ON THE VESICAL SPHINCTER AND THE MECHANISM OF THE CLOSURE OF THE BLADDER.*

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ALTHOUGH the physiology of micturition has received much attention from many investigators, there is still no little confusion and doubt as to the exact method by which the outlet of the bladder is closed so as to retain the urine. Anatomists, whilst differing considerably in minor details, describe three, more less distinct, constrictor muscles in connexion with the bladder and urethra, though their opinions differ greatly as to the part these muscles play in maintaining the closure of the bladder. They are as follows:

A. A slender, ill-defined ring of oblique muscular fibres, intermingled with elastic tissue, encircles the vesical opening. This muscle corresponds to the "prismatic ring" of Henle and to the "sphincter trigoni" of Kalischer,¹ and is formed of unstriated or involuntary muscular tissue. According as to whether it is regarded as belonging to the bladder proper or to the prostate it is called the "internal vesical," or "internal prostatic," sphincter.

B. Below the internal sphincter some short, transverse, muscular fibres are present on the anterior or ventral surface of the lower or distal half of the prostate. They rapidly increase in length as they approach the apex of the prostate until they completely encircle the urethra. The majority of these fibres, chiefly composed of voluntary muscular tissue, are situated on the outer surface of the prostate, and some of the lower ones are intermingled with the glandular tissue of that organ. All these fibres together comprise the external prostatic or vesical sphincter of Henle, which, according to Mr. Griffiths,² is merely the commencement of the constrictor urethrae.

C. And, lastly, surrounding the membranous urethra, contiguous to the anterior portion of the external prostatic sphincter is that muscle, or group of muscles, best known as the compressor urethrae.

The theory, put forward long ago by Rosenthal,³ that the closure of the bladder was maintained by the elastic, in contradistinction to the vital, power of the neck of the bladder no longer receives any support. For Heidenhain and Colberg⁴ proved by experiment that not only did it require enormous pressure, far greater than is possible for the detrusor muscle to exercise, to force the sphincter so that the urine could flow out of the urethra, but that the bladder is able to hold fluid at a much greater pressure in the living than in the dead subject. These experiments have been repeated by Uffelmann⁵ and Sauer,⁶ by Kupressow⁷ and von Rosenplanter,⁸ and also by Rehfish.⁹ Their results are, in the main, very similar, though the estimated amount of pressure necessary to force the sphincter shows considerable variation.

Henle, having noticed that the fibres of the detrusor muscle were inserted between those of the internal sphincter, suggested that the contraction of the former muscle mechanically pulled open the sphincter. Zuckerkandl¹⁰ has, however, shown that only a very small part of the detrusor fibres are so inserted, the greater portion being attached to the upper part of the prostate; so that it is impossible for the detrusor to open the sphincter, as Henle believed.

The theory put forward by Guyon¹¹ and Finger,¹² unlike those previously mentioned, has received very considerable support and has been widely adopted, especially by genito-urinary surgeons on the Continent. Doubtless this is partly due to the great renown of Finger, and also to the fact that this theory affords a ready and apparently satisfactory solution of many of the phenomena met with in the pathology of the urethra and bladder. According to Finger, the internal vesical sphincter is far too weak a muscle to withstand the pressure of the urine and prevent its escape from the distended bladder, this work being performed by the action of the muscular fibres surrounding the posterior urethral canal—that is, the external prostatic sphincter and the compressor urethrae muscle. When the bladder contains little fluid it assumes a round

ball-like form, sharply defined from the prostate by the contracted internal sphincter (see Fig. 1.). But as the bladder becomes distended, the pressure of the urine gradually causes the elasticity of the neck of the bladder and the internal sphincter to yield, thus allowing the fluid to enter the posterior portion of the prostatic urethra. When this takes place, the sharply-defined border between the bladder and urethra is lost, and a "bladder neck" is formed. The further collection of urine takes place, not only in the distended bladder, but also in the now encroached-upon prostatic urethra (Fig. 2). By this encroachment of the bladder the urethra is appreciably shortened. According to this view, when the bladder is either empty or but moderately distended it is closed by the internal vesical sphincter; when it is fully distended this function is performed by the external prostatic sphincter and the compressor urethrae.

It cannot be denied that when the voluntary muscles are contracted they can and do play an important part in maintaining the closure of the bladder. But the assertion made by Finger, Anatal, and Ultzmann, that in the distended bladder the prostatic urethra is taken up into it so as to form a "bladder-neck," and the escape of the urine is only prevented by the external sphincter and compressor urethrae, has never been conclusively proved, for

Fig. 1.—Diagrammatic representation of the shape of the male bladder, according to Finger, when it contains but little fluid. A, internal vesical sphincter; B, external vesical sphincter; C, compressor urethrae muscle.

Fig. 2.—Shape of male bladder, according to Finger, when fully distended. A, internal vesical sphincter; B, external vesical sphincter; C, compressor urethrae muscle.

no one has yet been able actually to demonstrate the presence of the "bladder-neck," either endoscopically or in frozen sections of the cadaver. Finger whilst noting M. v. Zeissl's¹³ striking experiments on the innervation of the urinary bladder of the dog (the results of which are in direct conflict with his own views), brushes them aside on the ground that it is unwise to draw deductions as to the action of these muscles of the urethra and bladder in man from experiments upon the lower animals, for both the anatomy of the parts and the physiology of micturition is markedly different in man. He¹⁴ asserts the presence of a bladder-neck can be readily determined by passing a catheter along the urethra until the urine begins to flow, and noting how far the catheter has been introduced. When the bladder is moderately full, but no desire to micturate is evinced, the catheter may be passed from 18 to 21 cm. before the urine will flow. But when the bladder is full enough to cause a desire to micturate, showing that the urine has entered the prostatic urethra, the flow will take place when the catheter has been passed from 16 to 19 cm. It has been shown, however, by Dreyssel and Rehfish that this is not a constant phenomenon; neither, when it does take place, is the difference in the extent to which the catheter needs to be introduced more than 1 or 1.5 cm.

Rehfish¹⁵ has also shown experimentally that the action of the external sphincter is very slight, and is not capable of resisting even the most moderate fluid pressure. It therefore follows that if the urine enters the posterior urethra in the manner described by Finger, its expulsion is only prevented by the powerful compressor urethrae muscle. But, if this were so, instead of the catheter showing a difference of some 2 cm., according to whether the bladder was strongly distended or not, it

* Read before the Birmingham Branch of the British Medical Association.

would show a difference of somewhere about 4 cm., that is, the entire length of the posterior urethra.

Rehfish quotes the following interesting experiment as evidence that the internal sphincter may be inhibited or set into contraction directly by voluntary impulses. He passed a rigid catheter into the bladder and fully distended that organ with fluid. He then withdrew the catheter until its eye lay just outside the bladder in the posterior urethra, then the flow of the fluid from the bladder at once stopped. He then asked the patient to micturate. This he at once did, and, as there was considerable distension of the bladder, the urine came away with considerable force, not only through the instrument but also by the side of it. The man was then told to stop micturating, and immediately the stream ceased. And, on his again being desired to micturate, the fluid again flowed. This alternate evacuation and arrest of the flow could be repeatedly performed. All the time this was going on the eye of the catheter was lying in the prostatic urethra just outside the bladder, and the experiment clearly showed that the internal sphincter is the chief agent in closing the bladder, even though it be greatly distended. During the experiment it

was impossible for the voluntary muscles, the compressor and external sphincter, to play any part in the arrest of the flow, as the rigid catheter excluded their action. I have repeated this experiment of Rehfish several times with various slight modifications, and have found that his account of it is correct; though, as one would naturally expect, men differ considerably in the amount of control they possess over the power of micturition under such circumstances.

from the urethra by the internal sphincter. When a large quantity was injected under greater pressure the cast was pear-shaped, on account of the prostatic urethra having been taken up into the bladder so as to form a "bladder-neck."

Finger also quotes Waldeyer¹⁷ (1899), who, by some experiments made by injecting the bladder of cadavers with a 10 per cent. alkaline solution of formalin, obtained similar results to Born. Such experiments on the dead bodies of animals are, however, so crude, and carried out under circumstances so totally unlike those met with during life, that no weight can be attached to their results. I have repeated this experiment under more natural conditions, and obtained very different results. I injected the bladder of certain men and youths with a suspension of bismuth, and then radiographed the pelvis. In every case I found that, whether the bladder was fully distended or not, the outline of the organ was oval, and not pear-shaped, and the urethra was sharply cut off from the bladder without a suggestion of a "bladder-neck."

Fig. 3 represents the bladder of a boy, aged 12, when fully distended with a bismuth suspension. The radiograph was taken with the patient lying on his back, with the thighs flexed and abducted. The photographic plate was placed behind the sacrum, and the tube above the symphysis pubis. The rays in passing through the body have struck the bladder obliquely, and so somewhat foreshortened its shadow, rendering it unnaturally round.

Fig. 4 is an excellent radiograph of the distended (20 oz.) bladder of a man. In this case a fine metal bougie was passed down the urethra, so as to illustrate

Fig. 3.—Radiograph of bladder fully distended with bismuth suspension (boy aged 12).

Fig. 4.—Radiograph of bladder distended with bismuth suspension (adult male).

Fig. 5.—Radiograph of bladder distended with silver albuminate solution (adult male).

Finger, in further support of the theory that as the bladder becomes distended the pressure of the urine causes the elasticity of the neck of the bladder and the internal sphincter to yield and the urine to enter the posterior portion of the prostatic urethra, quotes certain experiments by Born,¹⁸ who injected liquid plaster-of-paris down the ureter of certain recently-killed animals so as to distend the bladder. After a small quantity had been injected under slight pressure and had set, the cast of the bladder had the form of an egg, and was sharply cut off

more clearly the relation of the parts, and the complete absence of a "bladder-neck."

Fig. 5 shows the male bladder distended with 21 oz. of silver albuminate solution. It is of interest from the fact that it was only by means of a very considerable effort on the part of the man, and the calling into play of the accessory voluntary urethral muscles, that he was able to retain the fluid whilst the radiograph was being taken. Yet even under these circumstances there is no suggestion in the photograph of a "bladder-neck."

There are, therefore, reasons for believing that the sphincter of the bladder (the internal prostatic sphincter) plays a far more important part than Finger and Guyon credit it with, and that under ordinary circumstances it is by this muscle that the bladder is closed whether distended or not. And there is evidence¹³ that when the internal sphincter does yield, it does so, not because it is overcome by the mechanical pressure of the urine in the bladder, but because its muscular fibres relax as a vital act in response to a nerve impulse preliminary to the evacuation of the urine.

The normal act of micturition would appear to be as follows: As the bladder becomes distended with urine the vesical nerves are stimulated and evoke stronger and stronger contractions of the detrusor muscles, giving rise to the desire for micturition. To withstand the increased pressure of the urine the tone of the internal unstriated muscular sphincter is increased and, if necessary, even the accessory voluntary urethral muscles are called into play. When a favourable opportunity for micturition occurs the internal sphincter is voluntarily relaxed, together with the rest of the unstriated muscular tissue of the posterior urethra, and the urine is expelled by the contraction of the detrusors.

The objection which has been raised to an unstriated muscle, like the internal sphincter, being under the influence of the will is fairly met by a reference to the accommodation muscle of the eye, which, whilst unstriated, is completely under the control of the will.

In conclusion, I wish to acknowledge my indebtedness to Mr. Hall-Edwards for the care and skill with which he has produced the radiographs to illustrate this paper.

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THE MODERN MASTOID OPERATION.*

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THE mastoid operation as now performed has only been developed during the last few years, and one cannot but wonder that it was not described and carried out many years ago. This may be due partly to the fact that otology was formerly looked upon as of no importance, that the otologists had little or no knowledge of surgery, and that the surgeons who operated on the ear had no knowledge of otology. In his interesting paper on mastoid operation¹ Ballance says:

The operation for the cure of chronic suppuration in the temporal bone is practised abroad almost exclusively by highly skilled operators, who have devoted special attention to the subject. In this country it would appear to be considered within the competence of all. In skilled and careful hands it is attended by no more risk than other great operations, but, to quote a remark from a French book on surgery about another operation: if it is undertaken by "the rash, the ill-informed, and the ill-equipped," there is grave risk of disaster or injury to the patient, or perhaps still greater risk of failure to cure the disease, from the operation being ill-conducted and incomplete.

The operation for mastoid disease is in fact very tedious and difficult, and as the position and size of the important parts, facial nerve, lateral sinus, antrum, and mastoid cells vary so much in every patient, and are quite different in children and in adults, every case has to be treated on its

own merits, and we can never tell, until we explore the parts, how far the operation will extend, and what we shall have to remove. For these reasons it is much more difficult than many other important operations, and becomes dangerous if the surgeon is not perfectly acquainted with the topography of the surrounding parts.

The real history of mastoid operation begins with the publication of Schwartz's 59 cases in 1873. Schwartz opened up the mastoid antrum and a few cells in acute and chronic cases. At the present time this operation is only performed in acute cases, and in chronic cases we perform the so-called Stacke-Schwartz or complete mastoid operation.

There are three varieties of the mastoid operation: (1) Opening of a mastoid abscess and removal of any diseased bone; (2) opening of the mastoid process and the mastoid antrum—Schwartz's operation; (3) the radical operation in one of its forms, by which the middle ear, attic, mastoid cells, and antrum are reduced to one smooth-walled cavity—Stacke-Schwartz operation. This involves also the removal of the posterior wall of the meatus, the outer wall of the attic, and of all the bony ledges which overlap the antrum. I only intend to deal with the complete or radical operation.

A large skin incision should be made extending from the top of the ear to the apex of the mastoid (in cases of extensive disease an additional horizontal incision is made backwards), the periosteum is then carefully stripped off. Many operators make the incision much too small. We now carefully examine the exposed bone and look for a fistula. If there be one, it is generally found either just over the suprameatal triangle or near the apex of the mastoid, or further back on a level with the auditory meatus, when the lateral sinus or cerebellum is involved. If a fistula is found we, of course, follow this up, carefully exploring with a probe any cavities there may be. In some cases the antrum is lined with a thick membrane which may be mistaken for the dura. If no fistula is found, we chisel open the antrum from the posterior wall of the meatus, or in the area of the suprameatal triangle, cutting towards the centre of the triangle, thus making a conical cavity which points towards the antrum.

This is the old Schwartz operation, now only adopted in acute cases. In the modern operation for chronic cases the attic is also exposed, the posterior wall of the osseous meatus removed, and all the mastoid cells opened up and cleared out. We first turn our attention to the remaining bridge of bone which separates the mastoid antrum from the middle ear and attic. This is practically the posterior and upper wall of the auditory meatus. In the upper part we find the aditus to the antrum—that is, the communication between the attic and the antrum. The chisel is applied to the upper wall of the meatus, and thin layers of bone carefully removed. We thus open the so-called attic, or upper part of the middle ear, which contains part of the ossicles, and the aditus to the antrum. We then turn our attention to the posterior wall of the meatus. In its lower part lies the facial nerve, and near it the external semicircular canal. This part is very hard, and of a pale, shiny colour. We have to be very careful not to remove too much of this posterior wall, or we shall damage the facial nerve and the external semicircular canal. The assistant must carefully watch for any twitching of the face. For this part of the operation an electric forehead lamp is absolutely necessary. We then open up all the mastoid cells very carefully. These vary very much in extent, sometimes they extend forward into the zygomatic process, and backward well over the lateral sinus. All overlapping and rough bone should now be carefully removed by the forceps and gouge, or burr, and the walls of the cavity made as smooth as possible. At one time the burr was extensively used, but it is now practically discarded by most surgeons as unnecessary and tedious. Most of the operation can and should be performed with the help of bone forceps of various sizes, and the gouge. The chisel should be used as little as possible. We have now formed one large cavity consisting of the middle ear, attic, mastoid antrum, and mastoid cells. During the operation I frequently apply hydrogen peroxide, which not only arrests the aggravating haemorrhage from the bone or granulation tissue, but also cleanses the cavities and removes small pieces of debris which obscure the field of operation.

Instead of opening up the mastoid cells through the

* This paper was read before the Leeds and West Riding Chirurgical Society, and illustrated with numerous lantern slides.