joined together and the sutures tied consecutively. The proximal end of the artery, forming a cuff with the intima outside, is invaginated into the distal portion. (In suturing a vein the cuff is formed at the peripheral end of the vessel.)

At the end of the operation the proximal clamp is first of all removed and then the distal one. The pressure of the blood passing through the cuff at the proximal end presses the latter closely against the intima of the distal end, thus ensuring a hermetic suture. The injured parts of the vascular wall, the suture material, and even the stitch-holes remain outside the lumen and are separated from it by a band of intact intima in close adhesion. All factors contributing to the formation of thrombosis are thus excluded, the force of the blood pressure now blocking and isolating the lumen of the vessel instead of causing haemorrhage.

Out of a total of 52 experiments with the circular suture only two were followed by thrombosis at the site of operation. Vasographical and histological examination has shown that the slight constriction of lumen which occurs at the site of anastomosis completely disappears in a week or two, this process being due to atrophy of the media in those parts of the vascular wall which are isolated from the lumen of the vessel. Examination of the vascular nerves at the site of suture has shown that they grow through the outer adventitial coats across the line of anastomosis.

This modification of the circular suture has been successfully used in uniting not only vessels of equal diameter but those of different diameters as well. In a number of experiments on dogs end-to-end anastomosis between the left subclavian and pulmonary arteries has also been successfully performed. It should be noted that in such cases one to three additional adventitial interrupted sutures are usually needed, but even then the operation takes no longer than eight to ten minutes.

Conclusion

The new modifications of the hand-made and mechanical sutures here described have been used to divert arteries in plastic operations on the large arterial trunks. By means of such an operation it is possible, for instance, to repair a defect of the femoral artery below the branching of the deep femoral artery in man over a distance of 7-10 cm. by anastomosing the intersected deep femoral artery to the distal portion of the femoral artery. Animal experiments have shown that the substitution of smaller arteries for arteries with a diameter $1\frac{1}{2}$ -2 times greater secures a renewal of the general blood circulation which is functionally adequate.

The value of the methods of vascular suture, both hand-made and mechanical, elaborated in my department of operative surgery at the Medical Institute in Moscow has been amply proved both experimentally and in clinical practice.

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"Radiopage," a miniature personal radio-receiver using transistors instead of valves, was demonstrated recently in London. It is claimed to be "eminently suitable" for use in hospitals. The receiver fits into a pocket and the power is supplied by a battery with a life of 500 hours. Up to 50 calls can be effected with any one system, and each communication is received privately and separately. Messages can be heard without the need of putting the receiver to the ear. The makers are British Communications Corporation Ltd., Wembley, Middlesex.

RENAL PAPILLARY NECROSIS

OBSERVATIONS ON FIVE CASES

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It has long been known that papillae may necrose and separate from the rest of the kidney. This lesion has been variously named necrosis of the renal papillae, papillary necrosis, necrotizing renal papillitis, and papillitis necroticans. It was first observed by a pathologist (von Friedreich, 1877) and for years remained a post-mortem finding; consequently it was held to be a fatal complication. However, clinicians are becoming more aware of the condition, especially since the report of Robbins *et al.* (1946) and the classical paper by Edmondson *et al.* (1947). Nowadays the presence of papillary necrosis may be recognized clinically. As a result it is found that papillary necrosis is not necessarily fatal, and that function of the kidney may recover after papillae have necrosed and sloughed.

The following cases exemplify some factors that predispose to necrosis of renal papillae and illustrate different symptoms that may result. In one patient there was good evidence of healing and repair.

Case 1

A man aged 62 was admitted to hospital with uraemia in March, 1952. For five weeks he had had difficulty in passing urine and there had been haematuria at times. There was no fever; the prostate was enlarged; the urine contained no sugar, a little albumin, and on microscopy red cells and a few white cells were seen. Culture was sterile. The blood urea was 503 mg. per 100 ml.; haemoglobin 42% (6.2 g./100 ml.). He died the next day.

Necropsy Summary.—Senile hypertrophy of the prostate obstructed the urethra; the bladder showed an acute cystitis; bilateral hydronephrosis and hydronephrosis were present. Both kidneys, though distended by hydronephrosis, were small (left 102 g., right 105 g.) with narrow granular cortex and adherent capsule. Almost all renal papillae were affected by papillitis necroticans in an advanced stage, some having sloughed away, but most were still in the process of separation, the necrotic piece being shrunken and dark in colour. The gall-bladder was full of pus and contained a stone; on culture *Proteus vulgaris* and coliform bacilli were isolated. Uraemic pericarditis and colitis were also found.

Sections of 15 papillae from both kidneys were examined. Three of these appeared in the gross to be unaffected by necrosis but histologically all had some degree of clear-cut necrosis of the tip. In the three that looked normal there was some acute pyelonephritis but only a few chronic lesions. The chronic pyelonephritis was accompanied by some intimal thickening of the intralobular arteries but there were no hypertensive arteriolar changes and nothing to suggest diabetic glomerulosclerosis. The papillae with extensive necrosis had an increased vascularity of the adjacent living papillary tissue but no granulation tissue formation. There was no necrosis of the tissue of the renal pelvis.

Comment.—Papillitis necroticans was associated with urinary obstruction and pyelonephritis. There was no evidence of diabetes. In retrospect the necrosis of renal papillae was evidently responsible for haematuria and must have contributed to renal failure.

Case 2

A man aged 73 was admitted to hospital in August, 1950, with retention of urine. Symptoms of difficulty with micturition and incontinence started a year previously.

On admission the urine was chemically normal; the blood urea was 110 mg. per 100 ml. The prostate was hard and craggy. A clinical diagnosis of carcinoma of the prostate was made, and 15 mg. of stilboestrol was given daily. After five days he developed complete retention of urine and underwent cystotomy. After this his urinary output was satisfactory, but he began to vomit and became clinically dehydrated, and the blood urea rose to 303 mg. per 100 ml. The urine now contained albumin, many red cells, and scanty white cells, and on culture there was a mixed growth of organisms, including *Pseudomonas pyocyanea* and *Streptococcus faecalis*. Dehydration was corrected by intravenous fluids and the blood urea fell to 165 mg. per 100 ml. He received 1 g. of streptomycin daily for eleven days, and then 3 g. of sulphadimidine daily for four days. His condition deteriorated and he died in uraemia 37 days after admission.

Necropsy Summary.—Urinary obstruction was caused chiefly by senile prostatic hypertrophy, but an invasive carcinoma of the posterior lobe was also present. The bladder wall was hypertrophied and there was an acute cystitis. Bilateral dilatation of the ureters, more severe on the right side, was associated with pyonephrosis which was also greater on the right. Some gravely calculous material was mixed with the pus on both sides. The tips of all the renal papillae were necrotic, but this was more advanced on the right side. In addition, the right kidney had two separate anatomical pelves and two ureters which joined midway down; the papillae in both of these pelves were uniformly necrotic.

Chronic pyelonephritis with an acute pyelonephritis superimposed was seen histologically. There was the usual absence of any increased inflammatory reaction at the line of separation of the necrotic papillae, and the adjacent pelvic wall, although acutely inflamed, was not necrotic.

Comment.—In this elderly man urinary obstruction and urinary infection were followed by uraemia. There was no evidence of diabetes mellitus. Papillitis necroticans was not suspected as a cause of the progressive and fatal uraemia.

Case 3

This patient, a man aged 75, first attended the out-patient department in July, 1951, with a history of having had left epididymitis twice in the previous year and of dysuria and frequency for five weeks. He was found to have a large prostate and diabetes mellitus. On October 9 he was seized with severe right-sided stabbing pain radiating from the loin to the groin; he vomited. On admission to hospital the same day his temperature was 101° F. (38.3° C.), and there was tenderness and guarding in the right loin. The urine was obviously bloody and contained albumin, many red cells, and leucocytes; *Bact. coli* and a variety of other organisms were grown on several occasions. Penicillin and streptomycin were given, and the diabetes was controlled by six-hourly injections of soluble insulin. He steadily improved. Ten days after admission intravenous pyelography revealed no function of the right kidney, which two months before had excreted the dye normally. On cystoscopy the right ureteric orifice was puffy and reddened and a small mass impacted in the ureter could be seen bulging into the bladder close to the ureteric opening. On diathermy over this bulge there was a gush of debris followed by clear urine.

Progress was uneventful until two weeks later (November 3), when sacral pain developed, and after that he started to have rigors. On November 6 the right kidney was explored; it contained pin-head abscesses and petechiae. The kidney was drained by a Hyrtl nephrostomy; a pulsating mass was palpated in the right iliac fossa. Thereafter the

patient became steadily worse and developed pulmonary oedema; he died on November 15; during the last ten days the blood urea rose from 39 to 240 mg. per 100 ml.

Necropsy Summary.—There was a moderate degree of urethral obstruction due to prostatic hypertrophy, and the bladder, which was acutely inflamed, had some hypertrophy of its wall. The left ureter and renal pelvis were not dilated or inflamed, and the left kidney had no gross microscopical abnormality except a little arteriolar hyalinization attributable to a mild hypertension. The right ureter was constricted where it was adherent to an atheromatous aneurysm of the right common iliac artery that had evidently leaked slightly and caused considerable fibrosis round about. Above the obstruction the right ureter was dilated but not grossly inflamed; the pelvis was moderately dilated and inflamed, partly as a result of operative drainage through the kidney substance. All but one of the renal papillae in this right kidney were necrotic and becoming separated along a sharply defined line. There was acute pyelonephritis but no gross or microscopical evidence of chronic pyelonephritis. In neither kidney was there any sign of diabetic glomerulosclerosis.

Comment.—In this case the partial obstruction of one ureter by adherence to an aneurysm determined the unilateral pyelonephritis. The consequent papillitis necroticans was limited to the same side. Renal colic and obstruction at the lower end of this ureter were due to the passage of necrotic papillary tissue.

Case 4

A married woman of 62 was admitted to hospital on July 12, 1954, in diabetic acidosis. Two years previously she began to develop symptoms of diabetes mellitus and lost 60 lb. (27.2 kg.) in weight. Two weeks before admission she had an attack of abdominal pain which lasted four hours and she vomited.

On admission she was not dehydrated or shocked. Gerhardt's test on her urine was positive. The diabetes was readily stabilized on a daily total of about 30 units of insulin. She ran a fever—100° F. (37.8° C.)—and had severe dysuria and low back pain which was worse on lying in bed. The urine contained variable amounts of sugar, much protein, many red and white blood cells, and coliform organisms grew on culture. A 10-day course of sulpha-

FIG. 1.—Case 4. Two stages of papillary necrosis in the kidney. The necrotic papilla in the upper specimen is clearly demarcated but still attached; that in the lower is beginning to separate. (×1.7.)

dimidine had no effect. On 1 g. of streptomycin daily for five days the fever dropped but the urinary findings were unchanged. At this time she was alert and relatively well apart from mild symptoms of the urinary infection. Next day (August 4) she died suddenly. The blood urea on admission was 29 mg., and the C.S.F. urea at necropsy 27 mg. per 100 ml.

Necropsy Summary.—Death was due to a massive pulmonary embolism coming from an iliac vein thrombosis. Both kidneys were swollen (left 220 g., right 235 g.) and not scarred. On section there were evident isolated patches of acute pyelonephritis, and on each side about half the papillary tips were necrotic, some being still firmly attached to the kidney tissue but others were beginning to separate (Fig. 1). The pelves and ureters were acutely inflamed but were not dilated. Histologically the streaks of acute pyelonephritis were associated with an established chronic pyelonephritis and both were confined to the areas draining into papillae that had become necrotic. In this case, unlike the others, there was an intense leucocytic infiltration of the kidney tissue alongside the site of separation of the papillae. There was no diabetic glomerulosclerosis. The urinary bladder was slightly inflamed.

Comment.—This diabetic woman had a urinary infection and when she was apparently recovering she died from a pulmonary embolus. At necropsy there was no urinary obstruction. Mild and patchy areas of chronic pyelonephritis were present in both kidneys, and necrosis occurred only in those papillae draining these areas. During life there had been no symptoms to indicate the presence of papillitis necroticans.

Case 5

A married woman aged 56 had developed diabetes mellitus at the age of 35. She did not co-operate well, and her diabetes was poorly controlled, with alternating attacks of hypoglycaemia and heavy glycosuria and ketosis. Insulin requirements varied; at times she needed 80 units of protamine zinc insulin daily.

In 1948, when 50 years old, she underwent hysterectomy uneventfully. For several years she had experienced difficulty in passing water. At the age of 51 a chronic *Bact. coli* urinary infection was discovered, and intravenous urography at that time showed "distortion of the pattern of the calices and renal pelves." Cystoscopy revealed moderate chronic urethrotigonitis with the remainder of the bladder normal. The bladder held 3 pints (1.7 litres) without discomfort.

The diabetes became more difficult to stabilize and at times the blood sugar fell to low levels independent of insulin injection. A coexisting islet-cell adenoma was suspected and the pancreas was explored; no tumour was palpated; the body and tail of the pancreas were excised. After a stormy convalescence the patient was stabilized on a total daily dose of 50 units of insulin. Nine months later a pseudocyst formed anterior to the pancreas; after marsupialization it healed. At about this time she began having left loin pain and tenderness with fever. The urine contained variable amounts of albumin and white cells, coliform bacilli, and alpha-haemolytic streptococci.

She continued to have further bouts of left loin pain and vomiting. At times the urine contained much protein, pus, a few granular casts, and various organisms. These attacks responded to treatment in hospital.

In March, 1953, she was again admitted with a further attack of pyelonephritis. Sulphadimidine, 0.5 g. six-hourly with sodium citrate, was given. The left-sided pain was very severe and colicky, radiating down to the groin and vulva, and 50 mg. of pethidine was given six-hourly. Four days after admission the patient passed two pieces of pink fleshy tissue in her urine; these proved to be sloughs of renal papillae (Fig. 2). Afterwards the pain was less severe, but the fever remained and there was a urinary infection with a penicillin-sensitive non-haemolytic streptococcus. It did not belong to groups A, C, D, or G, and was heat-

sensitive and bile-intolerant. She was given 10 mega units of penicillin and 1 g. of streptomycin daily for 10 days. After this the urine remained sterile for a week and then was found to be infected again, this time with a non-haemolytic streptococcus of Lancefield group D. Subsequently pus and paracolon bacilli were often found in the urine. Throughout this stay in hospital the patient had further bouts of left-sided pain with vomiting and spikes of fever. Her insulin needs were little altered. There was no clinical evidence of renal failure; the blood pressure remained around 170/100 mm. Hg, which was rather less than that found on other admissions. The blood urea values were between 53 and 69 mg. per 100 ml.

Intravenous urography was performed 12 and 14 days after the renal papillae had been passed in the urine; both were technically poor, but excretion of dye on the left side was much decreased.

A retrograde pyelogram (Fig. 3) revealed small cavities in the renal parenchyma communicating with the calices. One month after the papillae had been passed, intravenous urography showed the left kidney to be concentrating diiodone well, though possibly slightly less than the right; the pattern of the calices seemed normal and no cavities in the renal parenchyma were detected.

The ureters were catheterized three months after admission. Urine from the right kidney contained scanty pus cells and occasional organisms on microscopy, while that from the left contained many pus cells and scanty organisms. From the right side the urea content was 1.8 g. and from the left 1.35 g. per 100 ml. The patient was last seen in August, 1955, 29 months after passing the two sloughed papillae in her urine. Her urine contained a cloud of albumin, with scanty red cells and granular casts. There was a mild urinary infection with *Staphylococcus aureus* which responded to penicillin. The blood urea was 47 mg. per 100 ml.

Comment.—This diabetic woman had pyelonephritis with no evidence of urinary obstruction, unless inflammation of the trigone of the bladder produced a little for a while. Renal papillary necrosis was detected because she passed two renal papillae in her urine. Left renal colic was caused by the passage of these papillae down that ureter. She made a satisfactory recovery, with radiological evidence of healing of the sites of the sloughed papillae.

Clinical Diagnosis

Although in only one of these five patients was the diagnosis reached in life, in four the clinical features were characteristic of papillitis necroticans. In fact they exemplify many diagnostic features in aetiology, symptoms, laboratory and x-ray findings, and clinical course. Thus

FIG. 2.—Case 5. Sloughed renal papillae found in the urine. ($\times 1.6$.)

FIG. 3.—Case 5. Showing a cavity connecting with the upper middle calix, cicatricial deformity of the lower major calix, and a cavity in the renal parenchyma distal to it.

renal papillary necrosis is virtually unknown except when there is an infection of the urinary tract: all five of the present series had a urinary infection. Such infection almost always is associated with either diabetes mellitus or some urinary obstruction: three of our patients were diabetics and two had obstruction from prostatic enlargement; one of the diabetics also had obstruction of one ureter. (These aetiological factors are elaborated below.)

Symptoms produced by papillary necrosis are most commonly those of uraemia: this was the picture in Cases 1 and 2. Less often the picture is of renal or ureteric colic caused by the passage of blood clots or of sloughed papillary tissue: this occurred in Cases 3 and 5. Complete obstruction of a ureter may result.

The diagnosis may be made if whole renal papillae or parts of them are recognized in the urine. In Case 5 the diagnosis was made in this way. There are four previous records of this (Edmondson *et al.*, 1947; Johnston, 1952; Knutsen *et al.*, 1952; Mandel, 1952). As in Case 3, renal pain and haematuria may lead to surgical intervention; if the kidney is removed papillitis necroticans may be discovered in it (Alken, 1938; Mellgren and Redell, 1941; Robbins *et al.*, 1946; Edmondson *et al.*, 1947; Günther, 1949). In none of our cases, however, was nephrectomy performed. On pyelography the kidney pelvis may be shown to communicate with a cavity in the kidney parenchyma, revealing a site from which a papilla has sloughed (Günther, 1949). Such an abnormality was detected in Case 5.

On the other hand, Case 4 shows that the necrosis of renal papillae may occur without much disturbance of the patient. Furthermore, as illustrated by Case 5, healing may occur (Alken, 1938; Robbins and Angrist, 1949; Knutsen *et al.*, 1952; Johnston, 1952). It would therefore seem that clinical diagnosis may sometimes be impossible.

Aetiology

The causes of papillitis necroticans are not yet fully understood. One of the most clearly established facts is the close association with diabetes mellitus. Renal infection is frequent in diabetes mellitus: between 1914 and 1939 Baldwin and Root (1940) found renal infection in 66 (20%) out of 339 necropsies on diabetics. Similarly, over the last 15 years we found renal infection in 9 (8%) out of 117 necropsies on diabetics. Clinical experience is in accord with these figures, for pyuria and bacilluria occur frequently in diabetics, though the effects are often slight and the infection is transient (Sharkey and Root, 1935; Bowen and Kutzman, 1942; Harrison and Bailey, 1942; Aarseth, 1953). Diabetics with urinary infection seem peculiarly predisposed to papillitis necroticans. Thus Edmondson *et al.* (1947), in a review of 32,000 routine necropsies, found that of 859 diabetics, 107 (over 12%) had an acute urinary infection, and in 29 (over 25%) of these there was papillary necrosis. These figures may be compared with those for their non-diabetics; 1,023 (3.3%) had acute pyelonephritis and in only 21 (2%) of these was there papillary necrosis.

Similarly, in a review of 155 reported cases of papillary necrosis, including 16 of their own, Knutsen *et al.* (1952) found 87 (56%) were diabetic. In non-diabetics there is usually urinary obstruction; Robbins and Angrist (1949) computed that urinary obstruction was present in 85% of 48 cases without diabetes. This observation probably explains the high proportion of males (6:1) in their non-diabetic group. In diabetics, on the other hand, urinary obstruction is not necessary to provoke papillary necrosis—a fact reflected in the observation that papillary necrosis is commoner in female than in male diabetics (Robbins and Angrist, 1949).

The mechanism of production of renal papillary necrosis has long been a subject for speculation. The area involved does not correspond with the normal pattern of the blood supply, and in very few cases are any occlusive vascular changes, venous or arterial, found in the kidney. Swartz

(1954) reports the case of an infant dying of meningitis in whom an incidental finding was papillary necrosis without any renal infection, but with thrombosis of interlobar veins, but this is a most unusual association.

The most frequent accompaniments of papillary necrosis are urinary obstruction, urinary infection, diabetes, and vascular lesions, but these are all factors that may be absent. It is therefore probable that another mechanism is actually responsible, although it may be brought into action by one of these factors. An attractive suggestion made tentatively by Sheehan (1937) is that overaction of the sphincter muscle of the fornix may be responsible. It is now well known, from radiographic studies, that the calices are highly contractile structures, and Narath (1940) has described an unstriated muscle above the fornix of the renal calix which, he claims, can lift the fornix farther up towards the kidney substance. During contraction of the calices in the emptying phase a part of the papilla is compressed by the sphincter muscles and one might postulate that excessive sphincter contraction could produce ischaemic necrosis of the papilla, especially if it were already damaged by inflammation. Contraction of Narath's levator fornicis muscle at the same time would tend to extend the process farther up into the muscle; this would approximately cover the area of medullary tissue that is commonly affected.

Summary

Five cases of renal papillary necrosis are reported.

In two there was renal colic. In one of these renal papillae were voided in the urine; this patient has survived for two years and both kidneys are functioning. In the other patient papillary necrosis was confined to the right kidney, the ureter of which was partially obstructed by an arterial aneurysm.

Aetiological factors include diabetes, urinary obstruction, and urinary infection. Contraction of unstriated muscle in the renal pelvis may determine the site of necrosis.

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The Central Council for Health Education, Tavistock House North, Tavistock Square, London, W.C.1, has issued a booklet, *Your Guide to the Food Regulations, 1955*. It draws attention to some of the more important ways in which the regulations apply to food premises and food-handlers, giving details of sanitary requirements and health rules. A copy of the Regulations themselves (S.I. 1955, No. 1906) is obtainable from H.M.S.O., price 6d.