Intravenous regional anaesthesia (IVRA) was first described by August Bier in 1908. He observed that when local anaesthetic was injected intravenously between two tourniquets on a limb, a rapid onset of anaesthesia occurred in the area between the tourniquets and a slower onset occurred beyond the distal tourniquet. The technique did not become popular until the 1960s when it was reintroduced by Holmes. Today, the technique is slightly modified, using either a single or a double tourniquet at one site and injecting local anaesthetic as distal as possible to the cuff. The double tourniquet is used to increase safety and to reduce tourniquet pain in the awake patient, but there is potential for confusion and accidental deflation of the wrong cuff, which may lead to toxic systemic levels of local anaesthetic.

IVRA is technically straightforward and does not require specific anatomical knowledge. Published series report successful anaesthesia in 96–100% of patients with a low incidence of side-effects. It is a reliable, simple and safe method of providing anaesthesia for minor surgical procedures to the extremities if it is administered by experienced clinicians. The advantages and disadvantages of IVRA are listed in Figure 1.

### Advantages and disadvantages of intravenous regional anaesthesia

**Advantages**
- Speed of onset and rapid recovery
- Reliability (in the absence of local infection and with adequate equipment)
- Muscle relaxation
- Technical simplicity

**Disadvantages and complications**
- Poor postoperative analgesia
- Limited time of surgical anaesthesia (< 90 minutes)
- Difficulty in providing a bloodless field
- The potential of systemic local anaesthetic toxicity
- Nerve damage secondary to direct compression by the tourniquet
- Compartment syndrome and loss of limb (very rare)

**Mechanisms of action:** Local anaesthetic diffuses into the small veins surrounding the nerves and then into the vasa nervorum and capillary plexus of the nerves, leading to a core to mantle (centrifugal) conduction block in the nerves involved. Local anaesthetic then diffuses into the small nerves in the skin, blocking their conduction. The tourniquet produces ischaemia, which contributes to the analgesic action of the local anaesthetic by blocking nerve conduction and motor endplate function. 20 minutes after tourniquet application alone there will be analgesia to pinprick without the injection of any local anaesthetic. However, the speed of onset and the density of anaesthesia are greater with injection of local anaesthetic.

**Indications:** IVRA is used for surgical interventions on the hand, forearm or elbow that will not exceed 1 hour. These include manipulation of forearm fractures, excision of wrist ganglia and palmar fasciotomy. IVRA is particularly useful for tendon grafting because it enables the surgeon to observe movement and tension of the grafted tendon (after deflating the tourniquet) before closing the wound (continued anaesthesia with a wrist block). IVRA can also be used for surgery on the foot, ankle or lower leg, for example for removing plates, screws or foreign bodies. Surgery on the elbow or knee is poorly tolerated using IVRA.
**Contraindications** are mainly related to tourniquet use. Absolute contraindications include sickle cell disease, Raynaud’s disease or scleroderma, allergy to local anaesthetics and patient refusal. Relative contraindications include severe hypertensive or peripheral vascular disease, local infection, and skeletal muscle disorders or Paget’s disease (local anaesthetic may spread to the systemic circulation via venous channels in bone).

**Procedure**
Before the procedure the patient should be:
- starved for 6 hours
- monitored closely (standard monitoring applied)
- placed on a tipping trolley
- adequately informed about the procedure and have consented to it.

The equipment required for IVRA includes:
- pneumatic tourniquet (checked for leaks before the procedure) and a pressure gauge
- Esmarch bandage or Rhys-Davis exsanguinator
- local anaesthetic solution
- resuscitation equipment and drugs.

**IVRA of the arm:** A 22 G cannula is placed intravenously as distal as possible in the arm to be anaesthetized. Venous access is established in the opposite arm to allow administration of fluids or drugs if necessary. The double tourniquet (two tourniquets each 6 cm wide) or a single one (14 cm wide) is applied on the arm with generous layers of padding, ensuring that no wrinkles are formed and the tourniquet edges do not touch the skin (Figure 2).

The arm is exsanguinated either by using the Esmarch bandage or a Rhys-Davis exsanguinator. If this is impossible, exsanguination can be achieved by elevating the arm for 2–3 minutes while compressing the axillary artery. The distal tourniquet is inflated to at least 100 mm Hg higher than the patient’s systolic blood pressure (250–300 mm Hg). The proximal tourniquet is inflated to the same pressure. After ensuring inflation, the distal cuff is deflated.

Before injecting local anaesthetic it must be confirmed that no radial pulse is palpable. The local anaesthetic is then injected slowly. A standard volume for injection
into the upper limb is 40 ml, which can be increased to 50 ml in a fit, large adult. If the injection is too rapid, the venous pressure may exceed the tourniquet pressure and the local anaesthetic solution may escape into the systemic circulation. Surgical anaesthesia is usually achieved within 15 minutes. The distal tourniquet, which overlies part of the anaesthetized arm, can then be inflated and the proximal one deflated to relieve tourniquet pain.

The cuff should not be deflated until 20 minutes after local anaesthetic injection because systemic toxic doses of local anaesthetic may occur. After 20 minutes, 30% of the injected drug is fixed within the tissues and is unavailable for immediate release into the systemic circulation. Cuff deflation should be performed in cycles with deflation/inflation times of less than 10 seconds until the patient no longer exhibits signs of systemic toxicity (e.g. tingling of the lips, tinnitus, drowsiness). Severe signs of systemic toxicity include bradycardia, hypotension, ECG abnormalities, fitting and loss of consciousness. Maximum blood levels of local anaesthesia occur within 10 minutes of cuff deflation. Therefore, the patient should be monitored closely for 30 minutes following tourniquet release. With lidocaine, 2.5–3 mg/kg, and cuff deflation after 10 minutes, blood levels have been reported to be less than 2 µg/ml.

If severe CNS intoxication occurs, appropriate resuscitation guidelines should be followed. Emergency drugs (e.g. thiopental, propofol) must be readily available and 100% oxygen should be administered.

**IVRA of the leg:** the basic technique is the same as for the arm but the dose and volume of local anaesthetic has to be doubled for IVRA of the leg, which is associated with an increased potential for local anaesthetic toxicity. The tourniquet pressure must be higher in the leg (350–400 mm Hg), to occlude blood flow in the femoral artery. This may increase the occurrence of tourniquet pain. Tourniquets may be applied to the thigh (two tourniquets about 9 cm wide) or one at the calf (below the head of the fibula) and one at the thigh. The latter is for safety in case of distal cuff failure and is not usually inflated.

**Choice of drugs**

Many local anaesthetic drugs, with or without additives, have been used for IVRA, but 0.5% prilocaine, 3–6 mg/kg, is the drug of choice because it has less systemic toxicity and is partially taken up in the lungs before reaching the systemic circulation. The usual dose is 40 ml (200 mg) without epinephrine. However, the manufacturers have ceased production of 0.5% prilocaine. 1% prilocaine remains available and is licensed for IVRA, though its stability is not guaranteed if diluted. In the USA, prilocaine is unavailable and 0.5% lidocaine, 3 mg/kg, is used. If IVRA is applied to the leg a larger volume must be injected (up to 100 ml). Prilocaine can be used undiluted (maximum recommended dose is 400 mg in adults) but lidocaine is commonly diluted to lower concentrations (e.g. 0.2–0.25%).

Prilocaine can cause methaemoglobinemia but unless doses in excess of 600 mg are used it is clinically insignificant in most patients. Although one has to be aware that in patients with anaemia or cardiac conditions even small amounts of methaemoglobin can significantly impair the oxygen-carrying capacity of their red blood cells. Intravenous regional anaesthesia with prilocaine in these patients should be considered carefully for its benefits.

Other local anaesthetic agents have been used but do not provide superior analgesia or more rapid onset of block. Severe toxic reactions and death have been observed with bupivacaine and its use is contraindicated. In one study, 0.2% ropivacaine was intraoperatively as effective as 0.5% prilocaine but postoperative analgesia was prolonged; no side-effects were reported.

**Additives to local anaesthetics** have not been consistently shown to have an effect during IVRA but may increase the length of postoperative analgesia, probably because of a systemic effect following tourniquet release. The reported enhancement of IVRA with pethidine, 1 mg/kg, may reflect intrinsic local anaesthetic activity of the drug.

Experiments with the addition of muscle relaxants produced marked muscle relaxation but did not augment analgesia.

Ketamine alone appears to provide good sensory analgesia but some patients lost consciousness and exhibited the typical features of ketamine anaesthesia after tourniquet release.

Many other drugs have been studied, but only the addition of clonidine, 150 µg, an α₂-agonist, or the non-steroidal anti-inflammatory drugs ketorolac, 20 mg, or
tenoxicam, 20 mg, to the local anaesthetic solution appeared to be effective in
prolonging postoperative analgesia and relieving tourniquet pain. Guanethidine
and calcium-channel blockers have been evaluated in the context of chronic pain
management only. ◆