STUDIES ON EXPERIMENTAL HYPERTENSION

XIV. The Effect of Intermittent Renal Arterial Occlusion on the Blood Pressure of the Dog*

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Loesch (1) studied the effect on systemic blood pressure of intermittent clamping of the renal pedicle of dogs' kidneys explanted under the skin. He produced temporary occlusion of artery, vein, and probably ureter, and reported the development of persistent hypertension as a result of this procedure. It took a month or more for the blood pressure to show a significant rise. The clamping of the renal pedicle was carried out every 2 or 3 days, the maximum period of occlusion at any time being 30 minutes. Three of the five animals used were unilaterally nephrectomized. All eventually had some impairment of renal excretory function, as evidenced by retention of urea in the blood. The unilaterally nephrectomized animals died early, in uremia. Up to the present a confirmatory report of this work has not been published, and the author has evidently not pursued it. Since it has been shown (2) that persistent constriction, without occlusion, of the main renal arteries is alone sufficient to produce persistent hypertension, without significant disturbance of renal excretory function, and since Loesch regarded the effect he observed as due to intermittent occlusion of the blood supply to the kidney, it was the object of this study to ascertain the effect on blood pressure of intermittent temporary occlusion of the main renal arteries alone.

Method

All the operations were performed under ether anesthesia, given by the drop method, half an hour after a hypodermic injection of a solution of morphine sulfate, $\frac{1}{20}$ grain, and atropine sulfate, $\frac{1}{3000}$ grain, per kilo body weight.

To make possible the intermittent occlusion of the main renal artery alone, it was

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enclosed in a silver watch ring attached to a fine silver chain (see Text-fig. 1), the end of which reached to the outside of the body. To apply the ring and chain, the main renal artery was exposed by the usual gridiron incision and retroperitoneal approach (2, 3), and dissected free of surrounding tissues for a distance of about 1 cm., close to the aorta. By means of a long pair of forceps the clasp on the watch ring was held back, the ring was then slipped around the renal artery, and the clasp released, leaving the artery enclosed in the ring. At the operation, a relatively gentle pull on the ring by means of the attached chain was found to be sufficient to occlude the renal artery. Release of the pull permitted the artery to pulsate freely. The inside diameter of the ring was 0.5 cm., which allowed ample room, without constriction, for the main renal artery of a dog weighing less than 20 kilos. The wound was closed in layers, as usual, the chain being brought out through the wound in the muscles, and then passed to the exterior through a separate stab wound in the skin and subcutaneous tissue, close to the main incision. To keep the dog from getting at the free end of the chain, the latter was protected by a comfortable wire cage strapped around the body and worn continuously by the animal (see Text-fig. 2). To keep the chain from becoming fixed to the healing wound by the ingrowth of granulation tissue into its meshes, it was pulled up for an instant and released every day, until the wound was healed and a channel for the chain established. After a variable period, during which the healing of the wound occurred, daily pulling upon the chain to occlude the main renal artery was begun. The pulling of the chain did not appear to cause pain or discomfort.

The direct intra-arterial femoral blood pressure of the dogs was determined (4) frequently for a control period of one month or more before the application of the ring and chain. To simplify the problem and increase the probability of the development of hypertension as a result of intermittent occlusion of the main renal artery, the opposite, normal kidney was finally removed in all the animals. In some dogs, the unilateral nephrectomy was performed before, and in others after, the application of the ring and chain to the main renal artery of the other kidney. In some of the dogs, the intermittent occlusion of the renal artery was begun while the opposite normal kidney was still present. This was for the purpose of investigating the effect of unilateral intermittent occlusion in the presence of a normal kidney on the other side. It has been shown (2–5) that persistent unilateral renal ischemia, in the presence of a normal kidney on the other side, is followed by temporary elevation of blood pressure which persists from weeks to months. To insure a uniformly adequate tension upon the chain, a thin cord was tied every day to the ring at the end of the chain, and a weight attached to the end of the cord, which was arranged to run freely over a pulley. The dogs were placed on one side and lightly restrained by straps. They did not appear to have pain and soon became trained to lie quietly during the time the chain was being pulled (see Text-fig. 3). A weight of 200 gm. was used during the first 2 weeks, as a rule, and this was then increased to 300 gm., the weight used during the greater part of the period in all the experiments. At the time of the application of the ring, it was found that the pull of even a 100 gm. weight was adequate to occlude the vessel. Tension was maintained upon the ring and chain for a period which was quickly increased from 10 minutes to 30 minutes daily, except Sunday. This was kept up for from 2 to 5 months. In some of the animals the initial daily period was 30 minutes. For experimental history, see Table I.

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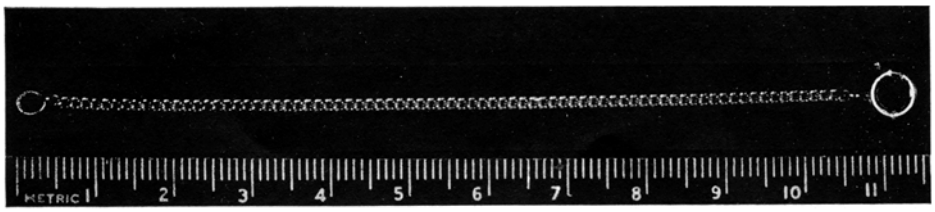
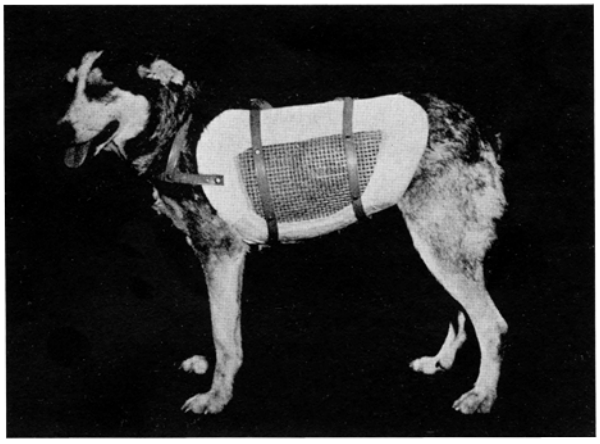
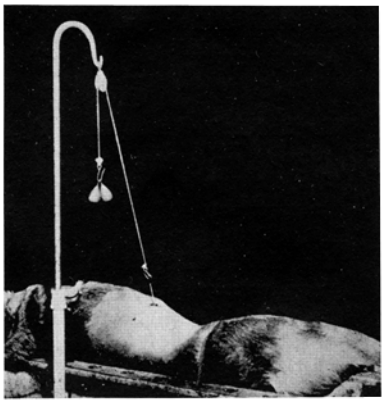


TEXT-FIG. 1. Silver chain, with watch ring at one end, to enclose the main renal artery, and a smaller ring at the other end for the attachment of cord and weights.



TEXT-FIG. 2. Wire mesh contrivance for the protection of the loose end of the chain. This was worn continually by the animal.



TEXT-FIG. 3. Animal lying on side. A cord was attached daily to the end of the chain. The cord was made to run through a pulley. Weights were hung on a hook at the end of the cord, to pull up the chain and occlude the artery.

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TABLE I

Experimental History of the Animals

Dog No.	Dates	Experiment	Average blood pressure	Maximum blood pressure
			mm. Hg	*mm. Hg*
5-30	July 14, 1939, to Nov. 26, 1939	Normal control period	130	145
	Nov. 27, 1939	Left main renal artery was constricted by a clamp and ureter occluded		
	Nov. 28, 1939, to Dec. 5, 1939		129	145
	Dec. 6, 1939	Ring and chain were applied to right main renal artery		
	Dec. 7, 1939, to Feb. 11, 1940	Before left nephrectomy and after chain pulling was begun	130	145
	Feb. 12, 1940	Left nephrectomy		
	Feb. 13, 1940, to Apr. 19, 1940	After left nephrectomy; chain pulling was continued	132	150
5-37	Aug. 9, 1939, to Oct. 24, 1939	Normal control period	120	135
	Oct. 25, 1939	Left nephrectomy		
	Oct. 26, 1939, to Dec. 18, 1939	After left nephrectomy and before chain pulling was begun	114	130
	Dec. 7, 1939	Ring and chain were applied to right main renal artery		
	Dec. 19, 1939, to Mar. 1, 1940	After chain pulling was begun	122	140
5-53	Aug. 31, 1939, to Nov. 26, 1939	Normal control period	128	150
	Nov. 27, 1939	Left main renal artery was constricted and left ureter occluded		
	Nov. 28, 1939, to Dec. 12, 1939		125	140
	Dec. 13, 1939	Ring and chain were applied to right main renal artery		
	Dec. 14, 1939, to Feb. 12, 1940	After chain pulling was begun but before left nephrectomy	129	145
	Feb. 13, 1940	Left nephrectomy		
	Feb. 14, 1940, to May 2, 1940	After chain pulling was begun and after left nephrectomy	124	135
	May 3, 1940, to Oct. 16, 1940	After constriction of the right main renal artery; chain pulling was discontinued	180	200
5-59	Oct. 12, 1939, to Dec. 18, 1939	Normal control period, including period after application of chain	128	140
	Nov. 29, 1939	Ring and chain were applied to left main renal artery		

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TABLE I—*Continued*

Dog No.	Dates	Experiment	Average blood pressure	Maximum blood pressure
			mm. Hg	*mm. Hg*
5-59 *cont.*	Dec. 19, 1939, to Feb. 11, 1940	After chain pulling was begun and before right nephrectomy	131	145
	Feb. 12, 1940	Right nephrectomy		
	Feb. 13, 1940, to Apr. 24, 1940	After right nephrectomy; chain pulling was continued	135	145
	Apr. 25, 1940	Main renal artery suddenly became greatly constricted or occluded. Blood pressure 205 mm.		
	Apr. 26, 1940	Blood pressure 215 mm.		
	Apr. 27, 1940	Blood pressure 200 mm. Dog was very ill. Killed		
5-61	Apr. 28, 1939, to Nov. 21, 1939	Normal control period	131	150
	Nov. 22, 1939	Ring and chain were applied to left main renal artery		
	Nov. 23, 1939, to Apr. 7, 1940	After the application of the chain; chain never pulled	161	210
	Apr. 8, 1940	Left nephrectomy		
	Apr. 9, 1940, to July 18, 1940	After left nephrectomy	128	135
5-66	Sept. 25, 1939, to Dec. 18, 1939	Normal control period, including period after application of chain	131	150
	Nov. 1, 1939	Ring and chain were applied to left main renal artery		
	Dec. 19, 1939, to Feb. 13, 1940	After chain pulling was begun	132	145
	Feb. 14, 1940	Left nephrectomy		
	Feb. 15, 1940, to May 1, 1940	After left nephrectomy; chain pulling was continued	132	150
	May 2, 1940	After right main renal artery was constricted		
	May 3, 1940	Blood pressure 170 mm.		
	May 4, 1940	Dog was found dead		
5-69	Oct. 16, 1939, to Dec. 18, 1939	Normal control period, including period after application of chain	125	140
	Nov. 15, 1939	Ring and chain were applied to left main renal artery		
	Dec. 19, 1939, to Feb. 7, 1940	After chain pulling was begun	132	145
	Feb. 8, 1940	Left nephrectomy		
	Feb. 9, 1940, to Mar. 27, 1940	After left nephrectomy; chain pulling continued	123	145
	Mar. 28, 1940, to Apr. 22, 1940	Chain pulling was stopped, but right main renal artery obviously became persistently constricted or occluded; dog died in uremia, with greatly elevated blood pressure	215	240

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TABLE I—*Concluded*

Dog No.	Dates	Experiment	Average blood pressure	Maximum blood pressure
			mm. Hg	*mm. Hg*
5-71	Oct. 16, 1939, to Dec. 18, 1939	Normal control period	124	140
	Dec. 19, 1939	Right nephrectomy		
	Dec. 19, 1939, to Mar. 4, 1940	After right nephrectomy and before chain pulling was begun	128	140
	Jan. 3, 1940	Ring and chain were applied to left main renal artery		
	Mar. 5, 1940, to June 20, 1940	After chain pulling was begun	128	140
	June 21, 1940, to July 30, 1940	After constriction of the left main renal artery; chain pulling was discontinued	154	165
	July 31, 1940, to Oct. 16, 1940	After the left main renal artery was occluded	150	175
5-85	Nov. 16, 1939, to Feb. 13, 1940	Normal control period	131	150
	Jan. 3, 1940	Ring and chain were applied to left main renal artery		
	Feb. 14, 1940	Right nephrectomy		
	Feb. 15, 1940, to Mar. 3, 1940	After right nephrectomy and before chain pulling was begun	127	130
	Mar. 4, 1940, to June 10, 1940	After chain pulling was begun	129	145
	June 11, 1940, to July 30, 1940	After constriction of the left main renal artery; chain pulling was discontinued	142	170
	July 31, 1940, to Oct. 16, 1940	After the left main renal artery was occluded	142	160
6-41	Apr. 21, 1940, to May 21, 1940	Normal control period	114	120
	May 22, 1940	Ring and chain were applied to left main renal artery; right nephrectomy		
	May 23, 1940, to June 3, 1940	After right nephrectomy; before chain pulling was begun	115	120
	June 4, 1940, to June 24, 1940	After chain pulling was begun	122	130

RESULTS

For periods ranging from 30 to 150 days, these animals were subjected to temporary daily (except Sunday) occlusion of the main renal artery. No significant rise in blood pressure occurred at any time during the period of chain pulling in six of these animals. The remaining three (5-59, 5-66, 5-69), unilaterally nephrectomized animals, became abruptly hypertensive

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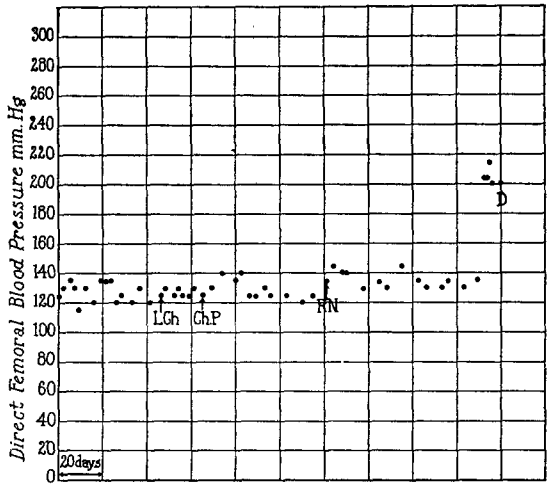
and uremic, after long periods of intermittent occlusion of the main renal artery of the one kidney, during which the pressure remained normal. Although the intermittent occlusion was stopped as soon as elevation of pressure was detected, yet the blood pressure remained high, the uremia increased, and the dogs either died in a few days or were sacrificed. Text-fig. 4, dog 5-59, is illustrative of the three animals. At autopsy, they showed the characteristic vascular lesions of the malignant phase of this type of experimental hypertension (6, 7) in many organs except the ischemic



TEXT-FIG. 4. Dog 5-59.

LCh, ring and chain were applied to the left main renal artery. ChP, the daily pulling of the chain was begun. RN, right nephrectomy was performed. Chain pulling was continued. During the entire period of chain pulling, both before and after the removal of the right kidney, the blood pressure showed no significant change from normal. A few days before death the blood pressure rose abruptly to more than 200 mm. Hg. D, the animal was killed. See Table I.

kidney. The kidney showed parenchymatous degeneration and necrosis. This and the presence of the vascular lesions showed that excessive permanent constriction or occlusion of the renal artery had occurred, and caused the late rise of blood pressure and renal insufficiency.

One dog (5-37) died unexpectedly after a perod of intermittent occlusion, during which time the blood pressure remained within normal limits. The last pressure determined 8 days before death was not elevated. Examination of the heart's blood, obtained in unclotted form post mortem, showed a B.U.N. of 198 mg. per 100 cc. of plasma. At autopsy, in the gross, there were petechiae in the gastro-intestinal tract, and microscopically these organs showed the usual necrotizing lesions and inflammatory arteriolar

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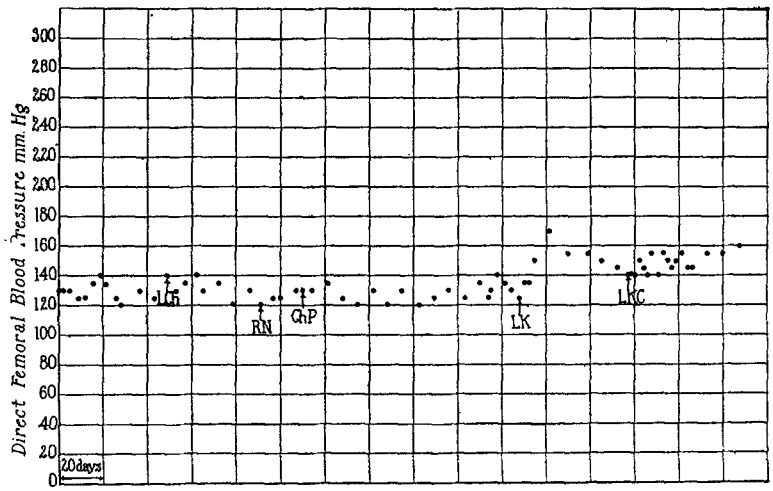
lesions of the malignant phase of experimental hypertension due to renal ischemia (5–7). This dog was therefore probably hypertensive in the last few days, due to sudden persistent excessive constriction, or actual occlusion, of the main renal artery of its one kidney. This is comparable to the effect produced deliberately in dogs 6-64 and 6-83, in experiments to be described later in this paper. See Table I.

In dog 6-41, a similar outcome to that of dog 5-37 probably occurred. This dog was found dead, but its heart's blood could not be obtained for chemical examination because the blood had clotted However, at autopsy, the lesions of the malignant phase were present in the arterioles of the gastro-intestinal tract, so it is reasonable to assume that hypertension was also present for several days before death, due to persistent oc-



TEXT-FIG. 5. Dog 5-85.

LCh, ring and chain were applied to the left main renal artery. RN, right nephrectomy was performed. ChP, daily chain pulling was begun. LK, left main renal artery was moderately and permanently constricted by a silver clamp. Ring and chain were removed. LKC, left main renal artery was occluded by tightening the clamp. Chain pulling had no effect on the blood pressure, but permanent constriction of the main renal artery caused a slight rise of blood pressure. See Table I.

clusion or excessive constriction of the main renal artery of the only kidney. See Table I.

In dogs 5-53, 5-66, 5-71, and 5-85, after a long enough period had elapsed to show that intermittent occlusion (30 minutes daily) of the main renal artery of a unilaterally nephrectomized dog does not result in hypertension, the renal artery was moderately constricted by a clamp (2, 3), which was left on the vessel. In every instance a significant but variable rise in blood pressure promptly developed, and the elevation persisted. (Text-figs. 5, 6, and 7, of dogs 5-85, 5-71, and 5-53, respectively, are illustrative of this effect). For experimental histories, see Table I.

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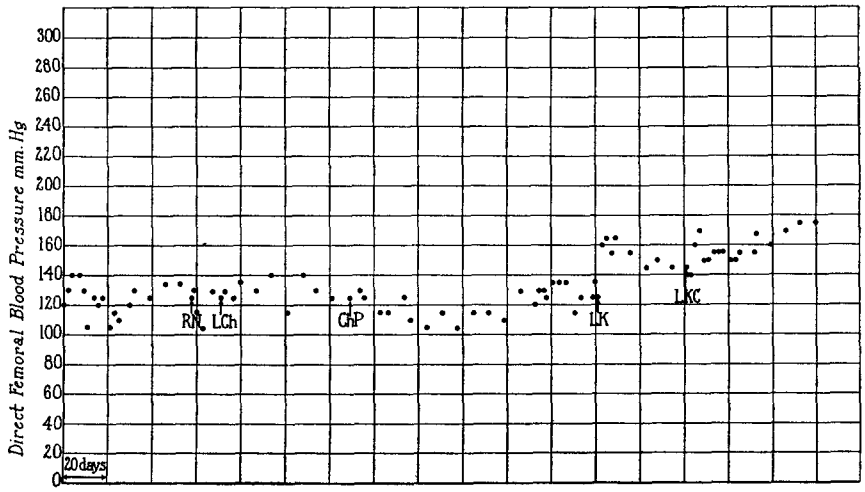
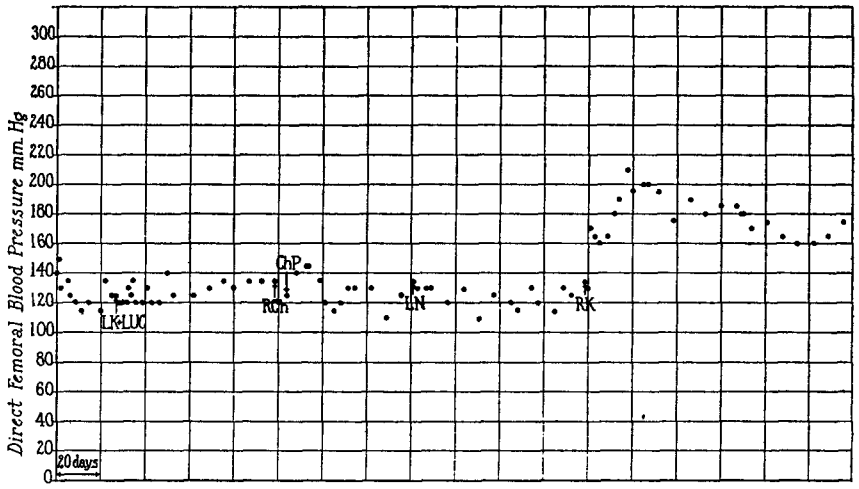


TEXT-FIG. 6. Dog 5-71.

RN, right nephrectomy was performed. LCh, ring and chain were applied to the *left* main renal artery. ChP, daily chain pulling was begun LK, the left main renal artery was moderately and permanently constricted by a clamp. LKC, the left main renal artery was occluded by increasing the constriction of the vessel by the clamp. Chain pulling had no effect on the blood pressure, but subsequent constriction of the main renal artery caused a moderate rise of blood pressure. See Table I.



TEXT-FIG. 7. Dog 5-53.

LK and LUC, left main renal artery was constricted and left ureter tied and cut. RCh, ring and chain were applied to the right main renal artery. ChP, daily chain pulling was begun. LN, left nephrectomy was performed. Chain pulling was continued. RK, marked permanent constriction of the right main renal artery by a clamp. Ring and chain were removed. The intermittent chain pulling had no effect on the blood pressure before or after the removal of the left kidney, but great permanent constriction of the right main renal artery caused a great rise of blood pressure. The animal is still alive. See Table I.

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In a tenth animal, 5-61, two main renal arteries to one kidney were encountered at the first operation. Separate rings and chains were applied to these arteries. Before any attempt was made to pull the chain, however, the blood pressure of this animal began to rise, and rose to a considerable level. This elevation persisted until the kidney was removed, after which the blood pressure promptly fell to the normal level, which always occurs (3–5), if a single ischemic kidney producing hypertension (the other kidney being normal) is removed. The hypertension in this case must be attributed to persistent constriction of the blood supply to the one kidney, just as if its two main arteries had been constricted by clamps (2, 3). This interference with the blood supply to the kidney resulted from constriction of the artery by kinking and by compression of scar tissue which formed within and around both rings. The existence of thrombosis in the main renal artery was not established at the autopsy on this animal. For experimental history, see Table I.

The Effect of Continuous Prolonged Pulling of the Chain to Occlude the Main Renal Artery of a Unilaterally Nephrectomized Dog

As an important control of the above experiments, it was considered necessary to determine whether the pulling of the chain actually could effect occlusion of a main renal artery. To determine this, the following experiments were performed.

In dog 6-83, after a control period of 48 days, during which time blood pressure was taken frequently, a ring and chain were applied to the left main renal artery, and the right kidney was excised. For 3 more weeks the chain was not pulled up, in order to give it an opportunity to become fixed to the tissue, if it would. The experimental history of this animal from then on follows:

Aug. 20, 7:40 a.m. The dog was placed in the usual position, and the chain was pulled up and kept pulled up continuously for 13 hours. A 300 gm. weight was used, as in most of the experiments.

At 7:30 a.m., before the chain pulling was begun, the femoral mean blood pressure was 130 mm. Hg, blood urea nitrogen (B.U.N.) 10.5 mg., creatinine (Cr.) 1.2 mg., and carbon dioxide combining power (CO_2) 58.6 volumes per 100 cc. of plasma.

10:35 a.m., B.U.N. 10.5 mg., Cr. 1.5 mg., CO_2 57 volumes.

1:35 p.m., B.U.N. 16.5 mg., Cr. 1.7 mg., CO_2 53 volumes.

4:35 p.m., B.U.N. 23.3 mg., Cr. 2.4 mg., CO_2 51 volumes.

4:45 p.m., 500 cc. of water administered by stomach tube.

7:30 p.m., B.U.N. 28.5 mg., Cr. 2.8 mg., CO_2 46 volumes.

8:40 p.m., B.U.N. 30.0 mg., Cr. 3.2 mg., CO_2 49.5 volumes.

It was obvious, when the results of the 4:35 p.m. specimen were obtained, that occlusion of the main renal artery was being effected by the pulling of the chain, so it was discontinued at 8:30 p.m. However, the release of the vessel evidently did not result in restoration of the circulation to the kidney because:

Aug. 21, 10 a.m., B.U.N. 99 mg., Cr. 4.2 mg., CO_2 42.1 volumes.

Aug. 23, 11 a. m. B.U.N. 144 mg., Cr. 6.4 mg., CO_2 38.8 volumes. Blood pressure 200 mm. Hg.

Aug. 24, 10 a.m., B.U.N. 196 mg., Cr. 7.2 mg., CO_2 39.3 volumes. Blood pressure 195 mm. Hg.

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At this time the animal was unconscious and obviously moribund. Despite this, the blood pressure was still elevated. The animal was killed at noon on Aug. 24. At autopsy, the main renal artery was found kinked at the site of the ring around the vessel, but no thrombus was present in the vessel. The kidney showed acute, diffuse necrosis, especially of the cortex, which was of a light yellow color in contrast to the dark red of the medulla. In the stomach, small intestines, large intestine, appendix, and urinary bladder, there were many petechiae. Microscopically, the typical lesions of the malignant phase, degenerative, necrotizing, and inflammatory lesions of the arterioles, were found in the sections of these organs.

In dog 6-64, after a normal control period of 31 days, a ring and chain were applied to the left main renal artery, and the right kidney was removed. For a period of 10 days after this operation, the chain was not disturbed Then, for 21 days, the chain was pulled up for 30 minutes daily (except Sunday) to occlude the vessel. A weight of 300 gm. was used as usual. During this period the blood pressure remained unchanged. The subsequent experimental history of this animal follows:

July 29, 9 a.m., B.U.N. 19.5 mg., Cr. 1.8 mg., CO_2 49.9 volumes. Femoral mean blood pressure 120 mm. Hg.

9:15 a.m., the chain was pulled up to occlude the vessel and this was continued without interruption for 26 hours.

2:30 p.m., B.U.N. 32.3 mg., Cr. 3.2. mg., CO_2 36.6 volumes.

5:15 p.m., 250 cc. of water given by stomach tube.

7:35 p.m., B.U.N., 46.5 mg., Cr. 3.4 mg., CO_2 34.3 volumes.

July 30, 2:25 a.m., B.U.N. 64.8 mg., Cr. 3.9 mg., CO_2 30.3 volumes.

7:25 a.m., B.U.N., 57 mg., Cr. 3.9 mg., CO_2 33.8 volumes.

11 a.m., B.U.N. 66 mg., Cr. 4.2 mg., CO_2 33.6 volumes. Blood pressure 115 mm. Hg.

11:15 a.m., the chain was released.

July 31, 10 a.m., blood pressure 120 mm. Hg.

10:15 a.m., B.U.N. 25.5 mg., Cr. 2.8 mg., CO_2 39.2 volumes.

Aug. 1, 9:45 a.m., B.U.N. 21.8 mg., Cr. 1.8 mg., CO_2 43.3 volumes.

Aug. 4, 3 p.m., B.U.N. 20.3 mg., Cr. 1.4 mg., CO_2 48.4 volumes.

This animal survived, despite the fact that the period of complete occlusion of the renal artery was twice as long as that of dog 6-83. The development of retention of nitrogenous products in the blood, and the reduction of the CO_2 combining power of the plasma, showed that occlusion of the main renal artery had been effective. 5 hours after chain pulling was begun, there was definite retention of nitrogenous products in the blood. The survival of the animal and the quick return of the values of nitrogenous products and of CO_2 in the plasma to normal showed that the release of the vessel had resulted in prompt complete restoration of the circulation to the kidney. The blood pressure was not significantly altered during the occlusion, and it has remained within the limits of normal during the period of 9 weeks since the release of the vessel. The animal is still alive.

It is safe to conclude from these experiments that the vessels of all of the dogs were actually constricted, as intended, whenever the chains were pulled up in the manner described.

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DISCUSSION

The results presented indicate that a brief daily period (up to 30 minutes) of renal ischemia for as long as 5 months does not cause persistent hypertension in dogs with a normal kidney on the other side or in those in which the other kidney has been removed. The probability becomes great that the effects which Loesch (1) obtained by constriction of the renal pedicle, with occlusion of artery, vein, and probably ureter, were due in some way to eventual *persistent* ischemia which developed as a result of both the explantation, with the abnormal position of the kidney, as well as due to the injury produced by the intermittent clamping of the pedicle by means of a pair of forceps. Loesch made no mention of the condition of the renal artery, vein, and ureter in his animals at autopsy, so that the possibility cannot be excluded that there was persistent constriction of one or all of the structures within the pedicle. This is definitely indicated in one animal that developed uremia but recovered after decapsulation and nephrostomy of its only kidney. In this animal the ureter, at least, must have become permanently obstructed.

In the experiments reported here, it has been found that intermittent occlusion of one renal artery, with the other kidney left intact, was not followed by elevation of blood pressure. The same obtained when intermittent occlusion of the main renal artery was practiced in a unilaterally nephrectomized animal. The blood pressure failed to rise. The occlusion was performed daily (except Sunday), rather than every 2 or 3 days, as practiced by Loesch, and, in most of the dogs, was carried on for longer periods than in Loesch's experiments. When, for some reason, great constriction or occlusion of the artery inadvertently became persistent in a unilaterally nephrectomized animal, hypertension developed which was accompanied by uremia that proved fatal. This result is similar to the one obtained by Loesch in his three unilaterally nephrectomized dogs and merely indicates that in his experiments also the effect was due to persistent great constriction or occlusion of the one main renal artery. The positive results obtained by Loesch in the other two dogs may well have been due also to persistent constriction, of lesser degree, of one or all of the components of the renal pedicle, with resultant persistent renal ischemia.

SUMMARY AND CONCLUSIONS

By means of a silver chain attached to a silver ring around the main renal artery, intermittent renal arterial occlusion, up to 30 minutes daily, was practiced for as long as 5 months in unilaterally nephrectomized dogs. This did not result in the development of persistently elevated blood pres-

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sure. Persistent moderate constriction of the renal artery of such animals by a silver clamp, after intermittent temporary occlusion had failed to affect the blood pressure, produced the usual rise of blood pressure, without accompanying significant impairment of renal excretory function. When the renal artery accidentally became persistently constricted to a great degree, or actually occluded, or if occlusion was deliberately produced by continuous pulling of the chain, hypertension and renal insufficiency (the malignant phase) quickly developed. The results do not lend support to the view that brief daily periods of renal ischemia from intrarenal vasospasm, or from any other cause, can produce persistent hypertension of renal origin.

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