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The Centennial of Spinal Anesthesia

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ON August 16, 1898, August Bier (1861-1949) performed the first operation with spinal anesthesia at the Royal Surgical Hospital of the University of Kiel, Germany. The patient, a 34-yr-old laborer, was to undergo resection of a tuberculous ankle joint, but he had suffered severe adverse effects from previous general anesthesia. Therefore, Bier suggested giving "cocainization of the spinal cord" a try. He injected 15 mg of cocaine intrathecally before performing the operation. Intraoperatively the patient felt no pain at all. Some vomiting and headache were present after surgery, but the adverse effects were minimal compared with the patient's previous experience.

Without doubt, this event was a milestone of the history of our specialty. Spinal anesthesia was the first major *regional* technique introduced into broad clinical practice. The only *local* anesthetic techniques to precede it were topical anesthesia of the eye (Carl Koller in 1884¹) and infiltration anesthesia (Carl-Ludwig Schleich in 1892²). Other regional techniques, such as axillary or supraclavicular brachial plexus block (Georg Hirschel³ and D. Kulenkampff⁴ in 1911), were first described many years later. Spinal anesthesia was introduced into clinical practice even before the breakthrough of orotracheal intubation (Franz Kuhn in 1901⁵).

The original paper written by August Bier (1899⁶) is not only part of our anesthesiology heritage—it is also fascinating reading (an English translation of Bier's original manuscript is found as an appendix to this report). It contains marvelously detailed descriptions of the first

six patients operated on under spinal anesthesia, of the experiments Bier performed on himself and on his colleague Hildebrandt, and of further clinical experience regarding spinal anesthesia. It is interesting to note that Bier did not start with the "self-experiment," as often stated, but rather used the self-experiment to further investigate some of the problems he encountered with the first administration in patients. Many specific points in Bier's description of spinal anesthesia are still pertinent 100 years later:

- Spinal anesthesia will only succeed if there is at least some backflow of cerebrospinal fluid.
- Post-dural puncture headache is the most common problem after spinal anesthesia.
- Post-dural puncture headache is probably related to the amount of cerebrospinal fluid lost.

Karl August Bier was born on November 24, 1861 in Helsen, a small village in the center of Germany. He studied medicine in Berlin, Leipzig, and Kiel. His most important clinical lecturers in Kiel were Friedrich von Esmarch and Heinrich Quincke:

- Friedrich von Esmarch (1823-1908) was one of the most famous surgeons of his time. Among his achievements were the invention of a technique ("Von-Esmarch-Handgriff [manoeuvre]") to keep the airway open in unconscious patients—thus preventing some of the major complications of chloroform anesthesia, and the invention of a technique for bloodless operations⁷ ("Esmarch'sche Blutleere," Esmarch's bandage).
- Bier's lecturer in internal medicine was Heinrich Quincke (1848-1922), who introduced the technique of lumbar puncture into clinical practice.^{8,9}

In 1888, Bier was awarded the M.D. degree on the basis of his dissertation thesis on syphilomata of muscle tissue. He started his career as a surgeon in the department of von Esmarch and soon became his vice chairman. In 1899, the year of his first publication on spinal anesthesia, he was appointed head of the university department of surgery in Greifswald. A few years later,

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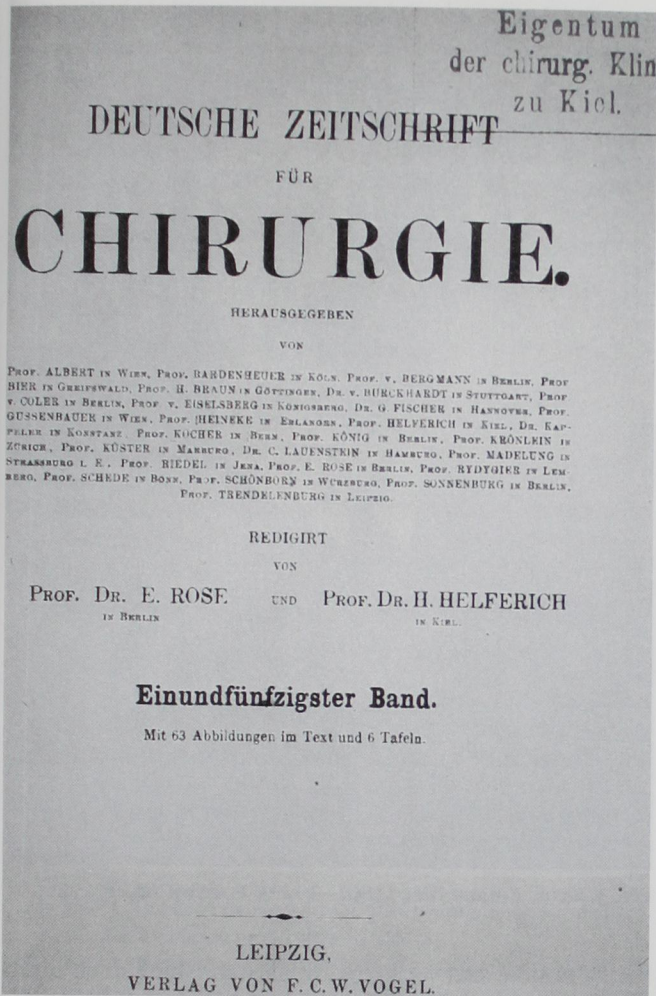


Fig. 1. Masthead Page, Deutsche Zeitschrift für Chirurgie, Volume 51, 1899

he moved to the chair of surgery at the University of Bonn, and in 1907 succeeded the famous surgeon Ernst von Bergmann at the University in Berlin. In the following years, Bier, like von Bergmann before him, became Germany's preeminent surgeon.

In 1908, August Bier described another technique of regional anesthesia—intravenous regional anesthesia (also known as a "Bier's-block").^{10,11} It is evident that both of Bier's innovations in anesthesiology were based on ideas of his lecturers: Quincke's lumbar puncture for spinal anesthesia and Esmarch's bandage for intravenous regional anesthesia. Being a surgeon, Bier believed, however, that his contributions to the more classical fields of surgery were more important, such as his articles on amputation techniques, hyperemia for the treatment of tuberculosis and other diseases, collateral

circulation, and so on. In addition to his many scientific and clinical papers and lectures, he made further contributions to non-medical topics. Bier developed new concepts for forestry and the famous "steel-helmet" for the German soldiers in World War I. After the first world war, Bier was a strong promoter of physical exercise and was the founder of Germany's first academic school of sports in Cologne. Nevertheless, his most popular publication was a philosophical one: "Die Seele" ("The Soul"),¹² first published in 1939.

Despite the fact that August Bier made some major contributions to the armamentarium of anesthesiology, he is probably not the father of anesthesiology in Germany. Anesthesiology becoming a specialty in its own right in Germany was obviously not his favorite vision: "In America they have professional anesthesiologists.

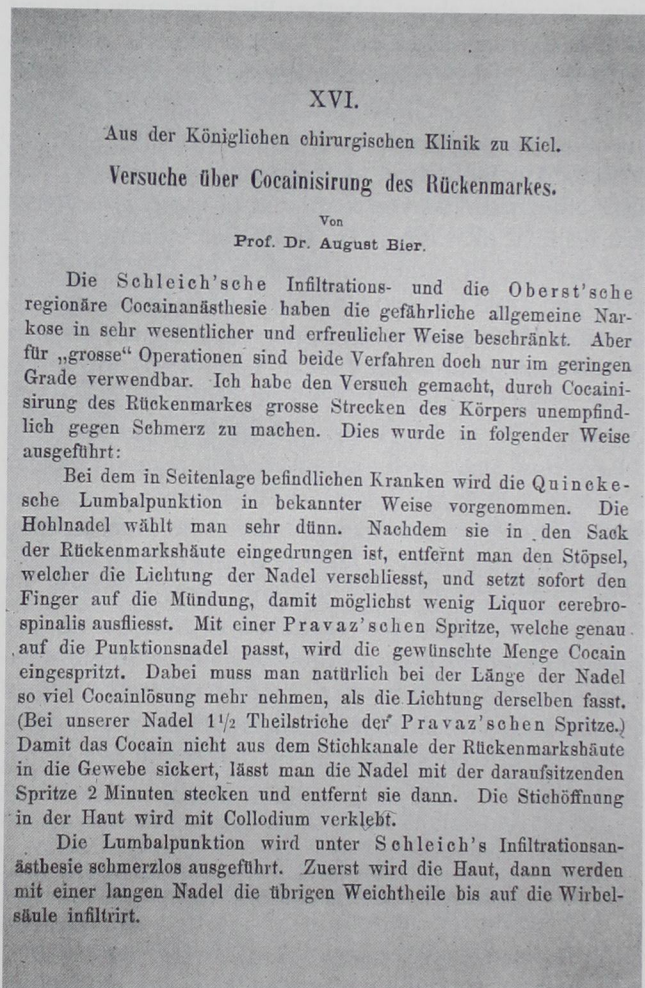


Fig. 2. First Page of Bier's article.

Even in Germany this institution is often praised. I can't think of anything more boring. . . ." (cited from K. Vogeler [1942],¹³ translation by the present author). August Bier retired from office after his seventieth birthday, but he continued to be active in his beloved woods and retreated to his forest domain. He died on March 12, 1949, aged 87 years.

Bier himself was far from being completely enthusiastic about his own discovery, spinal anesthesia. Of course, he did some further research on the subject and continued to report his further clinical observations.¹⁴⁻²⁰ He often stressed that the technique, and the local anesthetic agent itself, needed improvement and that spinal anesthesia could not become a truly established technique until the incidence of side effects—especially post-spinal headache—was reduced.

From the years soon after Bier's description of spinal anesthesia up to the present day, there has been continuing discussion about whether Bier was truly the first to use spinal anesthesia.²¹⁻²³ Some experts give this credit to the New York neurologist J. Leonard Corning. Even Bier's former assistant August Hildebrandt published some statements in favor of Corning.²² Corning described a technique of interspinal infiltration with local anesthetics for the treatment of "spinal weakness and seminal incontinence" and other indications outside the field of surgery. At least in his first reports of 1885 and 1888 he used 60 minims (0.0616 ml) of a 3% solution of cocaine or 100 minims of 1.5 grain cocaine in 100 minims of water (*i.e.*, 111 mg or 97 mg of cocaine, respectively).^{24,25} This calculation suggests that Corning most probably injected the local anesthetic in the epidural space as for spinal anesthesia much smaller doses are required (Bier used 10–15 mg). It was not until 1900, after Bier had published his first reports, that Corning claimed to have performed "real spinal" with 10 minims of a 2% solution (approximately 12 mg).²⁶ How August Bier managed to find the proper dose of cocaine for spinal anesthesia from the first patient on remains somewhat unclear because he does not describe any experiments in animals or any dose-finding studies. Nevertheless, the important fact is that August Bier realized the significance of his innovation and was, without doubt, the first ever to use spinal anesthesia for *surgery*.

Spinal anesthesia has had its ups and downs regarding clinical use during our century. Nevertheless, spinal anesthesia has nowadays gained worldwide popularity, and in the art and craft and complexity of modern anesthesiology, it is still one of the basic skills. Spinal anes-



Fig. 3. Prof. August Bier (1861–1949). Portrait taken 1906.

thesia is alive and well (*e.g.*, it is establishing itself internationally as the preferred method of anesthesia for cesarean section). Its centennial is a very welcome opportunity to look back at the roots of its history.

The English translation of Dr. Bier's article was done by Dr. Raymond Fink, and is part of The History of Anesthesiology reprint series published by the American Society of Anesthesiologists/Wood Library-Museum of Anesthesiology. The author thanks Patrick Sim of the Wood Library for his assistance in the preparation of this article, and Dr. Thomas Smith, London, for his help and humor while preparing the English version of this text.

This article is dedicated to the author's clinical teacher (lecturer), Professor Dr. Jürgen Wawersik, on the occasion of his 65th birthday in August 1998.

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An English version of the German titles is offered (as translated by the author) in italics.

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Researches on Cocainization of the Spinal Cord† by Dr. August Bier

General anaesthesia is dangerous, and its scope has fortunately and none too soon been greatly reduced by the advent of Schleich's infiltration anaesthesia and Oberst's regional method of cocainization. However, for truly major operations those two approaches have only limited application. I have therefore sought to render large areas of the body insensitive to pain by cocainizing the spinal cord. This was investigated as follows:

Lumbar puncture was undertaken by Quincke's technique in suitable patients. One selects a very fine hollow needle. After penetrating the dural sac one removes the occluding wire and immediately places a finger over the opening in order to minimize the escape of cerebrospinal fluid. The desired solution of cocaine is then injected with a Pravaz syringe that exactly fits the needle. One must of course include enough extra volume to fill the lumen of the needle (one and one-half divisions of the syringe in the case of our needle). To avoid escape of cocaine through the dural puncture site into the tissues one leaves the needle and attached syringe in place for two minutes before removing them. The skin puncture is then sealed with collodion.

The lumbar puncture is performed painlessly with the aid of Schleich infiltration anaesthesia, infiltrating first the skin and then, with a long needle, the soft tissues down to the vertebral column.

The cocaine spreads in the cerebrospinal fluid and reaches not only the surface of the cord but, most importantly, the unsheathed nerves that traverse the space, and also the ganglia. I am of the opinion that the striking abolition of pain achieved by small amounts of cocaine solution injected into the subarachnoid space is brought about by an action on these nerves and perhaps also on the ganglionic cells. The term "cocainization of the spinal cord" is a conveniently brief way of describing this.

The following are the cases in which I have performed cocainization of the spinal cord:

1. A 34-year old laborer who was hopelessly riddled with tuberculo-

† Translated from Bier, August: Versuche ueber Cocainisierung des Rueckenmarkes. Deutsche Zeitschrift fuer Chirurgie, 1899; 51: 361-8

sis in many parts of the body. He had previously undergone many operations. Although no general improvement could be expected, a resection was necessitated by high fever and painful, deep-seated tuberculous ulceration of the foot.

He had suffered many complications from the earlier general anesthetics and dreaded another one. I therefore proposed spinal cocaine-ization to him, and he accepted. On August 16, 1898, at 8:35 a.m. I injected 3 cc. of a 0.5 per cent solution of cocaine (a total of 0.015 g) as described above, and waited twenty minutes. By then the lower half of the body had lost all sensibility, including that of touch. Pinprick, pinching and other painful stimuli were appreciated only as ill-defined pressure. I carried out the resection of the ankle joint. The talus was removed, the lower ends of the leg bones were sewn off, and the tuberculous capsule excised. The patient groaned during the operation but remained motionless and explained later that he had not felt any pain but was aware that something was being done to his sick foot. His pulse speeded up but nothing else changed during the operation. Two hours after the operation his back and left leg became painful and the patient vomited and complained of severe headache. The pain and vomiting soon ceased, but headache was still present the next day.

2. A seventeen year-old baker suffered from osteomyelitis of the tibia. On August 20, 1898 at 10:11 a.m. 0.5 cc. of a 1 per cent solution of cocaine was injected as described, and at 10:13 a.m. a further 0.5 cc. (a total of 0.01 g of cocaine). Pain sensibility was lost in 5 minutes, but touch was still unimpaired. The operation began at 10:19 a.m. The tibia was laid open with a chisel throughout almost its entire length and several sequestra were removed. The patient felt nothing whatsoever of the procedure, which was over by 10:34 a.m. At 10:28 the patient vomited.

Sensibility was tested at 10:38 a.m. It was absent from the lower part of the body up to the following limits: anteriorly, in the nipple line, up to the level of the 8th rib on the right and the 5th rib on the left, posteriorly, in the scapular line, up to the 9th rib on the right and the 8th rib on the left. Neither pinprick nor touch was appreciated in the affected region.

At 10:52 a.m. sensation began to return. This delighted the patient, who laughed and chattered excitedly. When he was asked what made him so happy he explained it was because he had perceived nothing whatsoever of the operation. His excitement lasted 5 minutes. The pulse was full and strong, and the rate 120.

At 12 noon he developed a severe headache and vomited twice more during the afternoon.

The headache continued at intervals until August 22nd and tended to be most severe toward the end of the day. Headache recurred on August 26th and 28th, and vomiting on the 28th. Thereafter he remained well.

3. A fourteen-year old boy suffered from tuberculous ankylosis of the left knee joint, which was bent almost to a right angle. On August 20th, 1898 at 9:20 a.m. I injected an 0.5 per cent solution of cocaine and again at 9:22 a.m. (a total of 0.01 g cocaine) and then immediately performed a Helferich arched resection of the ankylosis. The ends of the bones were nailed together with three nails. The patient was extremely apprehensive and complained of pain during the operation but tolerated all the manipulations without resistance and probably did not actually feel pain. The next day he developed a backache and a pain in the left leg, which lasted until August 27. On August 26 he experienced a transient headache. There were no other problems. The boy complained unceasingly and was too backward and uncooperative for any tests of sensation.

4. On August 22, an eleven-year-old boy was operated on for tuberculous inflammation of the ischium. At 9:09 a.m. a half syringe of 1 per cent cocaine solution (0.005 g of cocaine) was injected in the usual manner. By 9:16 a.m. all sensation had ceased in the legs and buttocks. Stabs with a knife-point went unnoticed. The operation began at 9:18 a.m.; it consisted partly of curetting and partly of removing the tuberculous ischial tuberosity with bone cutting forceps. The lad was agitated by the operation, but explained that the cutting felt to him like scratching. Otherwise he felt nothing. A test of sensibility, performed at 9:36 a.m., showed that the entire body except the head was insensitive. Pricking evoked lively evidence of pain over the head but none whatsoever over the neck and arms. Slight touch sensibility, however, was retained. The pulse remained strong and regular throughout the operation. There were correspondingly few after-effects. The patient complained of pain at the site of injection on the day of the operation, but this disappeared the next day. There were no other complications; in particular, there was no headache or vomiting.

5. A thirty-year-old brewery salesman sustained a compound fracture of the right femur on August 14, 1898, about a hand's breadth above the knee joint. The wound suppurated. On August 24th at 7:47 a.m. I injected one syringe of a 1 per cent solution of cocaine in the usual manner (0.01 g cocaine). At 7:59 a.m. I made a long lateral incision to expose the ends of the fractured bone. These lay partly comminuted and devoid of periosteum. I merely brought them to the surface, sawed them off, opened several pockets of pus, and packed the wound. The patient did not feel anything of the operation, which speaks volumes, because exteriorization of a fractured of the femur close to the knee is a very forcible procedure. However the patient had no complications either during or after the operation, except for a quite minor headache which began the next morning and quickly went away.

6. A servant girl aged seventeen suffered from osteomyelitis of the upper end of the left femur. On August 27 at 8:20 a.m., I injected in the described manner a half syringe of 1 per cent cocaine solution (0.005 g of cocaine). I began the operation at 8:40 a.m. I made incisions along the medial and lateral sides of the thigh and exposed the bone which lay bare of periosteum in the depths of the abscessed area. The patient whispered during the operation, but explained later that she had not felt any pain. She suffered no complications from the cocaine injection, either during or after the operation.

These cases demonstrate that a small volume of cocaine solution introduced into the dural sac renders a large part of the body insensitive, enabling major operations of that region to be performed without causing pain. However in most such cases important complications have occurred which equalled those that usually follow general anesthesia. To reach a well-informed opinion I decided to perform some investigations on my own body:

On August 24, 1898 I had Dr. Hildebrandt perform a lumbar puncture on me and inject a half-syringe of a 1 per cent solution of cocaine. The puncture was performed as described above without causing any pain except for a brief twinge in one leg when the needle pierced the dura. The Pravaz syringe failed to fit the needle used for puncture. During the efforts to achieve a fit a lot of cerebrospinal fluid escaped and most of the cocaine to be injected was lost. The result was that no insensibility was achieved; small incisions and needle puncture everywhere elicited pain.

Because of the considerable loss of cerebrospinal fluid I postponed repetition of the procedure on me until a later occasion, but Dr. Hildebrandt immediately offered to have the same study performed on

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himself without delay. I will describe the circumstances meticulously because the study was successful and its performance on a well-informed physician resulted in an excellent account of the action of cocaine on the spinal cord.

I introduced the lumbar puncture needle after the usual Schleich infiltration anesthesia. H. experienced this as pressure, not pain. At 7:38 p.m. I injected 0.5 cc. of a 1 per cent solution of cocaine (0.005 g). This resulted in H. experiencing a feeling of warmth in both legs. The pulse rate was 75 per minute.

After 7 minutes: Needle pricks in the thigh were perceived as pressure; tickling of the sole of the foot was barely felt.

After 8 minutes: A small incision in the skin of the thigh was felt as pressure; introduction of a large, blunt, curved needle into the soft tissues of the thigh produced no pain at all.

After 10 minutes: A long needle was pushed down to the femur without evoking the least pain. Pinching the skin severely and seizing and crushing it in toothed forceps was experienced as pressure.

After 11 minutes: Pain sensibility was markedly diminished in the arm.

After 13 minutes: A burning cigar applied to the legs was felt as heat, but not as pain. Ether produced a feeling of cold.

After 15 minutes: Tickling the sole of the foot was no longer felt as such but only as movement. Pinching the leg was felt as light pressure but pinching the upper chest was very painful.

After 18 minutes: Strong pinching was hardly felt at all below the nipples.

After 20 minutes: Avulsion of pubic hairs was felt simply as elevation of a fold of skin, but avulsion of chest hair above the nipples on the contrary was very painful. Strong hyperextension of the toes was not unpleasant.

After 23 minutes: A strong blow to the shin with an iron hammer did not provoke pain.

After 25 minutes: Strong pressure and traction on the testicles was not painful.

After 32 minutes: Tickling the sole of the foot was perceived as faint touch. Needling down to the femur and strong pressure on the testicle were not painful.

After 40 minutes: Strong blows on the shin did not hurt. The entire body began to perspire gently.

After 42 minutes: Constriction by a rubber tube tourniquet around the thigh produced no pain, but around the upper arm was very painful.

After 45 minutes: Pain sensibility began to recover but was still considerably obtunded. It gradually recovered completely. The pulse rate, which had been 75 at the beginning of the study, was 72 to 75 beats per minute during the period of insensitivity. The sense of touch remained intact throughout the period of loss of pain; touches were perceived and correctly located. The patellar reflexes remained unimpaired throughout.

After performing these experiments on our own bodies we proceeded without feeling any symptoms to dine and drink wine and smoke cigars. I went to bed at 11 p.m., slept the whole night, awoke the next morning hale and hearty and went for an hour's walk. Toward the end of the walk I developed a slight headache which gradually got worse as I went about my daily business. By 3 p.m. I was looking pale and my pulse was fairly weak, though regular at about 70 beats per minute. In addition, I had a feeling of very strong pressure on my skull and became rather dizzy when I stood up rapidly from my chair. All these symptoms vanished at once when I lay down flat, but returned when I stood up. Toward the evening I was forced

to take to bed and remained there for nine days, because all the manifestations recurred as soon as I got up. I felt perfectly well as long as I remained horizontal. Appetite and sleep rhythm were unaffected but any prolonged period of reading made me feel dizzy.

The symptoms finally resolved nine days after the lumbar puncture. Three days later I was able to make a fairly long journey by rail without difficulty and was able to thoroughly enjoy an 8-day hunting holiday in the mountains.

Dr. Hildebrand, for his part, went to bed at 11 p.m. feeling entirely well but was nevertheless unable to get to sleep because of restlessness. At midnight a violent headache set in that quickly became insupportable. At 1 a.m. he began to vomit, and this recurred once later in the night. The next morning he felt very ill but was able with much effort to perform his service duties of operating and changing dressings. In the afternoon he was constrained to lie in bed but got up again the next morning and worked, although he continued to feel unwell for the next 3-4 days. During this period his appetite was poor and headache frequently recurred. Thereafter he felt entirely well except for a mild feeling of weakness that lasted another 2-3 weeks.

Dr. Hildebrandt's legs became painful and bruises developed in several places, especially over the tibia where sensibility had been tested by crushing and heavy blows.

These researches demonstrate that an extremely small amount of cocaine solution (0.005 g) injected into the subarachnoid space suffices to render almost two thirds of the body insensible enough for the painless performance of the most major operations. In the legs the insensibility sets in within 5-8 minutes. Presumably this is due the action of cocaine on the unmyelinated nerves or the nerve roots, as the case may be, and perhaps on the ganglion cells and not on the spinal cord itself. Generally, even with a small dose of cocaine, the upper border of insensibility in a large person gradually extends up to the nipples (cases 1, 2, 5, and Dr. Hildebrandt). With doses larger proportionately to body size insensibility extends to the entire body except the head (case 4; 0.005 g of cocaine in an 11-year old boy).

Complete insensibility lasts for about 45 minutes with a small dose of cocaine (0.005 g in adults), after which sensibility gradually returns (Dr. Hildebrandt).

So far, it appears that cocainization of the spinal cord can be employed with advantage for painful operations. It stands to reason that the method will only succeed if it leads to fewer hazards and disagreeable consequences than general anesthesia.

Although I have not yet encountered any real dangers there have been very unpleasant after-effects. These were more or less completely absent in three of our patients (cases 4, 5, 6) but in others unpleasant effects developed similar to those seen after chloroform or ether general anesthesia, and which in some cases were more pronounced and enduring than those following general anesthesia (cases 1, 2). The most severe symptoms occurred in us, the two physicians, perhaps because we treated our bodies too lightheartedly. Instead of lying down and resting following the lumbar puncture and injection of cocaine, we went about our avocations, drank and smoked more than was good for us, and performed our usual work the next day.

As regards the after-effects which cocaine evoked in these cases, it remains to be determined whether they were a specific toxic effect of cocaine or the result of irritating the central nervous system by injecting a foreign substance into the dural sac. Only once have I seen an effect that may be regarded as true cocaine poisoning, a very

mild and brief one, the excitement that occurred in the seventeen-year-old brewery salesman (case 2). The long delay in the onset of the disturbances argues against a toxic effect, since they happened at a time when the cocaine had probably already been eliminated or metabolized. I think it is more likely that the headache and vomiting which were observed in cases 1, 2, and 3, and in Dr. Hildebrandt and myself are to be regarded as due to circulatory disturbances (hyperemia or anemia) of the central nervous system. The regional loss of cerebrospinal fluid can also provoke such complications. In my own case at most only traces of cocaine could have entered the subarachnoid space, yet no one else suffered the complications of lumbar puncture for as long a period as I did. That my symptoms were circulatory in origin is suggested by the fact that I felt perfectly well while lying down and that the disturbances set in only when I stood up.

It is remarkable how rapidly the action of cocaine on the nerve tissue can render a large area of the body insensitive, and how small a quantity of cocaine subdurally suffices for this purpose. One gains the impression that cocaine acts preferentially on the pain-conducting structures. Since the nerve roots are quite thick and one can hardly assume that cocaine penetrates them completely, it would seem that the nerves conveying pain lie in the outer layer.

The first function impaired by cocainization is pain sensibility, while the sense of touch is still intact. With larger doses and longer exposure touch also becomes impaired; it disappeared completely in only one case (case 2) where a fairly large amount of solution was used. Whereas warmth and cold sensibility are preserved, great heat does not cause pain (Dr. Hildebrandt).

The reflex response to tickling the sole of the foot disappears very early and after quite small doses. The patellar reflexes remain unaffected (Dr. Hildebrandt). Unfortunately I did not test the retention of other reflexes. Motor power also remains unaffected.

It may be possible to avoid the unpleasant side-effects of cocaine by means of substitutes or by supplementary medication. So far I have tested this only once, with tropacocaine, which is said to be less harmful than cocaine; in the event, it too produced a severe headache, as well as a quite inadequate decrease of sensibility.

I did not feel justified in investigating this further in man. Animal experiments may be necessary. The dog would be a suitable research animal because this species vomits readily and allows observation of one of the important signs of unpleasant side-effects.

However, I have not met a single instance of serious danger to the patient from the injection, and, in particular, no untoward effect on the heart or the respiratory system. One might be well advised to use the smallest dose that suffices for insensibility (0.005-0.01 g of cocaine for an adult) in patients for whom general anesthesia would be dangerous, as in case No. 1. According to his own declaration, although he did experience unpleasant after-effects, they did not last as long as after his previous general anesthesia. The experiences of Dr. Hildebrandt and myself demonstrate that it is mandatory to prescribe strict rest in bed. Of course, this is already always done following major operations, which is what we are here concerned with here. In addition, as I myself can vouch, any escape of cerebrospinal fluid must be avoided if possible.