Neither the operative mortality nor the survival rate had changed significantly during the 15 years. The survival rate was not affected by the proportion of lobectomies among the resections, although this had risen considerably during the 15 years.

There was some correlation between the five-year survival rate and the resection rate.

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Intravenous Regional Analgesia: an Appraisal

BRYAN R. KENNEDY,*† M.B., CH.B., F.F.A. R.C.S., ASHLEY M. DUTHIE,* M.B., CH.B., D.OBST.R.C.O.G., D.A.; GEOFFREY D. PARBROOK,* M.B., CH.B., F.F.A. R.C.S.; T. L. CARR,‡ CH.M., F.R.C.S.

Brit. med. J., 1965, 1, 954–957

Widespread interest in intravenous regional analgesia was recently revived by Holmes (1963), who described a technique with the advantage of greater simplicity over methods advocated previously.

Although it had been shown by Alms in 1886 (cited by Adams, 1944) that the intravascular injection of a local anaesthetic agent was associated with analgesia in the area supplied by that vessel, this knowledge was not put to practical use until Bier (1908) published his account of venous anaesthesia for limb surgery. His method achieved considerable popularity in the next few years, and its use was widely reported.

Bier's technique, though effective, was cumbersome, and although an improvement in the form of a single-tourniquet method was described by Morrison (1931) few were then employing venous anaesthesia in this country. The subject was well reviewed by Adams (1944), but the credit for the reintroduction of the "technique" undoubtedly goes to Holmes. His series consisted chiefly of relatively short operative procedures of a type suitable for the casualty department. Our aims in the present trial were twofold: (1) to assess the suitability of the method for more extensive limb surgery, and (2) to investigate the incidence and nature of lignocaine toxicity phenomena occurring after release of the tourniquet.

Materials and Method

The technique described by Holmes was used. An indwelling needle was inserted in a vein before application of an Esmarch bandage and tourniquet. After exsanguination of the limb lignocaine was injected.

Patients due for peripheral limb surgery were interviewed, and, after explanation of the method, were asked whether they would agree to have their operation performed under analgesia of this type. Premedication, usually with an appropriate dose of papaveretum and hyoscine, was given in over three-quarters of the cases. Plate electrodes were attached to each limb in the anaesthetic room and connected to a direct-writing E.C.G. machine. A von Recklinghausen oscillotonometer cuff was put on the arm not scheduled for surgery and the systolic blood-pressure recorded. Difficulty was occasionally experienced through Gordh needles becoming dislodged from veins during application of the Esmarch bandage; polyvinyl chloride catheters inserted through a Macgregor (1960) introducing needle or fine-gauge Intracaths were occasionally used. After injection of the lignocaine and positioning the patient standard lead E.C.G. tracings were obtained. During surgery the blood-pressure was recorded by the oscillotonometer on at least four occasions.

After completion of surgery the tourniquet was deflated and an E.C.G. tracing begun: this ran for two and a half minutes, or longer if any irregularity was noticed. The blood-pressure was recorded at half-minute intervals during this period, and the appearance of the patient was closely observed. Before return to the ward the patients were asked whether they had experienced any symptoms on release of the tourniquet and whether they would have preferred to "be asleep" during surgery. The quality of analgesia and of operating conditions was recorded, as were the time of injection of lignocaine, the time of commencement of surgery, and the time of release of the tourniquet. A specially prepared cyclostyled form was completed with these details plus any other relevant points in every case.

Results

Intravenous regional analgesia was used in 77 patients. Analgesia was achieved for a wide range of surgical procedures on the hand, including median-nerve decompression, tendon repairs, and digital reconstructive operations. In 46 of the 77 cases E.C.G. records were obtained as described above.

Analgesia.—This was classified as: complete in 78%, good in 7%, moderate in 12%, and poor in 3%. Analgesia was

* The Department of Anaesthetics, Aberdeen Royal Infirmary.
† Present address: Department of Anaesthetics, Cardiff Royal Infirmary.
‡ Consultant Orthopaedic Surgeon, Aberdeen Royal Infirmary.

graded as good when discomfort, judged by movement and facial expression, was slight and no complaint of pain was made. It was graded as moderate when minor discomfort was persistent and complaints of pain were made: in this category, however, the pain was not severe enough to interfere with the performance of the operation. Poor analgesia interfered with the satisfactory conduct of the operation, necessitating supplementary infiltration with lignocaine or, if this was not successful, general anaesthesia.

Operating Conditions.—Venous ooze from the operation site was classified by the surgeon into the following categories: none in 31%, slight in 60%, moderate in 4%, and considerable in 5%. When venous ooze was absent or "slight" operating conditions were excellent. When "moderate" oozing was present the operation field was more congested, but not enough to cause any significant technical difficulty. "Considerable" oozing was troublesome.

Preference.—Each patient was asked whether he would prefer general anaesthesia to intravenous regional analgesia if he was to have the same operation again, and the replies were as follows: 19% would have preferred general anaesthesia, 64% would have preferred intravenous regional analgesia, and 16% had no preference.

Dosage of Lignocaine.—Except in four of the earlier cases, where 1% lignocaine was used, 0.5% lignocaine was employed throughout, and was found to produce satisfactory analgesia. In this series the average dose was 182.5 mg. of lignocaine. The maximum dose was 350 mg., but this was exceptional, and the next highest was in two patients who both received 300 mg.

Time Interval between Injection of Lignocaine and Release of Tourniquet (Injection–Release Interval).—The average injection–release interval in 77 cases was 26½ minutes.

Neurological Signs of Lignocaine Toxicity

Seven patients (9%) became drowsy within 30 seconds of release of the tourniquet, and two of these lost consciousness. In no patient was twitching or convulsion seen.

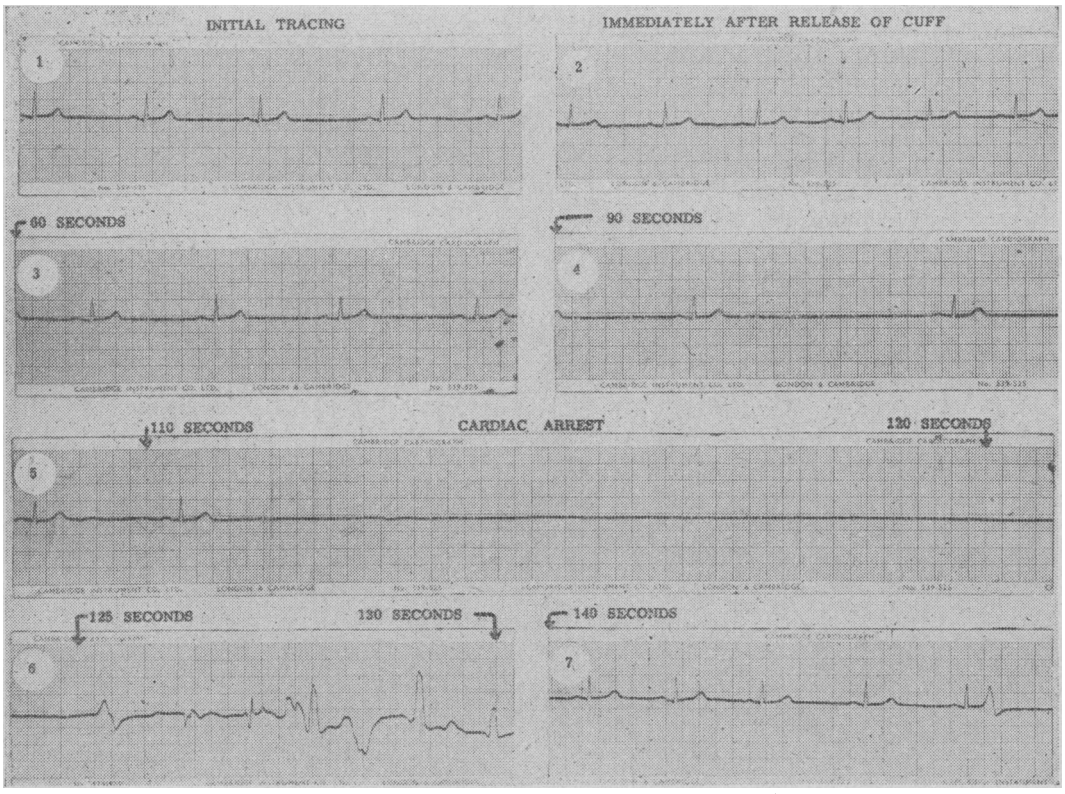
Cardiovascular Signs of Lignocaine Toxicity

Changes in Pulse Rate.—A fall in pulse rate of over 10 beats per minute was noted in 15% of cases. In only one instance did the pulse rate rise after release of the tourniquet, this patient developing a sinus tachycardia of 140 per minute from a resting level of 72 per minute.

Blood-pressure Changes.—A fall in blood-pressure was quite commonly observed after release of the tourniquet, occurring in 21% of the cases. In only one instance was a rise of blood-pressure observed. Changes were not considered to be of significance, and were not included unless the average of pre-operative and post-operative readings varied by more than 10 mm. Hg.

E.C.G. Abnormalities.—Of the cases studied with the E.C.G., 15% showed some deviation from their pre-operative appearance. Three showed ventricular extrasystoles, one atrial extrasystoles, one transient S-T segment depression, and one transient nodal rhythm. In addition one case of cardiac arrest in asystole occurred.

The patient, a 12-stone (76.2-kg.) man aged 41, with no significant previous medical history except for mild chronic bronchitis, was admitted to hospital for median-nerve decompression. Premedication was with papaveretum 15 mg. and hyoscine 0.3 mg. administered intramuscularly one hour pre-operatively. Analgesia was produced by intravenous injection of 38 ml. of 0.5% lignocaine. Thirty minutes after injection the tourniquet was released. At 30 seconds after release the blood-pressure had fallen from 130/75 to 110/60, and at 60 seconds to 100/60 mm. Hg. At 68 seconds the pulse rate had fallen to 40 from a pre-operative level of 48 per minute. At 110 seconds after release of the tourniquet asystole was seen to develop quite suddenly on an E.C.G. tracing which had been previously normal except for the sinus bradycardia (see Fig.). External cardiac massage was begun, and the first abnormal complexes were seen 15 seconds after cardiac arrest. The E.C.G. tracing became normal eight seconds later, and the patient's respirations, which had ceased at the time of the arrest, restarted when his lungs were inflated several times with oxygen. Within one minute of the arrest his blood-pressure had risen to 110/60 mm. Hg, and he had regained full consciousness. An E.C.G. and an E.E.G. recorded on the following day showed no abnormality, and the patient was discharged home, having apparently suffered no ill effects from his period of cardiac arrest. In view of this arrest it was not felt justifiable to continue the trial.



E.C.G. tracing showing sudden development of asystole.

Discussion

There is no doubt that with this technique analgesia of the limbs adequate even for major and prolonged surgery can be achieved speedily and simply: in 85% of the cases in this series analgesia was recorded as being complete or good, while in less than 3% was it classed as being poor. Surgical procedures lasting one hour and over were performed several times, and in no case was waning of analgesia observed. Operating conditions achieved were almost invariably good, as was reflected in the fact that venous ooze was nil or slight in 91% of the cases.

Sadove *et al.* (1952) have classified toxic reactions to

local analgesic drugs in normal individuals into (*a*) central, and (*b*) peripheral effects. In the former stimulation of the cerebral cortex and medullary centres was followed by depression, and in the latter the cardiovascular and respiratory systems were involved. Cortical effects ranging from vertigo to complete loss of consciousness were seen in our series. Moore and Bridenbaugh (1960) believe the bradycardia associated with overdosage of local analgesic drugs to be secondary to an initial tachycardia and to be caused by myocardial oxygen lack ; but this sequence of pulse-rate changes was not seen, nor was there any other suggestion of hypoxaemia, and the bradycardia encountered in 15% of the cases was attributed to medullary-centre stimulation. E.C.G. signs of deteriorating cardiac activity were seen in 30% of the cases described by Foldes *et al.* (1960) in which acute toxicity experiments with lignocaine were carried out, and are also described by Steinhaus (1957) and by Stewart *et al.* (1963). In our series a variety of E.C.G. changes, including S-T segment depression, atrial and ventricular extrasystoles, nodal rhythm, and sinus bradycardia were associated with release of the tourniquet, as was a fall in the systemic blood-pressure in over 20% of the cases studied.

There seem to be several factors involved in the appearance of toxic effects upon release of the tourniquet. It would seem clear that the most important causal factor is the dosage of lignocaine employed. Holmes (1963) advises the use of 200 mg. of lignocaine for an upper limb, and up to 400 mg. for a lower limb. Bell *et al.* (1963) have found that with a dose of 3 mg./kg. mild neurological symptoms were present in half their cases, and that bradycardia and E.C.G. changes were often seen: these changes were not seen when the dosage was halved, but then analgesia was insufficient unless limb ischaemia, produced by inflation of the tourniquet, was effected at least 20 minutes before injection of the lignocaine. This modification would seem to make the method tedious and time-consuming to the administrator and very unpleasant for the patient. The use of dosage as high as 800 mg. of lignocaine in two cases is mentioned by Dawkins *et al.* (1964). In our series the dosage recommendations of Holmes (1963) were followed, the maximum quantity of lignocaine used being 350 mg., and the average 182.5 mg. This dosage was found to give excellent results, and additional lignocaine would appear to increase the risk of the procedure without significantly augmenting the analgesia achieved.

The other major item involved in the occurrence of side-effects with this technique appears to be the injection–release interval. The importance of this was stressed by earlier workers. Bier (1908) thought that no matter how short the surgical procedure the tourniquet should not be removed for 20 minutes at least. Morrison (1931), after experimental work on cats, recommended that the minimum interval between injection and release of the tourniquet should be 30 minutes. Adams *et al.* (1964) thought that the negligible incidence of toxic effects seen in their series was largely due to the fact that the lignocaine had been in contact with the tissues for about one hour. In the series of Dawkins *et al.* (1964) it is tempting to try to correlate the high incidence of severe neurological side-effects with the short injection–release interval (usually under 10 minutes) ; but the high dosage they mention makes assessment of the relative importance of the two factors difficult.

In our series the overall average injection–release interval was 26½ minutes, and though the average for the cases showing any symptoms or sign of toxicity was no less than this, we believe that it may be wise to adopt a minimum injection–release time. Perhaps this might be 30 minutes, although even this cannot be taken as a guarantee of absence of toxic effects upon release, as is evidenced by the case of cardiac arrest described above.

Sensitivity as opposed to overdosage is probably a very rare cause of lignocaine toxicity manifestations. Moore and Bridenbaugh (1960) believe that in less than 2% of cases in which systemic symptoms arise after administration of a local analgesic drug can a true allergy to the drug be imputed. In the other 98% overdosage is responsible. de Clive-Lowe *et al.* (1958) used lignocaine intravenously as a supplement during general anaesthesia in many thousands of patients without seeing a single case of sensitivity to the drug.

Although the liver has been shown to play an important part in the metabolism of lignocaine (Sung and Truant, 1954 ; Geddes, 1958), the rate of metabolism is probably too slow to affect significantly the peak levels of the drug reached after release of the tourniquet. It may, however, be a factor of importance where bilateral procedures are carried out. The additive effects of previous administration of lignocaine shown by Bromage and Robson (1961) would be considerably magnified when associated with hepatic insufficiency.

Release of metabolites, including potassium, may be a remote contributory cause of some of the toxic effects associated with release of the lignocaine into the general circulation. In four patients in whom the tourniquet had been in place for over half an hour blood samples taken from either arm after its release failed to show a rise of serum potassium of over 1 mEq/litre.

In view of the high incidence of toxic phenomena associated with this technique, using lignocaine, we no longer feel justified in continuing to employ it. It may be that further developments in the field of local analgesic drugs will produce one safe to use in this manner, and in this context it is interesting to compare the mild and infrequent sequelae recorded by Hooper (1964), using prilocaine, with those in the parallel trial of Dawkins *et al.* (1964) where lignocaine was used.

Summary

A clinical trial was made of intravenous regional analgesia using lignocaine in 77 patients undergoing operations on the hand. The average dose of lignocaine administered was 182.5 mg., and the average time between injection and release of the tourniquet was 26½ minutes. The quality of the analgesia and operating conditions and the incidence of toxic side-effects were carefully recorded. Good analgesia was obtained in 85% of patients and good operating conditions in 91%. Neurological side-effects occurred in seven patients, two of whom became unconscious after release of the tourniquet. Cardiovascular side-effects also occurred, a fall in blood-pressure and slowing of the pulse rate being frequently noted. Seven patients were found to have arrythmias or other changes in the E.C.G., and one patient developed cardiac arrest in asystole which was treated successfully with external massage.

The previous literature on intravenous regional analgesia is reviewed. In conclusion, we do not feel justified in continuing to use this technique with lignocaine in view of the high incidence of toxic phenomena.

We wish to thank Professor S. C. Frazer, department of chemical pathology, for the serum potassium estimations, and Dr. W. N. Rollason, department of anaesthetics, for advice in the preparation of this paper.

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Regional Anaesthesia by the Intravenous Route

CHARLES SORBIE,* M.B., F.R.C.S.ED.; PESI CHACHA,† M.B., F.R.C.S.ED., F.R.C.S.GLASG.

Brit. med. J., 1965, **1**, 957–960

A satisfactory technique for the production of intravenous regional anaesthesia was first described by Bier (1908, 1909, 1910) but, surprisingly, it did not achieve any measure of popularity. It has recently been revived by Holmes (1963). The technique is simple and it provides perfect anaesthesia for short procedures to the distal parts of the limbs. It is particularly suitable for a busy casualty department, as no premedication or other preparation is necessary, and the patient is ready to leave hospital immediately after completion of the operation.

The method has been used on 128 patients without ill-effect and with few failures. The technique is described below, and an attempt made to explain the mechanism by which anaesthesia is produced.

Method

The patient lies on an operating-table or trolley. No premedication is required. A sphygmomanometer cuff is wrapped round the upper part of the arm. It is inflated until venous distension is produced. The back of the hand is cleaned with antiseptic solution and a Gordh needle is inserted into a dorsal vein. The sphygmomanometer cuff is then deflated and the arm is elevated to allow blood to flow out of the limb. If complete exsanguination is required for the operation an Esmarch bandage can be used. After about one minute the cuff is reinflated to a point well above arterial pressure, usually about 200–250 mm. Hg, and 20–40 ml. of 0.5% plain lignocaine, depending on the size of the limb, is then injected through the Gordh needle.

When anaesthesia is complete a second sphygmomanometer cuff is applied around the arm immediately distal to the first cuff. It is also inflated to above arterial pressure. The proximal cuff is then removed and the needle is withdrawn from the vein. It is necessary to use two tourniquets, as the tissues under the first tourniquet are not anaesthetized.

As the anaesthetic is injected the patient may experience a feeling of warmth in the arm or hand, followed by tingling in the fingers. Blotchy discoloration of the skin may be seen over small areas near superficial veins. After an interval of three to five minutes patches of numbness appear, and these gradually spread until the whole forearm is anaesthetic.

The technique for producing anaesthesia of the leg is similar to that for the arm except that 40–80 ml. of lignocaine is required. The veins on the dorsum of the foot are used for the injection and the tourniquets are applied to the thigh.

When the tourniquet is removed at the end of the operation, sensation is restored rapidly, usually in about five minutes.

Results

The ages of the 128 patients who had regional anaesthesia for surgical procedures (Table I) ranged from 12 to 86 years.

Anaesthesia was considered to be successful when the patient did not experience any discomfort at the site of operation during the surgical procedure.

TABLE I.—*Type of Lesion for Which Anaesthesia was Used*

Fractures of lower end of radius	48
Hand and finger infections	43
Injuries to hand and fingers and lacerations of forearm	22
Olecranon bursitis	4
Partial rupture of triceps tendon	1
Elbow dislocations	3
Abscess of leg	1
Abscess of foot	1
Ingrowing toenail	1
Fractures of the os calcis	3
Carpal-tunnel compression	1
	128

Fifteen patients complained of a greater or lesser degree of discomfort at the operation site. Ten of these required additional anaesthesia for the completion of the operation. In addition, 10 patients complained of pain under the tourniquet varying from mild to severe. In nine, only one tourniquet had been used. The remaining patient, a 15-year-old boy, had two tourniquets applied, but his operation lasted 45 minutes. Tourniquet discomfort has been almost eliminated by the use of two tourniquets.

It is evident (Tables II and III) that a much higher percentage of unsuccessful anaesthetics occurred with cubital injections

TABLE II.—*Mean Time for Complete Anaesthesia was Calculated Only for Successful Anaesthetics*

Site of Injection	No. of Injections	Mean Time for Complete Anaesthesia	No. of Unsuccessful Anaesthetics
Cubital	44	11·5 mins.	10 (22·7%)
Middle of forearm	10	8·1 mins.	2 (18·1%)
Leg	1		
Hand and wrist	68	7·3 mins.	3 (4·1%)
Foot and ankle	5		

TABLE III.—*Unsuccessful Anaesthetics*

Site of Injection	Type of Lesion
10 Cubital	7 Colles fractures; 2 Hand injuries; 1 Olecranon bursitis
1 Forearm	1 Olecranon bursitis
1 Long saphenous (equivalent to forearm)	1 Os calcis fracture
2 Hand	1 Hand injury; 1 Olecranon bursitis
1 Dorsum of foot (equivalent to hand)	1 Os calcis fracture

* Senior Orthopaedic Registrar, Western Infirmary, Glasgow.
† Orthopaedic Registrar, Western Infirmary, Glasgow.