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and
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# Roentgen Aspects of the Inferior Vena Cava

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I.

# UNIVERSITY OF MINNESOTA MEDICAL SCHOOL
## CALENDAR OF EVENTS

January 30 - February 5, 1949

No. 233

Sunday, January 30

9:00 - 11:30 Surgery Grand Rounds; Station 22, U. H.
The Effect of Dehydration on Iodine Uptake of the Thyroid of the Mouse; Samuel Hunter; Rm. M-109, U. H.

Monday, January 31

8:00 - Fracture Rounds; A. A. Zierold and Staff; Ward A, Minneapolis General Hospital.

9:00 - 9:50 Roentgenology-Medicine Conference; L. G. Rigler, C. J. Watson and Staff; Todd Amphitheater, U. H.

9:00 - 10:50 Obstetrics and Gynecology Conference; J. L. McKelvey and Staff; M-109, U. H.

10:00 - 12:00 Neurology Rounds; A. B. Baker and Staff; Station 50, U. H.

11:00 - 11:50 Roentgenology-Medicine Conference; Staff; Veterans Hospital.

11:00 - 11:50 Physical Medicine Seminar; Speech Training; Mrs. Bernice Rutherford, St. Paul Rehabilitation Center; E-101, U. H.

11:00 - 12:00 Cancer Clinic; K. Stenstrom and A. Kremen; Eustis Amphitheater, U. H.

12:00 - 1:00 Physiology Seminar; 214 M. H.

12:15 - 1:20 Obstetrics and Gynecology Journal Club; Staff Dining Room, U. H.

12:30 - 1:20 Pathology Seminar; Hyperparathyroidism; Robert Blomberg; 104 I. A.

12:30 - 1:30 Surgery Problem Case Conference; A. A. Zierold, C. Dennis and Staff; Small Class Room, Minneapolis General Hospital.

1:30 - 2:30 Surgery Grand Rounds; A. A. Zierold, C. Dennis and Staff; Minneapolis General Hospital.

1:30 - 2:30 Pediatric-Neurological Rounds; R. Jensen, A. B. Baker and Staff; U. H.

4:00 - Pediatric Seminar; Organic Aciduria; Charles Lowe; 6th Floor, Child Psychiatry, U. H.

5:00 - 5:50 Clinical Medical Pathologic Conference; Todd Amphitheater, U. H.

5:00 - 6:00 Urology-Roentgenology Conference; D. Creevy and H. M. Stauffer and Staffs; M-109, U. H.

Tuesday, February 1

8:30 - 10:20 Surgery Reading Conference; Lyle Hay; Small Conference Room, Bldg. I, Veterans Hospital.

9:00 - 9:50 Roentgenology Pediatric Conference; L. G. Rigler, I. McQuarrie and Staff; Todd Amphitheater, U. H.

10:30 - 11:50 Surgical Pathological Conference; Lyle Hay and Robert Hebbel; Veterans Hospital.

12:30 - 1:20 Pathology Conference; Autopsies; Pathology Staff; 102 I. A.

1:00 - 2:30 X-ray-Surgery Conference; Auditorium, Ancker Hospital.

2:00 - 2:50 Dermatology and Syphilology Conference; H. E. Michelson and Staff; Bldg. III, Veterans' Hospital.

3:15 - 4:20 Gynecology Chart Conference; J. L. McKelvey and Staff; Station 54, U. H.

3:30 - 4:20 Clinical Pathological Conference; Staff; Veterans Hospital.

4:00 - 5:00 Pediatric Rounds on Wards; I. McQuarrie and Staff; U. H.

4:00 - 5:30 Surgery-Physiology Conference; Parasitic Carcinogens; R. A. Huseby and C. R. Hitchcock; Eustis Amphitheater, U. H.

5:00 - 5:50 Urology-Pathological Conference; C. D. Creevy and Staff; Todd Amphitheater, U. H.

5:00 - 6:00 X-ray Conference; Curtis Nessa, St. Cloud; Powell Hall Amphitheater.

8:15 p.m. Duluth Clinic Lecture; The Pancreas as a Guardian of the Liver; Charles H. Best, University of Toronto; Museum of Natural History Auditorium.

Wednesday, February 2

8:00 - 8:50 Surgery Journal Club; O. H. Wangensteen and Staff; M-515, U. H.

8:30 - 9:30 Clinico-Pathological Conference; Auditorium, Ancker Hospital.

8:30 - 10:00 Orthopedic-Roentgenologic Conference; Edward T. Evans; Room 1AW, Veterans Hospital.

8:30 - 12:00 Neurology Rehabilitation and Case Conference; A. B. Baker and Joe R. Brown; Veterans Hospital.

11:00 - 12:00 Pathology-Medicine-Surgery Conference; O. H. Wangensteen, C. J. Watson and Staff; Todd Amphitheater, U. H.

12:00 - 12:50 Radio Isotope Seminar; Selective Deposition of Radio-Isotopes; J. Jorgens; Rm. 216, Hospital Court, Temporary Bldg.

3:30 - 4:30 Journal Club; Surgery Office, Ancker Hospital.

4:00 - 5:00 Infectious Disease Rounds; Medical Conference Room, Veterans Hospital.

Thursday, February 3

8:15 - 9:00 Roentgenology-Surgical-Pathology Conference; Craig Freeman and H. M. Stauffer; M-109, U. H.

8:30 - 10:20 Surgery Grand Rounds; Lyle Hay and Staff; Veterans Hospital.

9:00 - 9:50 Medicine Case Presentation; C. J. Watson and Staff;M-109, U. H.

10:00 - 11:50 Medicine Ward Rounds; C. J. Watson and Staff; E-221, U. H.

10:30 - 11:50 Surgery-Radiology Conference; Daniel Fink and Lyle Hay; Veterans Hospital.

11:00 - 12:00 Cancer Clinic; K. Stenstrom and A. Kremen; Todd Amphitheater, U. H.

11:30 - 12:30 Clinical Pathology Conference; Steven Barron, C. Dennis, George Fahr, A. V. Stoesser and Staffs; Large Class Room, Minneapolis General Hospital.

12:00 - 1:00 Physiological Chemistry Seminar; Studies with Pituitary Adrenocorticotropin; Benjamin Fuller; 214 M. H.

1:00 - 1:50 Fracture Conference; A. A. Zierold and Staff; Minneapolis General Hospital.

2:00 - 3:00 Errors Conference; A. A. Zierold, C. Dennis and Staff; Large Class Room, Minneapolis General Hospital.

4:00 - 5:00 Bacteriology and Immunology Seminar; Genetic Studies of a Bacterial Virus; Mrs. M. Sussman; 214 M. H.

4:30 - 5:20 Ophthalmology Ward Rounds; Erling W. Hansen and Staff; E-534, U. H.

5:00 - 6:00 X-ray Seminar; Conventional Methods in the Roentgen Diagnosis of Congenital Heart Disease; Herbert M. Stauffer; Todd Amphitheater.

Friday, February 4

8:30 - 10:00 Neurology Grand Rounds; A. B. Baker and Staff; Station 50, U. H.

9:00 - 9:50 Medicine Grand Rounds; C. J. Watson and Staff; Todd Amphitheater, U.H.

10:00 - 11:50 Medicine Ward Rounds; C. J. Watson and Staff; E-221, U. H.

10:30 - 11:20 Medicine Grand Rounds; Staff; Veterans Hospital.

10:30 - 11:50 Otolaryngology Case Studies; L. R. Boies and Staff; Out-Patient Department, U. H.

11:00 - 12:00 Surgery-Pediatric Conference; C. Dennis, O. S. Wyatt, A. V. Stoesser and Staffs; Minneapolis General Hospital.

11:30 - 12:50 University of Minnesota Hospitals General Staff Meeting; Infection Following Transurethral Resection of the Prostate Gland; Michael J. Feeney; Powell Hall Amphitheater.

12:00 - 1:00 Surgery Clinical Pathological Conference; Clarence Dennis and Staff; Large Classroom, Minneapolis General Hospital.

1:00 - 1:50 Dermatology and Syphilology; Presentation of Selected Cases of the Week; H. E. Michelson and Staff; W-312, U. H.

1:00 - 3:00 Pathology-Surgery Conference; Auditorium, Ancker Hospital.

1:00 - 2:50 Neurosurgery-Roentgenology Conference; W. T. Peyton, Harold O. Peterson and Staff; Todd Amphitheater, U. H.

4:00 - 5:00 Electrocardiographic Conference; George N. Aagaard; 1st Floor, Temp. Bldg., Hospital Court, U. H.

Saturday, February 5

7:45 - 8:50 Orthopedics Conference; Wallace H. Cole and Staff; Station 21, U. H.

8:30 - 9:30 Surgery Conference; Auditorium, Ancker Hospital.

8:00 - 9:00 Pediatric Psychiatric Rounds; Reynold Jensen; 6th Floor, West Wing, U. H.

8:00 - 9:00 Surgery Literature Conference; Clarence Dennis and Staff; Minneapolis General Hospital, Small Classroom.

9:00 - 9:50 Medicine Case Presentation; C. J. Watson and Staff; E-101, U. H.

9:00 - 10:30 Pediatric Grand Rounds; I. McQuarrie and Staff; Eustis Amphitheater, U. H.

9:00 - 12:00 Surgery-Roentgenology Conference; O. H. Wangensteen, L. G. Rigler, H. M. Stauffer, and Staff; Todd Amphitheater, U. H.

9:00 - 12:00 Psychiatry Conference; VA Hospital Annex, Fort Snelling.

10:00 - 11:50 Medicine Ward Rounds; C. J. Watson and Staff; E-221, U. H.

10:00 - 12:50 Obstetrics and Gynecology Grand Rounds; J. L. McKelvey and Staff; Station 44, U. H.

11:00 - 11:50 Urology Seminar; Ureterosigmoidostomy and Cystectomy; Dewar Ferris, Mayo Clinic; E-101, U. H.

11:00 - 12:00 Anatomy Seminar; Book Review of Cybernetics by Norbert Wiener, Berry Campbell; Evidence that the Atrophy Occurring in a Denervated Muscle is Due to Fatigue, Richard H. Swigart; 226 I. A.

## II. ROENTGEN ASPECTS OF THE INFERIOR VENA CAVA

B. J. O'Loughlin

In addition to the very specific interest which any of us may have in a study of the inferior vena cava, it is well to approach any such study, and to gauge its significance from the point of view expressed by Dr. Rigler who said that "any extension of our vision into that large hidden anatomical space which was so aptly named the abdomen is certainly welcome, no matter how limited the indications for its application may be."

### Historical Introduction

Shortly after the discovery of the roentgen ray in 1895, and its practical application by Conrad Roentgen, Hoschek and Lindenthal injected Teichmann's solution into an amputated hand, and made roentgenograms which were widely circulated on the continent and in the United States. Small wonder, then, that visualization of the vascular tree has appeared to be such an attractive project for anatomists, surgeons, and radiologists. The solutions available at that time proved to be highly toxic, however, and after some unfortunate experiences, contrast visualization of the vessels was relatively neglected until well after the turn of the century.

In 1916, Cameron, here at the University of Minnesota, tested and used sodium iodide solution for retrograde urograms and cystograms. He fould little toxicity resulting from concentrations of this substance up to 50 per cent, although he preferred to use lesser concentrations. Strontium and bromine, both having relatively high atomic weights, appeared to be logical contrast media for vessel visualization to Seth Hirsch, who, in 1923, used strontium bromide for arm-vein visualization with some success. Strontium, however, proved to be fairly toxic, so in his subsequent studies in cerebral angiography, he resorted to sodium iodide. A concentration of about 25 per cent gave fair roentgen visualization, but also resulted in convulsions and rather severe cerebral irritation. It was not until 1927 that Egas Moniz formulated a successful routine for cerebral angiography. His films were brilliantly successful, and he could easily reproduce them again and again. Thorotrast or thorium dioxide was found to be a relatively non-irritating and very dense medium for these studies. It had the unfortunate property, however, of being radioactive, and, in certain instances it was accused of causing severe scar formations, even connective-tissue sarcomas. Thorotrast was not readily excreted; it was stored in the reticulo-endothelial system of the spleen and liver, where its low but constant emission of alpha particles became a cause for concern in those patients with a good life expectancy.

In 1929 McPheeters of Minneapolis experimented with emulsions and colloidal suspensions of lipiodol, as a contrast medium for visualizing the peripheral veins. It proved difficult to maintain a suspension of this material, and diagnostic venograms were not uniformly attainable. In the aorta one can use sodium iodide with relative impunity, since here it is well diluted, and mixed with the systemic blood before returning to the heart, where high concentrations of sodium iodide cause an appreciable degree of bradycardia, and on occasion, congestive heart failure. This medium was utilized by Dos Santos to demonstrate the abdominal aorta by means of a translumbar injection. Not long after his first aortograms in 1929, Dos Santos visited the University of Minnesota, and demonstrated his technique, which was not adopted here until this last year. One of the interns, Keller Doss, now a practicing urologist in Fort Worth, Texas, learned the technique, and has become one of the most ardent proponents of aortography in the United States. In 1930 Von Lichtenberg introduced the organic iodinated compounds for use in intravenous urography. These were widely accepted almost imme-

diately, since the need for this type of examination was great. Contrast visualization of the heart, of the aorta and the pulmonary vessels was accomplished in 1937 by Robb and Steinberg, using 70% diodrast. This dramatic technique was well discussed and demonstrated here by Dr. Sussman just a few months ago.

Dr. Pendergrass and his associates in Philadelphia made a survey of radiologists and urologists using iodinated organic compounds in urography and reported a number of fatal reactions. Because of diodrast sensitivity they suggested that these compounds be given very slowly. Others, doing angiocardiography, seemed to be able to inject great amounts of highly concentrated compounds very rapidly, with relative impunity.

From the foregoing one can see that the development of vasography, particularly of the arteries and the peripheral veins progressed, as one might expect, with the development of roentgenography in general, and especially with the development of surgical procedures, which required good roentgenographic diagnoses. But in all of the above developments it does seem odd that there is no mention of the inferior vena cava. Clinical roentgenography of the vena cava seems to lag behind that of the other members of the vascular tree, and the reasons for this are not obvious.

Although the early anatomists had a clear concept of the structure of the inferior vena cava and its ramifications, and although no other veins have acquired a greater bibliography, it was not until 1936 that Franklin, in studying the physiology of the vena cava in animals, demonstrated the vena cava outlined by contrast media (thorotrast and perabrodil). The following year while attempting to outline the heart in their anatomic studies, Castellanos and Pereiras demonstrated extensive abdominal anastomoses continuous with the femoral veins, and in that same year Dos Santos published the first clinical application of contrast visualization of the vena cava. The technique of Dos Santos did not seem to gain wide acceptance; perhaps because there was no great demand by the surgeons for accurate information regarding the inferior vena cava; perhaps because the first case published by Dos Santos failed to demonstrate a known lesion in the vena cava, following renal surgery. Foster, Brouwer and Kurtz of The Student Health Service of the University of Wisconsin tried to use the angiocardiographic methods suggested by Costellanos and Pereiras to visualize the femoral vein in 1941. Theirs was a case of effort thrombosis of the inferior vena cava which occurred in a young female student after doing strenuous back flips in the gymnasium. She developed abdominal varices, transient albuminurea and fleeting leg edema. They were unable to demonstrate roentgenographically the vena cava or its collaterals.

During the last decade surgeons developed both the confidence and the technique to successfully operate upon the vena cava. In the past venacaval surgery has been largely inadvertent and usually considered a surgical catastrophe. Hyman, Priestly, Walters and others now plan their abdominal and renal operations with due consideration of the vena cava, and in certain instances included caval surgery in their plans of attack. But it is only recently that the radiologist has been enabled to offer more accurate diagnostic support based on cavography. In 1946 Farinas of Havana, Cuba, Castellanos and Pereiras, also of Havana, and we, of the University of Minnesota, independently developed different techniques for caval visualization. Thus we can now contribute information to that growing body of knowledge about the vascular tree.

## Indications and Contraindications

Whereas, in the past the diagnosis of anomalies of the great vessels of the abdomen was made in the dissecting room of the anatomy laboratory, or upon

the autopsy table, or in the operating room, now we can make such diagnoses pre-operatively in the living patient. Although these anomalies are rare, they occur frequently enough to complicate surgical procedures, and, in some cases, they are the anatomic basis of disease. The inferior vena cava is normally formed by the union of the iliac veins, at about the level of the 5th lumbar vertebra, just to the right of the midline, behind, and to the right of the right iliac artery. It passes upward over the psoas muscles, and the transverse processes of the vertebrae, lying over the sympathetic trunks, and the trunks of the right lumbar arteries. It lies anterior to the renal artery, the supra-renal artery, the sympathetic ganglia and phrenic artery. It receives contributions from the renal veins, at about the level of the first lumbar interspace; from the hepatic veins just below the diaphragm; and after passing over the medial valve goes through the pericardium into the right atrium. The iliac arteries pass over the iliac veins, and, on the right side, over the lower portion of the vena cava, causing an impression upon the vessel. Cephalad, the third portion of the duodenum, the head of the pancreas, porta hepatis, and part of the duodenum lie in close approximation to the anterior surface of the vena cava. It passes behind the liver through a deep groove, this portion of the vena cava being derived from the vascular portions of the liver, and occasionally being completely surrounded by the liver. The right ureter arises posteriorly, and passes caudally beside the vena cava, crossing anterior to the common iliac vein, as it passes into the pelvis. The most common anomalies are "retrocaval ureter", or persistent right post-cardinal vein. Both post-cardinal veins may persist, giving a double inferior vena cava, with bilateral retrocaval ureters. Another common anomaly is the persistent left supra-cardinal vein, which results in a left-sided lower inferior vena cava. A venous vascular collar occasionally surrounds the aorta at the level of the renal vessels. Of these only those anomalies involving the ureters are of clinical significance, since they may give rise to partial obstruction of the ureters, with resultant hydronephrosis. It is not infrequent that these anomalies of the vena cava are associated with anomalies of the kidney. Such cases have been reported by Boyden, Messing and Ashley-Montague, and Odgers.

On several occasions it has been advantageous to know the relation of the inferior vena cava to tumors of the abdomen. Extensions of tumors into the vena cava may seriously limit the prognosis as well as extent of surgery. The size and location of tumors are very important to the roentgen therapist. who should be delighted to be able to follow the progress in his patients of retroperitoneal, primary, or metastatic tumors. A bizarre group of symptoms can arise from caval obstruction. Cabot reports (Case 18172) a housewife whose weakness of lower extremities with subsequent chest pain, backache and jaundice did not lead to a diagnosis of carcinoma of the stomach with extension to the inferior vena cava until autopsy. Hallock, Watson, and Berman presented a patient with a confusing group of symptoms thought to indicate Chiari's disease which on autopsy proved to be due to primary tumor of the inferior vena cava. Gregory's patient, undiagnosed until autopsy, proved to have a primary carcinoma of the liver, with a tumor thrombus of the inferior vena cava, extending into the right atrium. Tillisch reported seven cases, undiagnosed until autopsy, of tumor thrombosis of the inferior vena cava arising from renal neoplasm. Trauma or exertion may result in thrombosis of the vena cava, causing vague renal and circulatory signs and symptoms. Metastatic lymph nodes, liver abscess, echinococcus cysts, pyometritis, septic phlebitis, and Wilm's tumor all have been listed as troublesome diagnostic problems when they involve the inferior vena cava. Logically, signs and symptoms may develop from varices of the epidural veins secondary to an increase in the venous pressure here due to obstruc-

the autopsy table, or in the operating room, now we can make such diagnoses pre-operatively in the living patient. Although these anomalies are rare, they occur frequently enough to complicate surgical procedures, and, in some cases, they are the anatomic basis of disease. The inferior vena cava is normally formed by the union of the iliac veins, at about the level of the 5th lumbar vertebra, just to the right of the midline, behind, and to the right of the right iliac artery. It passes upward over the psoas muscles, and the transverse processes of the vertebrae, lying over the sympathetic trunks, and the trunks of the right lumbar arteries. It lies anterior to the renal artery, the supra-renal artery, the sympathetic ganglia and phrenic artery. It receives contributions from the renal veins, at about the level of the first lumbar interspace; from the hepatic veins just below the diaphragm; and after passing over the medial valve goes through the pericardium into the right atrium. The iliac arteries pass over the iliac veins, and, on the right side, over the lower portion of the vena cava, causing an impression upon the vessel. Cephalad, the third portion of the duodenum, the head of the pancreas, porta hepatis, and part of the duodenum lie in close approximation to the anterior surface of the vena cava. It passes behind the liver through a deep groove, this portion of the vena cava being derived from the vascular portions of the liver, and occasionally being completely surrounded by the liver. The right ureter arises posteriorly, and passes caudally beside the vena cava, crossing anterior to the common iliac vein, as it passes into the pelvis. The most common anomalies are "retrocaval ureter", or persistent right post-cardinal vein. Both post-cardinal veins may persist, giving a double inferior vena cava, with bilateral retrocaval ureters. Another common anomaly is the persistent left supra-cardinal vein, which results in a left-sided lower inferior vena cava. A venous vascular collar occasionally surrounds the aorta at the level of the renal vessels. Of these only those anomalies involving the ureters are of clinical significance, since they may give rise to partial obstruction of the ureters, with resultant hydronephrosis. It is not infrequent that these anomalies of the vena cava are associated with anomalies of the kidney. Such cases have been reported by Boyden, Messing and Ashley-Montague, and Odgers.

On several occasions it has been advantageous to know the relation of the inferior vena cava to tumors of the abdomen. Extensions of tumors into the vena cava may seriously limit the prognosis as well as extent of surgery. The size and location of tumors are very important to the roentgen therapist. who should be delighted to be able to follow the progress in his patients of retroperitoneal, primary, or metastatic tumors. A bizarre group of symptoms can arise from caval obstruction. Cabot reports (Case 18172) a housewife whose weakness of lower extremities with subsequent chest pain, backache and jaundice did not lead to a diagnosis of carcinoma of the stomach with extension to the inferior vena cava until autopsy. Hallock, Watson, and Berman presented a patient with a confusing group of symptoms thought to indicate Chiari's disease which on autopsy proved to be due to primary tumor of the inferior vena cava. Gregory's patient, undiagnosed until autopsy, proved to have a primary carcinoma of the liver, with a tumor thrombus of the inferior vena cava, extending into the right atrium. Tillisch reported seven cases, undiagnosed until autopsy, of tumor thrombosis of the inferior vena cava arising from renal neoplasm. Trauma or exertion may result in thrombosis of the vena cava, causing vague renal and circulatory signs and symptoms. Metastatic lymph nodes, liver abscess, echinococcus cysts, pyometritis, septic phlebitis, and Wilm's tumor all have been listed as troublesome diagnostic problems when they involve the inferior vena cava. Logically, signs and symptoms may develop from varices of the epidural veins secondary to an increase in the venous pressure here due to obstruc-

tion of the vena cava. Torres and Miranda have reported meralgia paraesthetica as the only sign pointing to disease of the iliac veins, which were found to be completely thrombosed at autopsy. Foster, Brouwer, and Kurtz found electrocardiographic changes in their patients which had also been reported in animal experimentation as being due to caval thrombosis. Indeed it appears that the characteristic leg and scrotal edema, abdominal swelling and ascites usually associated with the diagnosis of caval disease are commonly absent during most of the course of the disease. In such cases, obviously the diagnosis must depend upon the cavagram.

Patients whose hospital course is difficult often have all available veins thrombosed by trauma and medication. The femoral veins offer a logical alternate route for administration of iodinated contrast media for intravenous urography in these cases. There should be little objection to the routine administration of such contrast media in this way. One would obviously gain much additional information as well as an increase in dexterity in this type of puncture, that would serve well in time of need. It seems obvious that such routine use of the examination would add greatly to the extent of knowledge of the inferior vena cava in man.

Occasionally fatal consequences of diodrast sensitivity have been reported. Perhaps most of the cases assembled by Pendergrass and his associates were of this type. When one cosiders the number of intravenous urograms performed throughout the country by radiologists, urologists and general practitioners, the seriousness of this contraindication is somewhat mitigated. Attempts to test for sensitivity to the various iodinated compounds have not proved to be extremely successful. Cases in whom reactions have developed to the sensitivity test have not had serious consequences following the examination, whereas some who demonstrated no sensitivity to the initial test subsequently had severe reactions to the administration of the diodrast. Perhaps because of these paradoxical results, sensitivity tests are not widely done. One takes a graver view of the rapid administration of large amounts of highly concentrated diodrast or similar substances as in angiocardiography.

Thrombosis of the veins of an extremity, which had been the subject of venography is reported by Homans. In this instance 50 per cent Diodrast was the contrast medium. After the development of a similar thrombosis under similar circumstances on using uroselectan B, Kent followed a large group of patients who received this medication for urography. He found that upon direct questioning many admitted pain, tenderness and occasionally linear bands of hardness over the veins injected. Using diodrast, some of our patients did demonstrate nausea, vomiting, dyspnea and three had urticaria. None developed thromboses. The possibility of extravasation of the contrast medium is a real one,and the pain following such an extravasation is severe. However, it is relieved by novocaine injection about the vessel or cephalad to the puncture site, or is easily relieved by morphine. In one instance in which we were attempting to demonstrate the collateral vessels of the patient who had had his vena cava ligated, such an occurrence was followed by a fairly rapid absorption of dye from the injection site. This has been the general rule. In fact, in many situations, this is the preferred route to administer diluted diodrast to children for kidney visualization. Tissue sections are available from a patient who died of other causes shortly after perivascular injection of Neo-iopax. No great damage could be seen along the vessel microscopically.

Other technical difficulties do exist. We have encountered trouble in finding the femoral vein for injection in obese patients, in females, and in patients who have had amputation or ligation of the inferior vena cava or of

the iliac or femoral veins. Thrombosed veins also are occasionally troublesome, but these difficulties are lessened by practice.

Cavography appears desirable as a method for the intravenous administration of kidney contrast substances, in addition to being a method of clarifying diseases of an obscure nature having a possible relationship to the inferior vena cava. Proven sensitivity to iodinated contrast media may be a contraindication.

## Current Methods of Examining The Inferior Vena Cava

A technique similar to that used for angiocardiography is recommended by Pereiras and Castellanos. They incise the skin over the saphenous vein at the ankle, cannulate the vein, and inject 75 per cent Neo-Iopax very rapidly, using as much as 20 cc's for a small child. This method has the advantage that lateral and antero-posterior views should be easy to obtain. Much more of the vascular tree is opacified by this method than by the others in use. Dense shadows are obtained. Although a long route of passage exists from the ankle to the inferior vena cava, nevertheless, the administration of such a great amount of highly concentrated medium compensates for the increased possibility of error in timing exposures due to varying circulation time. This is essentially the method recently adopted at the University of Minnesota Hospital by Mellins, and in his hands has proven to be successful.

Farinas uses essentially the same technique as that of Dos Santos who cannulated the saphenous vein at the thigh, and injected 50 per cent diodrast solution with very good results.

The original method which we have previously described has been further simplified. At the present time, after having obtained a scout film of the abdomen to assure correctness of exposure factors and proper preparation of the patient, we inject percutaneously into the femoral vein 20 cc's of only 35 per cent diodrast or neo-iopax. The roentgen exposure is made at the end of injection; the injection usually takes about 10 seconds. The patient is instructed to hold his breath just before the exposure is made. We no longer tilt the table or use tourniquets since these measures contribute so little to the examination.

The method of Castellanos and Pereiras has demonstrated extensive anastomoses of the superficial thorace-lumbar veins in babies having post-salmonella thromboses of the inferior vena cava. Our method and that of Farinas show only the lower part of such anastamoses probably because we use relatively less of the contrast medium and that in a greater dilution.

We have demonstrated vertebral and epidural anastamoses by our method. Farinas' demonstration of these venous anastamoses with the pelvic veins and cava were published earlier without comment. We believe these to be the first such demonstrations in the living human.

To determine a normal roentgen appearance of the vena cava we performed the examination upon fifty patients sent to the department for routine intravenous urograms. The only change in procedure for these patients was the substitution of the femoral for the anticubital vein for injection of the 35 per cent diodrast and the exposure of an antere-posterior film of the abdomen during the injection. At present cavagrams are obtained only upon the request of the referring physician. It is not surprising then that in approximately seventy patients examined over half had significant abnormalities involving the inferior vena cava.

## Various Aspects of the Vena Cava

### Anatomical Aspects

The anatomy of the vena cava was early described by Breshet who not only outlined its course and relations, but

its ramifications into the so-called vertebral vein system. These veins so well described by Messing are directly continuous with the vena cava, in the pre-sacral lumbar, renal and phrenic regions. Batson demonstrated these as well as the vena vesorum by injecting Weber's vermillion into the femoral vein. Their course in the femoral vein were described physiologically at about the same time as they were demonstrated by Short.

Clinically significant anomalies of the vena cava were described in an earlier paragraph, but a brief resume' of the embryological development of the vena cava might well be repeated here. The inferior vena cava is formed terminally by the end of the right vitelline vein. Outgrowths extending down to the level of the renal vein, which anastomose with the right subcardinal and, below the renal, with the right supracardinal, form the normal vena cava. It is in this region that most of the anomalies occur. Franklin found a sphincter about the mouth of the vena cava of certain animals, a structure not as yet identified in humans. This is apparently a sling attached to the diaphragm, which compresses the vena cava on inspiration. The nerves of the vena cava and of the femoral vein were described by Pereiras, who described the spasm associated with irritation of the end organs in the adventitia. Although no end organs were found in the intima of the vein it was noted that intra-luminal novacaine relieved the pain and the spasm associated with irritation. This relief lasted longer than one would expect of novacaine indicating that the venous spasm also caused pain. Experiments on the response of the inferior vena cava to stimulation of the splanchnic nerves showed the vena cava constricting on direct stimulation of its walls or of its splanchnic afferents. Concomitant increase in venous pressure was noted. The contraction spread proximally along the vena cava, the greatest point of constriction, occurring at the bifurcation just below the renal vein, These constrictions could be relieved by tapping the vein with the finger, somewhat rhythmically.

Physiological Aspects

Contractions of a more diffuse nature, are noted with respiration. These were observed at the operating table by Fremont-Smith and experimentally by Franklin, Eckstein and Wiggers. Franklin, in 1936, made x-ray moving pictures of the thorotrast-filled vena cava in cats, guinea pigs and dogs, which during expiration showed the vena cava shortened by one-third and widened about one-third. On inspiration the vena cava lengthened and narrowed about a similar degree, resulting in an estimated volume decrease of 19 to 37 per cent. Potts and Smith noted very little change in volume flow with normal respiration. With passive exercise some increase in blood flow was noted; with both passive and voluntary exercise 100 to 250 times the resting blood volume passed through the vena cava. The gradient of pressure within the vena cava is low. The venous pressure at the auricle is practically zero, while that in the distal veins is normally between 10 and 20 mm. of water. This was dramatically demonstrated at operation upon the malignant polycystic kidney of a patient in whom the renal vein was avulsed from the vena cava by Henlein who noted that the pressure within the vena cava was not sufficient to force the blood through the rent. He also observed a to-and-fro movement of the column of blood corresponding to cardiac and respiratory phases. Batson theorized that tumor thrombi are forced through the pelvic veins into the vertebral plexas to the spine and the brain and skull by a reversal of pressure gradients caused by coughing and sneezing. This is not the experience of Hamilton, nor is it our experience. Pressure waves do not imply a concomitant change in direction of fluid flow.

To verify this concept we instructed a patient in the Valsalva maneuver. Then we filled his inferior vena cava with diodrast, and had him increase his abdominal pressure against the closed

glottis. None of the opaque medium passed into the vertebral plexus. It was sharply delimited by the valves present at the entrance of the great vessels into the vena cava. Hamilton found immediate variation in intra-cerebral and intra-spinal press res with varying intrathoracic and arterial pressures. In fact, increase in the cerebral and spinal pressure was noted before the arterial pressure wave reached these regions, thus, before a change in gradient had opportunity to cause a change in flow the gradient had been equalized. In fact, because of the depletion of the blood volume in the right atrium and the inferior vena cava the flow toward the heart was sharply increased for a short period following the Valsalva effort.

The contributions of the various great vessels to the vena cava remain fairly discrete as they pass cephalad. Franklin noted the phenomenon called "stream lines" by hydraulic engineers, on examining the blood flowing through the vena cava of a cat which had recently been pregnant. The highly oxygenated blood of the uterus caused a thin red stream to extend through the vena cava in sharp contrast to the blue venous blood. We have observed similar phenom ena on injection studies of the vena cava with contrast medium. These changes were particularly prominent in the case of a young man who had a large renal cyst in the lower pole of the right kidney which deflected the vena cava medially. The stream-lines are particularly prominent where the change of direction of flow is sharp.

Pathological Aspects

Continued increase in pressure within the vena cava results in thickening of the intima, with formation of some subintimal longitudinal fibers not found in a normal vena cava. Replacement fibrosis or phlebo-sclerosis may develop. The greatest amount of muscular hypertrophy is noted in the longitudinal muscles of the adventitia. It has been reported that sections of vein may be substituted as arterial grafts and will subsequently be almost indistinguishable from the neighboring arteries. Phlebosclerosis may result in calcification and cases are reported in which a long rod of calcium occupies the site of an old thrombotic vena cava. In cases of increased venous pressure, studied by Allen and Page, no such changes were noted in the inferior vena cava. Such hypertrophic changes easily could result in occlusion of the vena cava. These cases, because of the gradual onset and the excellent collateral formations, are usually asymptomatic. Septic thrombi of the vena cava are similar in that the onset is gradual, the symptoms are vague and the diagnosis is usually unsuspected. Infectious and post-infectious thrombosis form the greatest number of vena-caval occlusions, only 24 per cent falling into the group obstructed by an intraluminal neoplasm. Common causes are Salmonella infection in infancy, other bacterial diarrheas, puerperal sepsis, ascending and septic thrombi from the legs, appendicitis, psoas abscess, tuberculosis; even chronic ulcerative colitis has been thus associated.

Woodruff and Levin in their discussion of hypernephroid carcinoma of the kidney with malignant thrombus of the inferior vena cava quote Simpson as finding 50 per cent of malignant thrombi caused by extension of renal neoplasm, 20 per cent due to testicular tumors, 10 per cent hepatic, 9 per cent adrenal in origin. Our experience has been limited to the first group. Extrinsic obstruction may also be on either a malignant or benign basis although our only proved case of extrinsic obstruction at this time was due to a surgically distorted liver. Ferris and Blankenhorn say that liver abscess of any size of echinococcus cyst of the liver will occlude the vena cava by extrainsic pressure. In our case a history of duodenal malignancy and a nodular impression upon the vena cava led us to a diagnosis of malignant thrombus. This patient was surgically explored, and it was found that the vena cava was patent, but occluded by rather a large liver which extended over its entire anterior surface. The patient expired shortly after surgery, and no thrombus was demonstrated at autopsy.

The vena cava may be displaced, or

partially occluded by aneurysm of the descending abdominal aorta. A pulsating abdominal mass was the presenting problem in two of our patients, both of whom showed pressure deformities of the abdominal viscera, but only one of whom showed displacement of the inferior vena cava. The historyes are similar; clinical impressions are similar; the former at operation had acute diffuse swelling of the pancreas, the latter had an aneurysm. The first patient was treated by common duct drainage, the aneurysm of the second was wrapped in cellophane.

Tumors may displace the inferior vena cava without occluding it, and such was the case in the renal neoplasm of an ex-stone cutter whose extension was into the adrenal on the same side rather than into the vena cava. The operation was palliative since he also had diffuse metastases to the lungs and to the humerus. Aggregations of nodes may also displace the vena cava without occluding it, and lympho-sarcoma was identified in one of our patients treated with roentgen therapy. Unfortunately we were not able to get repeated examination on follow-up study, but since the tumor was palpably reduced it would undoubtedly have demonstrated similar changes on the roentgenogram. Scar formation about a pyonephrotic or tuberculous kidney may retract the vena cava away from its course, raising an additional hazard to the surgeon, who in resecting the scarred kidney might open the vena cava. In addition, the danger of infecting the wall of the vena cava with the infectious material within the capsule frequently precludes intracapsular extirpation of the kidney. An abdominal aneurysm has been reported to have ruptured into the vena cava, with formation of an arterio-venous fistula. We have not seen such a case.

The therapeutic and prognostic possibilities raised by the Roentgen contrast examination of the vena cava cannot be completely realized at this time for such diagnostic problems.

The ordinarily grave prognosis associated with malignant tumors is heightened immeasurably by evidence of caval invasion, particularly if the tumor thrombus invades the atrium of the heart. Ney suggests that prognosis must be less than six months in renal tumors exhibiting invasion of the vena cava. As inferred in the previous paragraph cavography seems necessary to the diagnosis in many cases. Identification of hepatic abscesses by this means should result in proper drainage and specific therapy with a resultant decrease in morbidity. Mallory reports a Cabot case where eosphageal varices, and distal caval thrombosis were the manifestations of a primary fibroma of the inferior vena cava arising at the level of the hepatic veins. Asymptomatic caval thrombosis may be the cause of varicose veins in the abdomen and extremities, and should be considered contra-indication to injection treatment, according to D'Abreu. Identification of patent vessels for the formation of Blakemore or Eck fistulas may prove valuable to patients with portal obstruction, where surgical treatment is contemplated. Perhaps the greatest value of the examination will be to the urologist, who may, on demonstration of anomaly, tumor thrombus or adhesions to the vena cava elect to use an abdominal incision rather than the trans-lumbar approach usually used. This renders the vena cava more accessible, and diminishes the possibility of avulsion of the renal veins, or of separation of partially-attached thrombi; it makes more feasible the resection and anastomosis of a retro-caval ureter, or the removal of a tumor thrombus from the vena cava. Available information on the anatomy, physiology, pathology and therapeusis of the vena cava may be made applicable by this examination. Much of this information is derived from animal experimentation. The extension of these principles to man may result in new concepts of abdominal disease with more emphasis upon vascular factors.

## Summary and Conclusions

1. A brief historical review shows a

large gap in the recent knowledge of vasography (inferior vena cava).

2. Caval visualization is indicated in
   a) Obscure diseases, possibly involving vascular system of abdomen, pelvis or lower limbs.

   b) Definition, approach, and progress of primary and metastatic abdominal masses.

   c) Clinical evaluation of vascular anomalies.

3. No present absolute contraindications to this study are known.

4. A new, easy, safe technique is described for roentgen visualization of the inferior vena cava.

5. Cavography has contributed and will continue to contribute to our knowledge of the anatomy, physiology, pathology and therapeusis of the vena cava. It will make more applicable our present information, much of which is derived from the experimental animal.

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## III. MEDICAL SCHOOL NEWS

### Coming Events

Jan. 31 - Minnesota Mental Hygiene Society - Dr. Benjamin Spock, Mayo Foundation - "A Pediatrician Looks at Mental Health" - 8:00 p.m. - Museum of Natural History Auditorium.

Feb. 1 - Duluth Clinic Lecture - Prof. Charles H. Best, University of Toronto - "The Pancreas as the Guardian of the Liver" - 8:15 p.m. - Museum of Natural History Auditorium.

* * *

### Duluth Clinic Lecture

Dr. Charles A. Best, Professor of Physiology of the University of Toronto, will deliver the annual Duluth Clinic Lecture on Tuesday, February 1 at 8:15 p.m. in the Auditorium of the Museum of Natural History. Dr. Best is well known to medical and lay audiences throughout the world because of his work on the physiology of the pancreas and the discovery of insulin. The subject of Dr. Best's Duluth Clinic Lecture will be "The Pancreas as the Guardian of the Liver."

Physicians and the public are welcome to attend. The Medical School is happy to be able to present Dr. Best as a participant in this Duluth Clinic series of distinguished lecturers.

* * *

### Heart Hospital Construction Begins

Alumni and friends of the University of Minnesota Medical School will be happy to learn that work is actively in progress on the Variety Club Heart Hospital. This hospital for the care and study of cardiovascular diseases has been made possible through the generous support of the Variety Club and will form a new unit in the group of hospitals which make up the University of Minnesota Hospitals.

The hospital will serve as the University Center of research in cardiovascular diseases. Approximately 80 hospital beds will be available for patients with cardiovascular disease which require hospitalization. In addition, the building will also house cardiovascular out-patient clinical facilities for the care of ambulatory patients in both the pediatric and adult age group. Excavation has already been begun at the Building site which is just south of the west wing of the University of Minnesota Hospitals and the building is expected to be completed in June 1950.

* * *

### Continuation Center Courses for Physicians

A course in pediatrics for General Physicians will be presented at the Center for Continuation Study February 7, 8, and 9. The course which is sponsored by the Maternal and Child Health Division of the Minnesota Department of Health will be centered around problems of premature and normal newborn infants. Distinguished visiting physicians who will participate in this course as members of the faculty are Dr. Julius Hess, University of Illinois, and Dr. L. Emmett Holt, Jr., New York University. Clinical and full-time members of the Medical School faculty will also participate in the course.

A course in Cardiovascular Diseases will be offered at the Center on February 14 and 15. This course is also intended for general physicians and is sponsored by the Minnesota Heart Association. Faculty for the course will be made up of members of the clinical and part-time staff of the Medical School and the Mayo Foundation.