Myelography

MYELOGRAPHY

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THIRD EDITION

With chapters on:

VASCULAR MALFORMATIONS
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PNEUMOMYELOGRAPHY
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Preface to the Third Edition

THIS NEW EDITION includes completely new chapters dealing with selective arteriography of the spinal cord, pneumomyelography and extradural venography. In each instance, the chapter has been written by an outstanding authority. I am grateful to Dr. Rene Djindjian, a pioneer in vascular radiology of the spinal cord, for his discussion of this subject, to Dr. Milan Roth for the chapter on pneumomyelography, especially the provocative presentation of neurovertebral relationships, and to Dr. Fredie Gargano for his lucid exposition of extradural venography. The present revision also contains an evaluation of the newer aqueous-positive contrast media and substantial additions to the chapters on spondylosis, congenital, inflammatory and various non-neoplastic lesions of the cord and cauda equina.

As before, a number of colleagues (Robert M. Lowman, Maer B. Ozonoff, William Griffin and Richard Cobb) have contributed interesting cases. In this regard, I am happy to acknowledge the generosity of friends in Israel, particularly Drs. Samuel Schorr, Moshe Lerner, Menachem Hirsch and Albert Bartal.

This monograph would not have been possible without the expert photography of Ovidio Gallo and Doris Barclay and the untiring efforts of my devoted secretary, Angela Brunetti, who typed and proofread the manuscript. I am also grateful to Dr. Kornelia Keszler for translating Dr. Djindjian's chapter from French to English. Finally, I would like to thank my wife for her understanding and saintly forbearance.

ROBERT SHAPIRO

Preface to the First Edition

ALTHOUGH myelography has become an important method of examining the spinal canal and its contents, no comprehensive treatise dealing with the subject is available. This haitus is painfully evident when one is concerned with training residents. The purpose of this book is to help correct the deficiency by describing in some detail the technique of examination, the anatomic basis of the normal myelogram and the findings in various pathologic states.

The bulk of the material has been drawn from personal experience at The Hospital of St. Raphael and The Grace-New Haven Community Hospital, augmented by original studies in the postmortem and anatomic laboratories. However, when my personal files were meager, I have not hesitated to borrow freely from many generous colleagues, to whom I am greatly indebted. In this regard, I would be remiss if I failed to acknowledge a special indebtedness to Drs. William German, Robert M. Lowman, Franklin Robinson and Charles M. D'Alessio. I am also happy to express my appreciation to that masterful myelographer, Dr. H. O. Peterson, for teaching me his technique, to Harry Assadurian and Tom McCarthy for the photography, to Drs. Orlando F. Gabriele and Franklin Robinson for reading portions of the manuscript and to my secretary, Angela Brunetti, for her invaluable assistance, including the typing of the manuscript. Last but not least, I wish to express my gratitude to Mrs. Franklin Robinson for her excellent illustrations.

ROBERT SHAPIRO

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History

THE BIRTH OF MYELOGRAPHY was presaged by Dandy's classic description of pneumoencephalography in 1919. In this paper, he prophetically remarked "It seems probable that we shall be able to localize spinal cord tumors by means of intraspinous injections of air. In one of our cases, the spinal cord and the surrounding air-filled space are sharply outlined." However, Dandy did not actually publish his experience with myelography until 1925, when he reported a series of 10 spinal cord tumors that he localized with this technique. Meanwhile, in 1921, Jacobeus in Sweden described the successful use of pneumomyelography to localize intraspinal tumors in 3 patients. The same author noted that Josephson had presented a patient with a spinal cord tumor diagnosed by this technique earlier that year to the Medical Congress in Helsinki. Also in 1921, Wideröe in Norway unsuccessfully attempted pneumomyelography on a patient with a spinal cord tumor.

Further impetus was given to myelography in 1922 through a striking example of serendipity. While treating a patient with sciatica by the extradural injection of iodized poppy seed oil (Lipiodol), Sicard and Forestier accidentally introduced some of the oil into the subarachnoid space. Noting that the subarachnoid oil moved freely, they decided to use it for the localization of spinal cord tumors. Before long, Lipiodol supplanted air as the myelographic medium of choice. Eventually, myelography achieved widespread popularity, largely due to Mixter and Barr's publication in 1934 on the syndrome of the herniated intervertebral disk.

The universal acceptance of Lipiodol myelography brought to light a number of its disadvantages. The relatively high viscosity of the oil and its nonmiscibility with spinal fluid frequently produced large, irregularly distributed globules, which made interpretation and removal difficult. Moreover, Lipiodol proved to be irritating to the pia-arachnoid. These drawbacks soon spurred efforts to find a more satisfactory contrast medium, a search that proceeded in the following directions.

Thorotrast myelography.—In 1932, Radovici and Meller in France injected colloidal thorium dioxide (Thorotrast) into the cisterna magna, but the alarming severity of the reaction soon prompted them to abandon this medium. Capua and Lucherini in Italy and Löhr and Jacobi, as well as Wüstman, in Germany had similar experiences. In an effort to reduce this

toxicity, Nosik and Mortensen introduced forced spinal drainage to remove the Thorotrast after completion of the study. Even with this technique, 10–15% of the Thorotrast remained in the subarachnoid space to produce varying degrees of meningeal irritation. This undesirable consequence eventually led to the abandonment of Thorotrast for myelography.

Abrodil (Skiodan) myelography.—In 1931, Arnel and Lidström first employed Abrodil, a water-soluble, organic iodine compound for myelography. Arnell's experimental studies, carried out in collaboration with a German chemist, were interrupted by World War II. Nevertheless, he continued to use Abrodil in a small group of patients during this period, summarizing his experience before the Swedish Society for Radiology in 1944. In the meantime, Felström published a brief communication on Abrodil myelography in Norway in 1942. Since that time, numerous reports dealing with Abrodil myelography have appeared in the continental literature, climaxed by Arnell's classic monograph in 1948. At present, Abrodil is used for lumbar myelography in the Scandinavian countries because of its ready miscibility with spinal fluid and its rapid, complete absorption from the subarachnoid space. Abrodil has failed, however, to achieve popularity in the United States because of its irritating effect on the meninges and spinal cord.

Pantopaque myelography.—The next major development in contrast media occurred in 1944 with the introduction of Pantopaque by the University of Rochester group. Although also an oil, Pantopaque is considerably less irritating to the meninges than either Lipiodol or Abrodil. For these reasons, even though it must be removed from the subarachnoid space, Pantopaque has become the myelographic medium of choice in the United States.

Nonetheless, pneumomyelography properly continues to play an important role in the examination of the spinal canal. This is largely due to the efforts of Young and Scott in the United States, Lindgren in Sweden and Jirout and Roth in Czechoslovakia. In 1938, Young introduced the technique of complete filling of the lumbar subarachnoid space and replacement of the entire fluid reservoir by air instilled via cisternal puncture. Prior to this, only small quantities of air had been used to localize the site of an obstruction. We are indebted to Lindgren, Jirout and Roth for numerous refinements in technique, especially the principle of distending the subarachnoid space and the use of body section radiography.

Conray and Dimer-X myelography.—Recently, the use of water-soluble contrast media has achieved new popularity on the Continent. Two compounds, Conray 60 and Dimer-X, are employed solely for lumbosacral myelography. Their advantages and disadvantages are discussed in detail in the following chapter.

BIBLIOGRAPHY

Arnell, S., and Lidström, F.: Myelography with Skiodan (Abrodil), Acta radiol. 12: 287, 1931.

Capua, A.: Encephalomyelography with subarachnoid injections of Thorotrast; clinical and experimental study, Radiol. med. 20:1376, 1933.

Dandy, W. E.: Ventriculography following the injection of air into the cerebral ventricles, Ann. Surg. 68:5, 1918.
Dandy, W. E.: Roentgenography of the brain after the injection of air into the spinal canal, Ann. Surg. 70:397, 1919.
Dandy, W. E.: Diagnosis and localization of spinal cord tumors, Bull. Johns Hopkins Hosp. 33:190, 1922.
Felström, E.: On myelography with Abrodil, Nord. med. 14:1653, 1942.
Jacobeus, H. C.: On insufflation of air into the spinal canal for diagnostic purposes in cases of tumors in the spinal cord, Acta med. scandinav. 21:555, 1921.
Lindgren, E.: Myelographie mit Luft, Nervenarzt 12:57, 1939.
Löhr, W., and Jacobi, W.: Die Darstellung der peripheren Nerven im Röntgenbild, Arch. klin. Chir. 171:538, 1932.
Mixter, W. J., and Barr, J. S.: Rupture of the intervertebral disc with involvement of the spinal canal, New England J. Med. 211:210, 1934.
Nosik, W. A., and Mortensen, O.: Myelography with Thorotrast and subsequent removal by forced drainage, experimental study; preliminary report, Am. J. Roentgenol. 39:727, 1938.
Radovici, A., and Meller, O.: Encéphalographie liquidienne par le thorotrast sous-arachnoidien, Rev. neurol. 1:479, 1932.
Ramsey, G. H. S., and Straim, W. E.: Pantopaque: New contrast medium for myelography, Radiol. & Clin. Photog. 20:25, 1944.
Sicard, J. A., and Forestier, J.: Méthode générale d'exploration radiólogique par l'huite iodée (Lipiodol), Bull, et mém. Soc. méd hôp. Paris 46:463, 1922.
Wideröe, S.: Über die diagnostische Bedeutung der intraspinalen Luftinjektionen bei Rückenmarksleiden besonders bei Geschwülsten, Zentralbl. Chir. 48:394, 1921.
Wideröe, S.: Diagnosis of spinal cord tumors, Norsk mag. laegevidensk. 82:491, 1921.
Young, B. R., and Scott, M.: Air myelography, substitution of air for Lipiodol in roentgen visualization of tumors and their structures in spinal canal, Am. J. Roentgenol. 39:187, 1938.

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Contrast Media

THE IDEAL MYELOGRAPHIC MEDIUM is as yet undiscovered. Such a medium should have the following characteristics: (1) thorough miscibility with cerebrospinal fluid; (2) complete resorbability; (3) absence of local and systemic toxicity; (4) pharmacologic inertness, and (5) satisfactory radiopacity. The lack of an ideal compound has necessitated the use of less desirable substitutes. This chapter will review the various substances that have been utilized for myelography.

Air and Other Gases

Air, the original myelographic agent, still is the medium of choice in many centers. Occasionally, other gases (particularly oxygen) are used because of their greater diffusibility and more rapid elimination. From the diagnostic point of view, however, air is equally satisfactory. In general, gases are the least irritating of all the known contrast media. Save for a transient slight pleocytosis and increase in spinal fluid protein, they are essentially nontoxic. Furthermore, they are completely resorbed in a relatively short period of time. Consequently, there are no absolute contraindications to gas myelography except increased intracranial pressure.

There are, however, a number of disadvantages associated with pneumomyelography. Because gases do not mix with cerebrospinal fluid, the fluid must be drained off and replaced by the gas. This makes the examination uncomfortable and trying for the patient, particularly when it is necessary to study the entire spinal subarachnoid space. In such cases, postmyelographic headache may be quite severe and last for several days.

Most of the other problems associated with pneumomyelography are functions of the modest contrast produced by gases in the spinal canal, which can be overcome by meticulous radiographic technique and body section radiography. In this regard, Heinz has suggested the use of 125–130 KVP and a 2-mm Cu filter. However, since gases do not freely permeate the subarachnoid space along the nerve roots, the latter are not visualized. Thus, sacral root cysts, nerve root avulsions and small lateral-lying disk protrusions may be completely missed. Furthermore, various nonobstructive lesions such as arachnoiditis and vascular malformations may not be recognized as such. On the other hand, pneumomyelography is superior to positive contrast tech-

niques in demonstrating intramedullary lesions and atrophy of the spinal cord and in delineating the detailed anatomy of the conus medullaris.

Thorotrast

Thorotrast is a stable, aqueous colloidal sol containing 25% thorium dioxide by volume suspended in a tapioca-dextrin medium. A preservative of 0.15% methyl *p*-hydroxybenzoate is added to the sol. Thorium is a potent alpha emitter with a half-life of 1.4×10^{10} years. Because of its prolonged retention within the body, the surrounding tissues are continuously bombarded by alpha particles with a penetration range of 30–50 microns. Of all the media employed for myelography, Thorotrast is the most irritating to the pia-arachnoid. It not only produces an alarming systemic reaction accompanied by high fever but also local inflammatory changes resulting in intense arachnoiditis, which may culminate in a disabling cauda equina syndrome. In this regard, Maltby described 3 patients with a slowly progressive cauda equina syndrome that manifested itself approximately 8 years following Thorotrast myelography. In addition, various benign and malignant tumors have been reported as late sequelae. For these reasons, there is no present justification for using Thorotrast for myelography.

Lipiodol

Lipiodol is a viscid, halogenated, poppy seed oil containing 40% iodine (w/v) in organic combination. Normally, it has a light yellow color that turns dark brown on long standing or exposure to light due to the liberation of free iodine. In the latter circumstance, the material should be discarded.

Because of its oily nature, it is not miscible with cerebrospinal fluid. It is also irritating to the leptomeninges, as evidenced by a prompt, significant increase in cell count and spinal fluid protein after injection. Furthermore, it is absorbed extremely slowly (if at all), has a distinct tendency to become encysted and produce varying degrees of late arachnoiditis. The relatively high viscosity not only makes complete removal difficult but also favors fragmentation and the formation of large, irregular globules. Because of these disadvantages, Lipiodol should no longer be used as a myelographic medium.

Abrodil

Abrodil, a Swedish trade name for sodium iodomethanesulfonate, is an aqueous, organic salt containing 52% iodine firmly bound. This material, originally introduced for myelography by Arnell and Lidström, should not be confused with Per-Abrodil (Diodrast, 3,5-diiodo-4-pyridone-*N*-acetic acid diethanolamine), which is extremely toxic when injected into the subarachnoid space. Because Abrodil has a number of desirable properties, it is widely employed in 20% concentration in the Scandinavian countries. These advantages include satisfactory radiopacity, miscibility with cerebrospinal fluid and rapid, complete absorption into the bloodstream. The latter characteristic obviates the necessity for removal of the contrast material from the subarachnoid space. Its ready solubility permits clear visualization of the

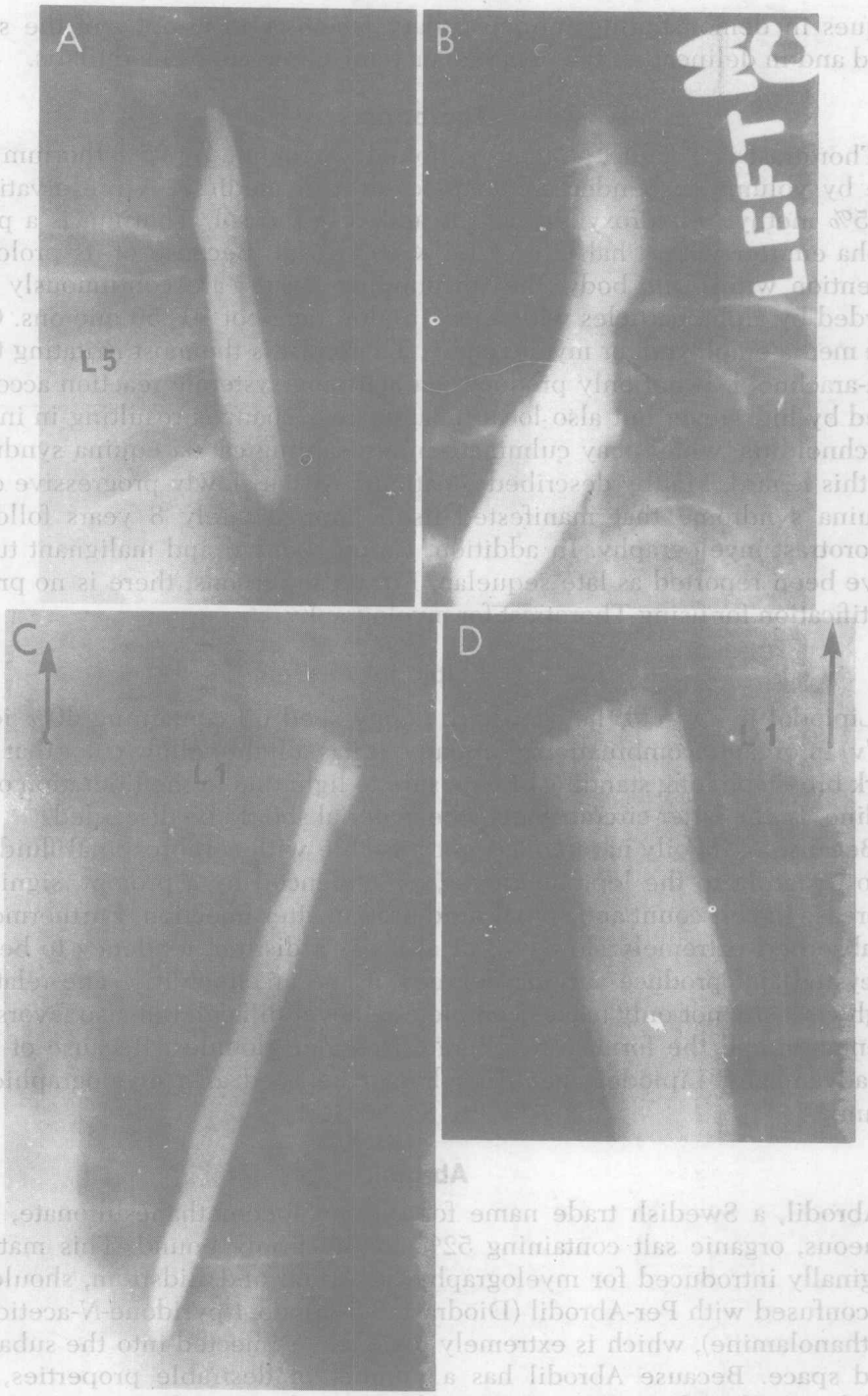

Fig. 1.—The patient, a 65-year-old female, had a myelogram because of left-sided sciatica. Unfortunately, the study was confined to the area below the level of L1–L2, which is the usual procedure in myelography with water-soluble media. Note the slight spondylolisthesis at L4–L5 (A) and the defect in the Pantopaque column at that interspace *(arrow)* (B). Laminectomy and removal of a bulging disk at L4–L5 failed to relieve the patient's pain. A second myelogram demonstrated an intradural lesion with a block at the level of T12–L1 (C and D). At operation, a cystic neurolemmoma was removed; postoperatively, the patient's sciatica disappeared.

roots of the cauda equina, thus facilitating the diagnosis of small, laterally placed herniated disks. In this respect, it is definitely superior to Pantopaque.

On the other hand, there are serious disadvantages associated with Abrodil myelography. Because of its marked hypertonicity (sp. gr. of Abrodil 1.130 versus sp. gr. of spinal fluid 1.006–1.008), Abrodil is quite irritating to the pia-arachnoid and the enclosed neural elements. This is readily demonstrable by an initial fairly severe pleocytosis and increase in spinal fluid protein the day following Abrodil myelography. These changes usually subside in 5–7 days, so that lumbar puncture performed a week after the subarachnoid injection of Abrodil generally reveals a normal spinal fluid. The prompt leptomeningeal irritation is evidenced clinically by pain sufficiently severe to require the preliminary use of spinal anesthesia. Indeed, if the spinal anesthesia is inadequate or the Abrodil is permitted to drift above the anesthetic level, shock may occur in addition to excruciating pain. Occasionally, this technique may also be associated with severe spasm and leg cramps, and rarely with paraplegia, sphincteric disturbances, transverse myelitis and death.

Since sciatic pain may be produced by lesions as high as the tenth thoracic vertebral level, the lower thoracic as well as the lumbar subarachnoid space should be routinely studied in patients with sciatica. Because the toxicity of Abrodil limits the examination to the lumbar and lumbosacral regions, Abrodil myelography is not adequate for thorough investigation of these patients. I have seen several neoplasms of the lower thoracic cord mimicking a ruptured intervertebral disk that were missed by myelography terminated at the level of the first lumbar vertebra (Fig. 1).

In my opinion, the advantages of Abrodil are outweighed by its disadvantages. It is difficult to submit the average patient with benign disease (e.g., suspected ruptured disk) to a procedure that is incomplete and carries the risk (albeit small) of shock, permanent neurologic damage and even death.

Conray and Dimer-X

In 1936, Kodama and his co-workers reported that methylglucamine iothalamate had a relatively low toxicity when injected intrathecally into laboratory animals. The following year, Campbell *et al.* independently published their studies on the same compound in a series of 12 patients, as well as in rabbits and dogs. In the latter report, there was one fatality, a second patient with tonic spasm of the legs that lasted for several days and a third patient with weakness of thigh flexion of several days' duration. In October of 1968, a group of physicians met in Paris to pool their experience with Conray in myelography. In this collective series of 847 Conray myelograms, there was 1 death, 1 cauda equina syndrome (24 hours' duration), 6 serious meningeal reactions (4 lasting 4 days) and 29 patients who experienced chronic contractions of the legs. In 1971, Gonsette reported 3 additional fatalities and 4 patients with medullary or cortical irritation. Gonsette recommended the following precautions: (1) no spinal anesthesia, (2) a maximal dose of 5 ml of Conray diluted with cerebrospinal fluid, the total maximal

volume not to exceed 10 ml, (3) low injection of the contrast medium, (4) maintenance of the patient in the sitting position for 6–8 hours and avoidance of sudden movement after the examination, (5) careful monitoring of the patient for at least 24 hours postmyelography, (6) the use of diazepam (Valium) at the onset of signs of spinal irritability, i.e., hyper-reflexia, myoclonia. (7) avoidance of contact of the conus medullaris with the contrast medium, i.e., it is important to keep the upper level of the Conray column below L2–L3.

Because of the neurotoxicity of Conray, Gonsette was led to evaluate Dimer-X, i.e., methylglucamine iocarmate. The latter compound is formed by linking two molecules of methylglucamine iothalamate with adipic acid. The principal physicochemical difference between Conray and Dimer-X in similar iodine concentrations (28%) is the lower osmolarity of the latter compound (Dimer-X 1040 mOsm/L vs. Conray 1570 mOsm/L).

The physicians who participated in the cooperative study of Conray met again in Paris in 1970 to share their experience with Dimer-X. In a collective protocol of 630 Dimer-X myelograms, there was a substantial decrease in radicular irritation and no fatalities. However, meningeal irritation was more frequent (22% Dimer-X vs. 12% Conray). Hammer and Scherrer suggest that the dichotomy between meningeal and radicular irritation may be due to the slower absorption of Dimer-X, which necessitates a longer period of immobilization of the patient in the sitting position. Under these circumstances, cerebrospinal fluid and contrast medium drain off through the puncture site, perhaps thereby increasing local meningeal irritation. In 1971, Gonsette estimated that 3,000 Dimer-X myelograms had been performed uneventfully except for a "few rare cases" of myoclonia, which responded to diazepam (Valium). It is noteworthy that electromyographic studies demonstrate similar subclinical irritation of the spinal cord with both compounds.

Even though Conray and Dimer-X do not require spinal anesthesia as Abrodil does, I have similar objections to their use. Admittedly, the water-soluble compounds visualize the lumbar roots better than any other myelographic medium. However, I find it difficult to expose a patient with the presumptive diagnosis of a herniated lumbar disk to the risk of neurologic damage and the sequelae of myoclonia, i.e., primum non nocere. Moreover, the need to keep the contrast agent below the level of the conus medullaris makes the examination incomplete. If Dimer-X is to be used, it probably should be restricted to young, healthy, cooperative patients who can be carefully monitored. My own preference is to begin with Pantopaque myelography and to restudy younger patients with indeterminate myelograms by disk puncture.

SH-617L

In 1963, Zeitler reported on the use of SH-617L as a myelographic contrast medium. This substance is a 20% crystalline suspension of β-(3-dimethylaminomethylenamino-2,4,6-tri-iodophenyl) propionic acid ethyl ester in 5.5% glucose. The same year, Vogler and Walcher published their investigations in rabbits and dogs as well as in a clinical series of 160 myelograms. The

compound contains 60.45% iodine, all organically bound. The material is hyperbaric, requires no preliminary anesthesia, is absorbed almost completely in 6–8 weeks (50% absorbed in 3–4 weeks) and may be instilled by either cisternal or lumbar puncture. Its lower viscosity results in coating of the nerve roots and cord, permitting visualization of the latter in both the frontal and lateral projections. The original enthusiasm expressed by Vogler and Walcher was followed by a number of critical reports culminating in Lindgren and Törnell's paper, which clearly demonstrated that SH-617L produces parenchymatous degeneration of the spinal cord as well as severe leptomeningeal irritation. This substance, therefore, has been abandoned for myelography.

Pantopaque

Originally introduced by Strain and his co-workers at the University of Rochester in 1940, Pantopaque is a mixture of ethyl esters of isomeric iodophenylundecylic acids containing 30.5% of firmly bound organic iodine. Normally clear or pale yellow in color, it tends to become discolored when exposed to sunlight and should not be used in the latter state. Pantopaque has a specific gravity of 1.260 at 20°C and is, therefore, much less viscous than Lipiodol ($^1/_{22}$ as viscous at 20°C and $^1/_{17}$ as viscous at body temperature). Consequently, it flows more freely, has a lesser tendency to form large, irregular globules and can be more readily removed from the spinal canal than Lipiodol. When injected into the subarachnoid space, Pantopaque produces a modest lymphocytosis and a prolonged elevation of total CSF protein and gamma globulin (Ferry *et al.*). The latter authors point out that the findings of elevated CSF gamma globulin and total protein and a normal or slightly elevated beta globulin fraction differentiate the postmyelographic inflammatory response from multiple sclerosis, which usually is associated with normal total protein values, low or normal beta globulin values and a decreased beta-gamma globulin ratio. Uncommonly, the spinal fluid changes may be associated with mild fever, headache and malaise (Schnitker and Booth, Ford and Key, Tarlov).

Rarely, more severe reactions have been described in the literature. Erickson and Van Baaren reported a patient who exhibited acute meningeal irritation after a Pantopaque myelogram for a dorsal angioma (6 ml). Four months thereafter, persistent headache developed, followed a year later by disorientation, meningismus, headache and vomiting. Ventriculography revealed a cerebrospinal fluid protein of 650 mg, intracerebral Pantopaque and hydrocephalus associated with obstruction of the fourth ventricle. A suboccipital craniotomy with lysis of adhesions of the fourth ventricle led to death on the second postoperative day.

Taren also described a patient who had a lumbar myelogram (9 ml of Pantopaque were used but only 4 ml were removed). Nineteen hours after myelography, the patient complained of severe headache with a temperature of 103°F. Thirty hours postmyelography, the patient became irritable and irrational, with marked rigidity and a white blood cell count of 22,000/cu mm. At this point, he was given penicillin and intravenous sulfadiazine. Because of