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INFLUENCE OF DRAINAGE CONDITIONS ON MUCOSAL BLADDER DAMAGE BY INDWELLING CATHETERS

II. *Histological Study*

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Abstract. A previous study demonstrated a strong but short-lasting suction through the catheter eyes by a hydro-dynamically generated negative pressure fluctuation terminating bladder evacuation in some frequently occurring circumstances of indwelling catheter drainage. This report regards the biological effect. Fifteen successive evacuations on such drainage conditions in each of 4 anesthetized pigs were followed by cystectomy and histological examination. All bladders presented small swollen areas, histologically showing localized mucosal elevations dominated by edema of lamina propria and submucosa, occasionally with urothelial thinning or defects. Drainage with suction prevented in 3 animals caused normal bladders. The changes were similar to those following hydro-statical suction and much like those of the "polypoid cystitis" so commonly occurring with indwelling catheters. This suggests both types of suction by ordinary drainage as a major pathogenetic factor in the latter condition. The clini al significance and the occurrence during regimes of straight drainage or intermittent clamping are discussed.

Key words: bladder pathology, indwelling catheters, cystitis, adverse effects of suction, urinary catheterization.

Lesions of the vesical mucosa in patients with indwelling catheters are extremely common findings at endoscopy (1, 3) and autopsy (2, 8, 12). They are mostly ascribed to mechanical and chemical injuries by the catheter itself. However, when the drainage tube forms a stagnant column of urine below the level of the catheter tip the resulting hydro-statical suction draws the mucosa up against the holes (eyes) or partly into the catheter causing identical lesions (6, 8). The magnitude of this type of suction equals the vertical difference of level between the catheter holes and the outlet' of the system. Now a hydro-dynamically generated pressure fluctuation 4-8 times more negative than a statical one of the identical drainage system has been demonstrated in the end of a bladder evacuation, when the moving column of urine is abruptly stopped by mucosal plugging of the holes, at the moment when all urine around the tip has entered the catheter (5). On conditions like those of a bedridden patient (and in the present study) the negative maxima reach about 150-180 em of water when catheters based on latex are used, and mostly about 300-350 em by fabrics of 100% silicone. The total duration of the negative wave is only about 70-80 ms and 50-60 ms, respectively. The biological effect of repetitive exposure to such strong but short-lasting suction is unknown and therefore the present investigation of the early histological responses was undertaken.

MATERIAL AND METIIODS

Female pigs weighing 28-38 kg were premedicated with azaperonum vet. i.m. and anesthetized with pentobarbital sodium i.v., intubation and artificial respiration with NO/O_2. Atropine was omitted to avoid unphysiological relaxation of the bladder. In the supine position a urethral 18 F nelaton Foley catheter was introduced, Rusch Gold Silkolatexin half of the cases, Argyle Doverl!l of 100% silicone in the rest. The balloon was inflated with 5 ml of water, the catheter drawn taut, fixed externally, and connected to our routine PVC urinary drainage system, the bag of which was cut off to leave 105 em tube (inner diameter 5.18 mm, wall thickness 0.66 mm). The tube always formed a solid column of fluid during evacuations.

Great difficulties arose from using catheters too large for the small meatus urethrae situated 4-5 ern deep in the narrow vagina of young pigs. Size 18 F was necessary to imitate clinical conditions as the previous study had shown catheter size to influence the duration of the negative peak pressure (5). A pilot study of 12 animals was required to design the final catheterization technique (8 suction experiments and 4 controls showing results as those of the study proper except for one of each group revealing the necessity of a change cf technique). It proved a stylet in the catheter dur-

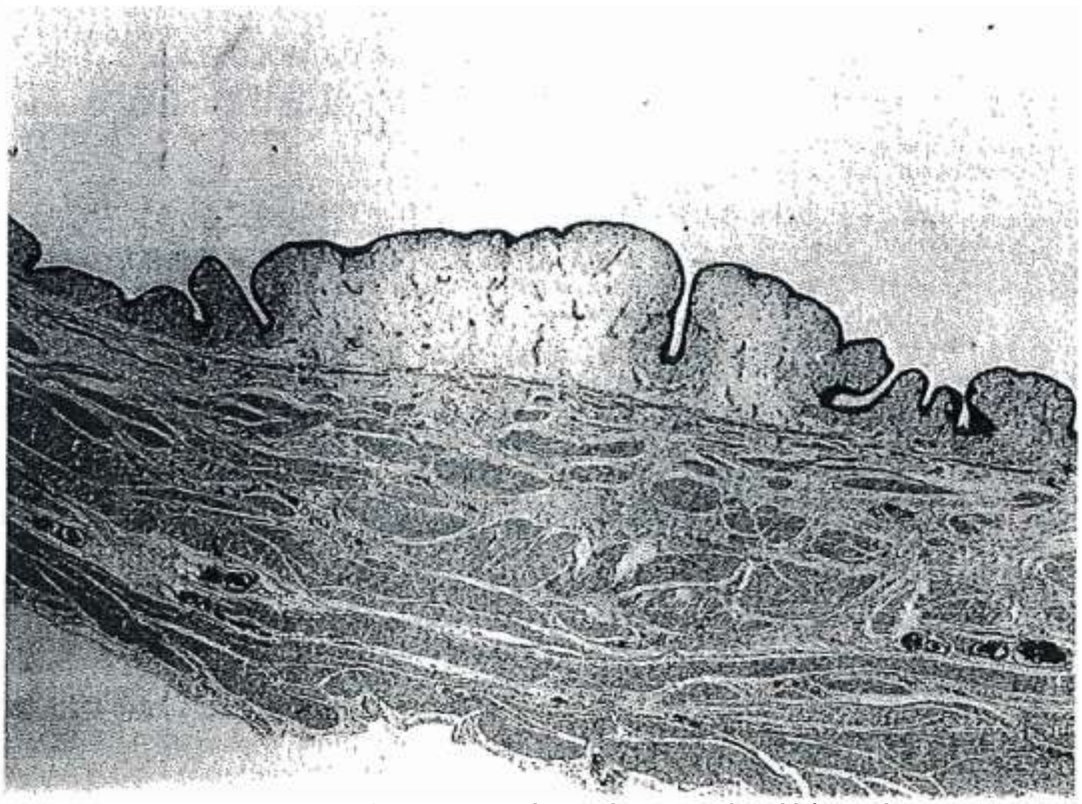


Fig. 1. Bladder wall with localized edema of lamina propria and submucosa (central half of the photo) after hydro-dynamical suction. Right and left normal mucosa. (H&E X23.)

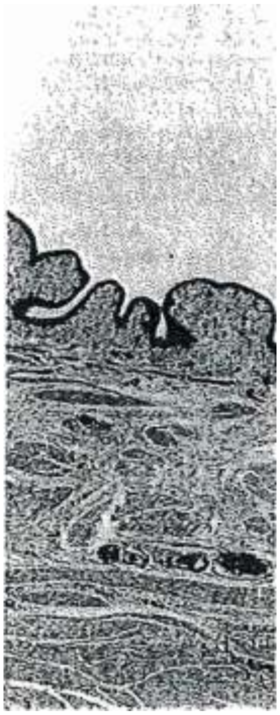
ing introduction to be a potential source of artefacts and therefore in the study proper meatus was exposed by perineal opening of the vagina, and a meatotomy was performed when necessary. At first, catheters were placed with no attention to the holes; the absence of lesions in one suction experiment led to careful antero-posterior positioning in the study proper since in supine individuals the bladder tends to collapse in an antero-posterior flattened shape and thus this positioning might facilitate the abrupt total plugging of the catheter holes, which ensures the maximum response (5). The possibility of more gradual blocking by the mucosal foldings would seem greater with the holes facing sideways, and the fixed position during an experiment demanded optimum placing.

After primary bladder emptying 80 ml of sterile isotonic saline water of 37° was instilled during 1 min. Following a pause of 1 min the catheter was unclamped for an ordinary evacuation with the distal end of the tube 40 em below the estimated level of the catheter tip in 4 animals. In 3 control experiments the end of the tube was elevated towards termination of the evacuation to a level which reduced the flow into drop rate, thus minimizing the inertia of the fluid column at the moment of arrest, thereby preventing the hydro-dynamical suction. In both types of experiment filling and evacuation were repeated every 5 min until 15 cycles were completed. Hydro-statical suction was carefully avoided by keeping the end of the tube above the level of the bladder except during evacuations. Great care was taken to avoid air bubbles in the bladder or drainage system which would reduce the hydro-dynamical response.

Finally 1 ml of atropine i.v. was allowed 45 min to produce a maximum relaxed bladder for inspection and preparation. It was filled with 80 ml of water to facilitate cystectomy which was preceded by symphysectomy to minimize trauma to the bladder during removal. The pig was not sacrificed until after the cystectomy. The isolated organ was opened anteriorly by a Y-incision from urethra, mounted on a cork plate, inspected, described, and stored in 4% formaldehyde buffered solution for at least 24 hours before multiple samples were taken from areas with and without visible changes, guided by the primary description. The samples were embedded in paraffin, cut in 4 μ sections, stained with haematoxylin and eosin, and mounted for microscopy.

RESULTS

All 4 experiments with drainage conditions allowing hydro-dynamical suction produced mucosal lesions; the 3 control experiments did not. No difference was



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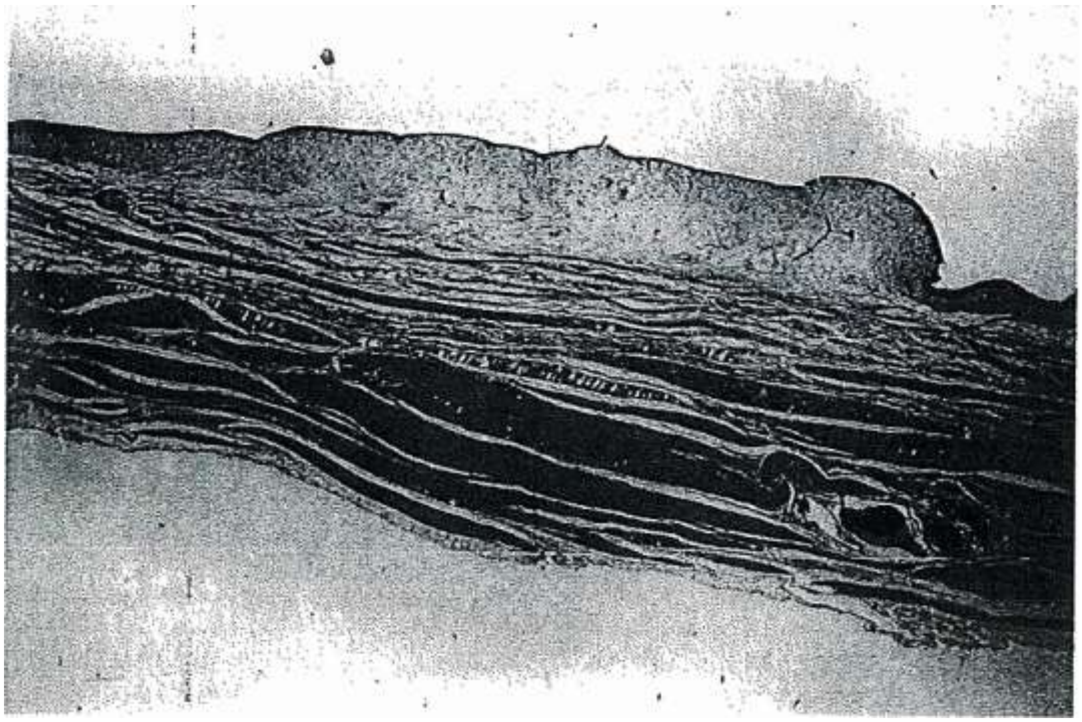


Fig. 2. Bladder wall with localized edema of lamina propria and submucosa after hydro-dynamical suction. (H&E x23.)

found between the results from the two types of catheter. The changes mainly occurred in the central part of the posterior wall and in the opposite anterior region as small localized areas of edema, often barely discernible from other small irregularities. Thus, histopathological changes were found in about half of the suspected areas only; reversedly, they hardly ever occurred in sections from normal looking areas.

On microscopy the lesions typically presented rather sharply demarcated elevations of the mucosa with subepithelial edema (Figs. 1, 2 and 3). In some lesions the surface was partly denuded (Fig. 4) or the urethelium was stretched into monocellular thickness with occasional disruptions. Often small vessels in the edematous areas were dilated with granulocytic "pavementing" of the endothelium and subsequent emigration of granulocytes into the surrounding connective tissue (Fig. 4). Petechial haemorrhage could be observed in some lesions.

DISCUSSION

The mucosal changes related to inwelling catheter have been termed catheter cystitis, catheter edema, bullous cystitis, haemorrhagic pseudopo!yps and polypoid cystitis. Endoscopy (1, 3, 10, 11) shows areas of swollen mucosa, pale or erythematous, most often with irregular surface; regions of multiple reddened elevated polypoid or bullous elements may simulate tumor, even on radiography {10) and sonography (1). On microscopy (2, 3, 8) the lesions are also mostly bullous, polypoid or papillary. The urothelium often shows defects, degeneration and necrosis with small microabscesses, but even mild hyperplasia may occur. The lamina propria and submucosa arc edematous, often with abundant inflammatory cells, an increased number of capillaries, and sometimes large ectatic vessels. Signs of old and recent hemorrhage are frequent and later fibrosis and dysplasia may occur. The changes may be present with sterile urine as well as disappear with removal of the catheter in spite of persisting bacteriuria (1, 2,

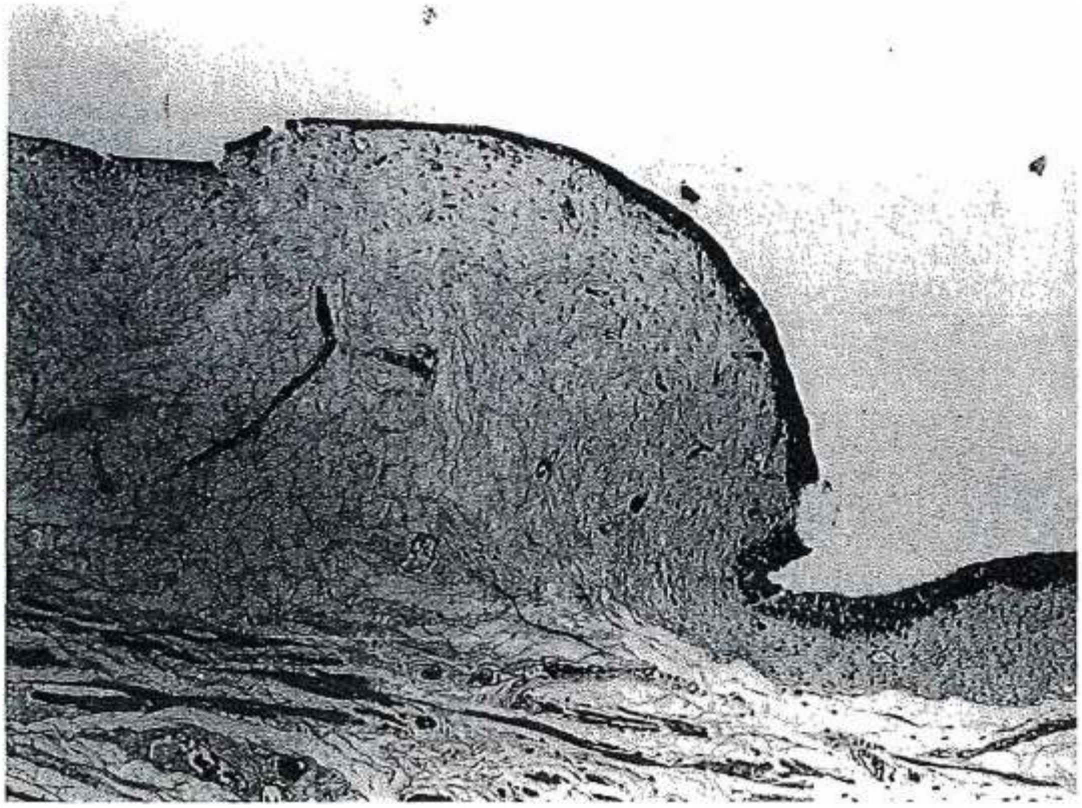


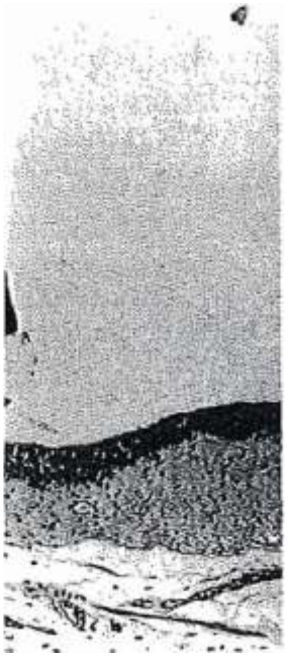
Fig. 3. Detail of Fig. 2. (H&E xiOO.)

3). To some degree they progress with increasing length of the catheter treatment but have been observed after a few days. Reports concerning the first days seem not available.

The immediate lesions following the present short-lasting experiments cannot be expected to imitate completely the results of clinical treatment described above. However, qualitatively they are very similar. Also, they are similar to the description of those following hydro-statical suction (8), which was further confirmed by one experiment after conclusion of the study proper, by changing the intermittent evacuations into straight drainage for 75 min during which the tube constantly formed an unbroken column of urine 40 em below the catheter tip (Fig. 5). The lack of lesions in control experiments excludes an etiology related to the catheter as such. Thus the suction lesions produced by the drainage conditions-whether hydro-statically or hydro-dynamically generated-strongly suggest themselves as a major element of the clinical condition "polypoid catheter cystitis" and indicate the drainage circumstances as an important genetic factor.

The lack of difference between the lesions from the two types of catheter is inconclusive, as the method is obviously inadequate for quantitative purposes.

The clinical significance of mucosal suction lesions would seem to be, that they represent areas of lowered resistance inviting bacterial invasion, nidation, and growth in the tissue. Thus they may contribute to establishment and maintenance of cystitis from any accidental bacteriuria as suggested by Milles (8), and evidenced by identical bacterial flora in urine and biopsy material from patients with the clinical condition (3), and by the occurrence of urothelial microabscesses in the lesions (3). In some cases the lesions would seem likely to facilitate episodes of bacteremia. Hematuria caused by the suction in especially vulnerable or congestioned bladders (e.g. in



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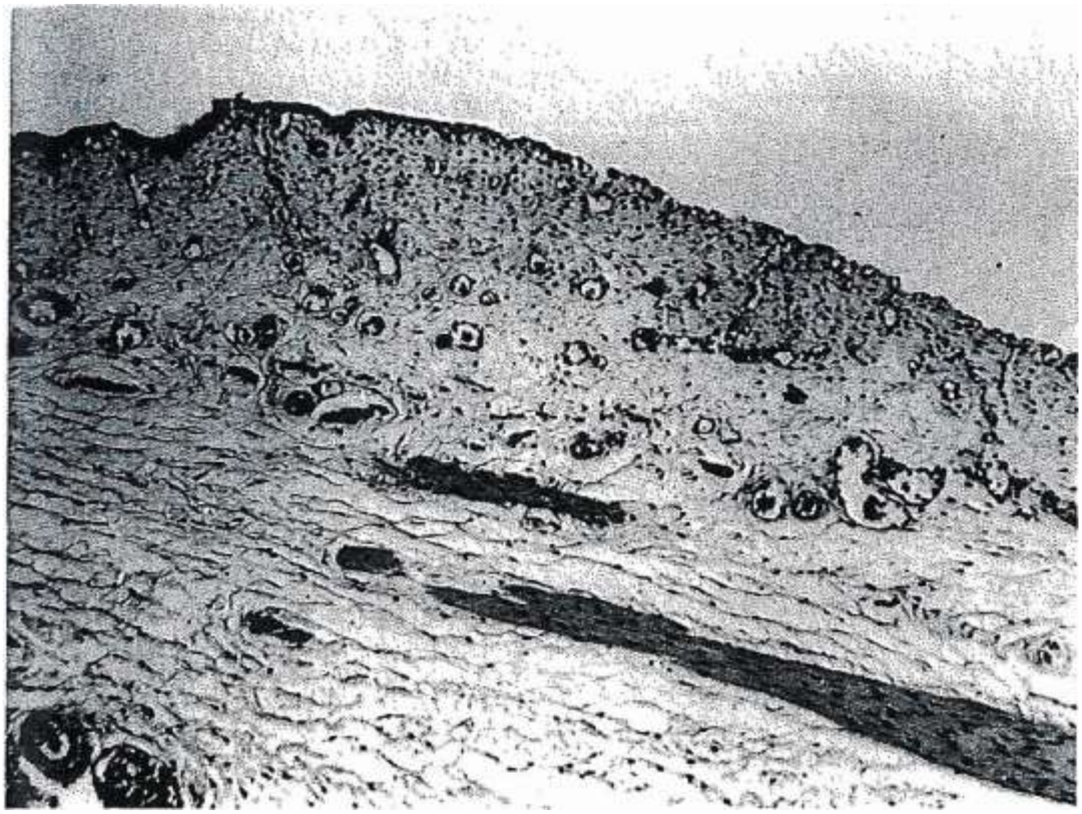

Fig. 4. Submucosal edema with dilated vessels and early inflammation after hydro-dynamical suction; the epithelium is thinned and the surface partly denuded. (H&E x94.)

severe cystitis or following surgery or acute retention) most often would erroneously be ascribed to the known clinical condition. In some patients the hydro-dynamical suction is registered as a painful sting in the bladder; this indicates an afferent stimulation which may presumably enhance uncontrolled detrusor activity in bladders so disposed.

Clinical measures to oppose both types of suction (5) represent a tricky challenge. One important factor is the tendency of a tube to form a column of urine (5, 6, 8); it varies with the total design of the drainage system (4, 13), including the inner diameter of the tube (5). According to basic physical laws the suction of both types is decreased or avoided when the column is broken up or eliminated. Attempts to confirm a clinical benefit from this principle by using top-vented drainage seem inconclusive (7, 9, 13), perhaps due to inadequate study materials, unspecific parameters, or failure of the vent in preventing the hydro-dynamical type of suction (5). Clinical occurrence of the two types of suction is illustrated by the following discussion of some drainage situations but it should be stressed, that so far there is not the slightest indication as to which one is the more deleterious to the mucosa.

A. *On a regime with the catheter clamped* hydrostatical suction does not occur (and while the bladder accumulates urine a noxious contact with the tip is reduced). *Hydro-dynamical* suction occurs only at the end of the intermittent evacuations, the magnitude depending on the drainage conditions (5).

B. *On a regime of straight drainage* some hydro-*statical* suction is almost inevitable, irrespective of the tube, as the narrow catheter itself contains a column of urine when the catheter outlet is lower than the tip. Even when of slight degree, the hydro-statical suction makes the catheter cling to mucosa like a leech, and when it is strong-due to a filled tube end-

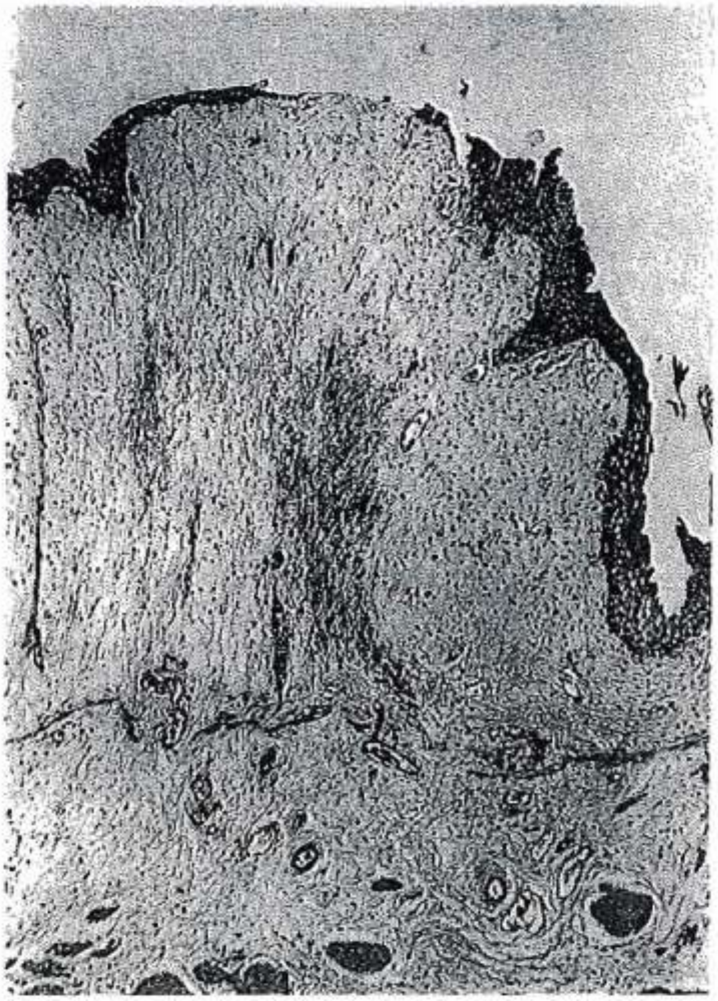

Fig. 5. Urothelial damage and edema of lamina propria and submucosa, with early inflammation and hemorrhage after *hydro-sratica!* suction. (H&E X83.)

ing far below the level of the catheter tip-it may cause serious lesions (Fig. *5);* at times it causes a mucosal sealing of the holes firm enough to cause accumulation of urine until some mechanical force (e.g. respiratory variations, talking, coughs, body movements) occasionally relieves the holes for intermittent evacuations, which may then rise a hydro-*dynamical* suction wave at even small volumes (5). Nor is a truly continuous drainage ensured when the drainage system (catheter+ tube) is passing a level higher than that equalling the pressure at the catheter tip and the tube is empty (whether due to a wide tube or a top-vent); the absence of the hydro-statical suction causes urine to accumulate until the bladder pressure is accidentally raised (by detrusor activity or mechanical forces as mentioned above) sufficiently to fill the drainage system beyond the highest level causing an evacuation which may rise a full hydro-dynamical suction. This type of "tidal-drainage" situation especially occurs in the lying position with the drainage system passing over the leg. Particularly, it is difficult to avoid in men, as in the supine position the male urethra itself passes a level, which most often is higher than that equalling the pressure at the catheter tip in the bladder at rest. Both types of small intermittent evacuations during straight drainage is often observed in the wards, when after a period of rest the lying patient starts to move or merely to speak. "Residual urine" in testing the efficiency of various systems for continuous drainage

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can only be truly estimated if the catheter is initially clamped after a period of complete rest, still undisturbed.

In conclusion, on present conditions it seems that mucosal suction by indwelling catheter drainage may well be reduced but hardly eliminated no matter the type of management. Once the attention has been called to this aspect of the drainage, more clinical regard is to be hoped for, as the resulting lesions evidence a noxious effect which may presumably contribute to important and costly clinical complications. A really satisfactory solution to the problems of conflicting principles and technical obstacles involved in indwelling catheter treatment seems utopian without completely new developments in design of catheters and drainage systems, including guidance and testing by hydro-physical expertise. Designs, indeed, as difficult to imagine as recommendations properly meeting the present need of compromizes are to state today. However, studies like the present analysis of isolated individual factors involved, serve to reveal sources of adverse effects and outline the basic principles and final aims for future improvement of methods and devices.

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