickname is by Viscomi) could be the economic one. Compared to general anaesthesia, and plexus blocks too, IVRA is the most efficient considering waste of time and expense<sup>58</sup>.

Its intrinsic cost (lidocaine, normal saline solution, i.v. catheter, 50 ml syringe, any pharmacologic adjuvant) is small; the overall cost (shorter operating room times, faster discharge, least postoperative nursing care requirements) is minimal; the comfort for the patient (he/she can walk, eat, drink, and does not experience postoperative emetic symptoms) is maximal if a good postoperative analgesia is assured.

It is general knowledge that costs related to anaesthesia represent only a few percentage of overall hospital costs, but the Authors of this paper agree with Rizzi et al<sup>59</sup> when they asked as a conclusion of their presentation at 1995 Italian Conference on Orthopaedic Anaesthesia: "How many and wich anaesthesia techniques cost less than 5000 Italian Lire?". (Now the currency has changed: 5000 It. Lire = 2.58 Euro; one should add the increase of cost of life since 1995).

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