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MYRINGOPLASTY

SURGICAL REPAIR OF TYMPANIC MEMBRANE PERFORATIONS

BY

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The tympanic membrane is a diaphragm capable of being set in vibratory motion by sound waves. The movement takes place at the periphery of the membrane, the central portion moving in and out like a plunger. The plunger action is transmitted to the oval window by the ossicular chain with a hydraulic effect ; that is to say, the disparity in sizes between the two membranes results in augmentation of energy per unit area. In addition, there is a slight augmentation by the lever action of the ossicles. The handle of malleus (integral with the membrane) is longer than the long process of the incus, and the two bones together act as a bent lever round an axis running roughly through their bodies. The ratio of advantage derived from the hydraulic and lever effects is about 18 to 1. Impairment of the tympanic membrane therefore is inseparable from some impairment of auditory function. The degree of impairment, however, will not be a simple function of the size of perforation, but will depend also upon the position of the defect and the integrity of other portions of the conducting mechanism.

The passage of a sound-wave through the cochlea demands a sound pressure differential between the oval and round windows ; the sound "flows," as it were, down the pressure gradient between them. For optimal function the sound must be concentrated at one window and "kept" from the other. The round window is normally "kept" from sound, paradoxically, by the tympanic membrane. A defect in the membrane may therefore allow exposure of the round window to sound, with reduction of the differential and impairment of hearing additional to that sustained by loss of hydraulic and leverage action at the oval window. It goes without saying that these hydraulic and leverage actions will be lost anyway if there is any disruption or fixation of the ossicular chain. It may also be accepted that part of the essential conducting mechanism is an air-transmitting eustachian tube : free vibration of tympanic membrane and inner-ear membranes requires air in the middle ear at atmospheric pressure.

Finally it is a vital condition of perfect hearing that the cochlea and its central connexions should be unimpaired. Hearing cannot be made better than the cochlear potential.

The auditory effect of a breach in the integrity of the tympanic membrane is therefore variable and somewhat unpredictable, as is the auditory prognosis associated with repair. Repair will be efficacious in restoring hearing loss in proportion as the hearing loss can be attributed to the defect. Where other factors are involved—for example, discontinuity of the ossicular chain—the result of repair may be ineffective as regards the hearing. The selection of cases for myringoplasty for this and other reasons is of great importance.

The Safe Ear

Persistent perforations of the tympanic membrane are for practical purposes legacies of either otitis media or traumatic rupture. Renewed interest in the investigation and treatment of perforations has been partly due to the post-war appearance of greater numbers of traumatic rupture in which the defect appeared to be the only barrier in many cases to normal hearing and a normal ear (Fox, 1945 ; Baron, 1948 ; Derlacki, 1953). Persistent cases of traumatic rupture are deserving of every effort towards closure and generally constitute cases presenting no inherent difficulty in selection for operation.

It is when the perforation is a legacy of otitis media that difficulty in selection arises. Prior to the advent of antibiotics it was an accepted and strongly held principle of otology that free drainage of infections of the middle ear and mastoid was the essential condition for safety. The control of infection without drainage (witness the spectacular decrease in myringotomy and mastoidectomy for acute infections) is a post-war phenomenon. Acute infections are now invariably treated with antibiotics, drainage being reserved only for those cases where pus is under tension or persistent, or where complication is threatened. Antibiotics, however, did not and do not allow the same control in chronic as in acute infections,

and it remained a firm principle in the management of chronic otitis media and mastoiditis that free access must be allowed to the exterior until Wullstein (1951), at Wurzburg, began to demonstrate that careful removal of all diseased tissue undertaken with microscopical magnification, under antibiotic cover, secures such surgical control of infection as to allow closure of the middle ear by skin grafts.

At the same time Zöllner (1951) was demonstrating the practicability of closing perforations with full-thickness skin grafts, and in 1955 he published a paper in Britain (Zöllner, 1955) on the principles of his plastic surgery, which included the opinion that it was reasonable to close perforations by simple skin-graft patches provided the ear had been inactive or dry for some time. Wullstein continued to advocate prior control of the mastoid antrum and middle ear by inspection involving removal of bone. The question arose, therefore, whether simple skin-grafting operations, without removal of bone for inspection purposes, were justified in perforations where the otitis media was clinically inactive, or whether they were never justified until microscopical exclusion of infection in the mastoid antrum and posterior middle-ear recesses had been carried out.

Another principle of otology relevant to this question, subscribed to certainly by British opinion, was that perforations of the membranes could be classified as "safe" or "unsafe" according to their position. Posterior or attic (*pars flaccida*) perforations presupposed association with infection in a part of the ear dangerous as regards risk of complication. Even in the absence of discharge these perforations were potentially unsafe. If cholesteatoma was suspected the ear should be regarded as so unsafe as to require immediate operation. Under this principle there was no exception to the view that an "unsafe" perforation should never be closed without detailed inspection. The "safe" ear, however, should theoretically be suitable for grafting without the prior necessity of submitting the patient to excavations of bone to inspect the mastoid antrum or cells. The "safe" ear for purposes of myringoplasty definition was one with a central, anterior, or subtotal perforation in which there had been no middle-ear infection, as evidenced by absence of discharge, for two months, and that discharge when it had occurred previously was explicable on grounds of reactivation via the upper respiratory tract and eustachian tube or via the external auditory meatus.

Thorburn (1954), of Blackpool, had concluded, from his observations of Zöllner's techniques, that closure of perforations was practical but selection of the right cases was difficult. Wright (1956), of Houston, Texas, had experience with 56 perforations so treated. Frenckner, of Stockholm, was using pedicle grafts from the wall of the external auditory meatus in 1951 (Frenckner, 1955). There was also a vast literature of previous experience

gained with other methods, involving plugs of cotton-wool or plastic; patches of rubber, sized paper, elastic, collodion, egg membrane, sheep's membrane, cigarette paper, gold foil, human amniotic membrane, and caustic stimulation to the edges of the perforation to encourage it to close. This last was an accepted method (Dunlap and Schuknecht, 1947; Derlacki, 1953; Wright, 1956), and repeated applications of trichloroacetic acid gave good results in small central perforations. If these small central perforations could be closed with impunity with acid it seemed reasonable to attempt to close slightly larger ones with skin grafts.

In the belief that a clinically "safe" ear was indeed safe, and that otitis media could be regarded as inactive if there had been no discharge or other symptoms for two months, the simple operation of external onlay skin-grafting was offered to all patients in this category who sought advice primarily because of a perforation of the ear-drum or because of deafness thought after examination to be primarily arising therefrom. This paper presents the results of the first five years' experience with the operation. During this time certain modifications in techniques have been made, but the above principles controlling selection of cases have been adhered to in order that the principles themselves might be tested. The number of cases, therefore, is not large, since adherence to these principles of selection results in the exclusion of a great many perforations seen as unsuitable for myringoplasty.

Technique

After selecting a perforation suitable for repair, the next problem is one of technique. Grafts may be onlaid externally or internally. For internal grafting Shea (1960) has found vein a suitable material. For external onlay grafting theoretical consideration (Mawson, 1958) and practical experience indicate that free graft of full-thickness skin (Wolfe, Krause) denuded of all subdermal fat and connective tissue is the material of choice. In most cases here under consideration the skin has been taken from the back of the auricle. In recent months, for the smaller perforations, the skin of the anterior meatal wall has been preferred, except when this skin has not had enough substance to be separated easily without tearing.

Survival of the graft after application to the membrane probably depends for the first 48 hours on intragraft circulation (Wright, 1956) together with some extracellular nourishment by imbibition (Conway *et al.*, 1951). At 72 hours, continuity of host and graft blood-vessels has been noted and normal circulation has been seen established by the eighth day (Wright, 1956). A raw surface is required for the graft bed but haematoma formation beneath the graft must be prevented. Fixation of the graft occurs naturally by fibrin clot, and strong pressure is neither required nor desirable to hold the graft in position.

FIG. 1.—Preparation of receptor area and placing the graft.

Where there is a defect to be bridged the principle has been followed of providing approximately twice the surface area of supported graft as for unsupported. Very large perforations may entail denuding the surface of the promontory of the middle ear to provide added support for the graft. The operation has been performed under general anaesthesia with penicillin cover, and with an operating microscope at a magnification of 10 diameters.

Operative Details

Preparation of Receptor Area (Fig. 1).—The preparation of the graft bed is conveniently preceded by endomeatal haemostatic injection as for stapes operations and, if the meatus is too narrow for access, by endaural incision and burring of bone. The area to be denuded depends on the size of the perforation. Small central perforations may not require more than that the squamous epithelium be removed from the pars tensa. Large subtotal perforations may require a circular incision at the junction of the inner third and outer two-thirds of the meatus and a stripping of all the membranous meatus *inwards* towards the perforation. As Beales (1957) has pointed out, dissection outwards from the perforation will only tend to enlarge it. In some of the earlier cases in this series the meatal skin, if in a suitable state of preservation, was retained as an inward facing flap so that the skin graft could be supported by it across the perforation (Mawson, 1958). The advantages of this, however, did not seem to outweigh the theoretical risk of enclosing squamous epithelium in the middle ear and has not since been advocated.

Preparation of Graft (Fig. 2).—An incision, slightly convex backwards, is made in the post-auricular sulcus, and as much skin as is required is obtained from the back of the auricle by a circular incision parallel with the auricular margin. The incision is thus like a letter D, smaller or larger according to requirement. The skin is dissected conveniently from above downward with as little subcutaneous tissue as possible included. The D bed is straightened by inserting a hook in the top, and the margins are sutured together from below upwards. Little or no undercutting is necessary and the post-operative scar is negligible. Excess fat and connective tissue is removed from the under surface of the graft with fine scissors, the procedure being controlled microscopically.

Placing the Graft (Fig. 1).—In the early cases a circular graft was invaginated around a sponge by a purse-string suture placed in readiness before removal from the donor area and inserted blindly down the meatus (Mawson, 1958). The lack of precision was felt, however, to be unsatisfactory, and this technique has not been used in the last 41 cases in the series. In these the straight edge of the D has been positioned on the superior aspect of the tympanic membrane above the perforation, if necessary upon the attic, and the curved border of the graft placed inferiorly, reaching externally along the posterior wall, floor, or anterior wall of the

meatus as necessary. Great care has been taken to tease out the edges of the graft so as to avoid incurling and winking, and the graft has been gently *held* (not pressed) in position by pledgets of "sterispon" soaked in penicillin.

Post-operative Care.—The patient is ambulant on the first post-operative day, and the stitches from the donor area are removed on the sixth. Warning is given against blowing the nose too hard or getting water in the ear. Towards the end of the first fortnight the sterispon, if not dissolved, is removed from the meatus and the graft inspected. If it appears to have "taken" and there is no infection, either in the upper respiratory tract or in the meatus, the patient is encouraged to perform Valsalva's manoeuvre. Failing a positive inflation by this method, a eustachian catheter may be passed and the middle ear gently inflated by this route. The patient is seen at suitable intervals until it is judged that the maximal recovery of hearing has taken place and the repaired membrane has settled into a trouble-free final state. The length of time involved in the follow-up is usually proportional to the size of the perforation grafted, small central perforations becoming stabilized soonest, as might be expected.

Results

Table I summarizes the objective and subjective results of 62 operated ears at the time of the latest follow-up carried out for this record. The two primary objectives of operation were complete closure of the perforation and total restoration of the hearing. The wholly successful operation would achieve both. Since the hearing cannot be improved above the cochlea potential, closure of the gap between air and bone

TABLE I.—Results of Myringoplasty in 62 Cases

Objective Result	No.	%	Subjective Result			
			Good	Fair	No Change	Worse
100% closure perforation ..	27	43.9				
100% " A-B gap ..	8	12.9				
100% " perf. + A-B gap	6	9.7				
Unqualified success:						
100% closure perf. + A-B gap	6	9.7	5		1	
Qualified success:	28	45.2				
A. 100% closure A-B gap (without 100% closure perf.)	2		1	1		
B. 50-99% closure A-B gap (with 100% closure perf.)	10		3	5	2	
C. 5-49% closure A-B gap (with 100% closure perf.)	16		5	5	6	
Qualified failure:	9	14.5				
A. 100% closure of perforation; no closure A-B gap	7		1		5	1
B. 100% closure of perforation; A-B gap widened	2				2	
Unqualified failure:	19	30.6				
A. No closure A-B gap or perforation	6				6	
B. No closure perforation; gap wider	13			1	10	2
Total ears operated ..	62	100	15	12	32	3

FIG. 2.—Preparation of graft.

conduction on pure-tone audiometry provides the most exact and at the same time severe objective test of success as regards restoration of hearing. Total elimination of the gap at speech frequencies might be regarded as an unqualified success, and this was achieved in eight cases. In six of these complete closure of the perforation was also obtained. The total of *impeccable* successes was therefore six. Partial closure of the air-bone gap, however, constitutes a qualified success regardless of whether the perforation is totally closed.

Those cases with an average gap closure of over 50% were placed in one group of qualified successes, while those with an average gap closure of less than 50% were placed in another. The total of these cases of qualified success, including two cases of total closure of the air-bone gap without complete closure of the perforation, was 28. Of these qualified successes it is interesting to observe that 20 patients indicated a subjective improvement in hearing, and 10 of these were pleased with the result despite an average gap closure below 50%. Total closure of the perforation without improvement in hearing occurred in seven cases. This might be regarded as a partially successful outcome of operation, since the patients are enabled to dispense with precautions and to compete more effectively for life-insurance purposes and for positions requiring a previous medical examination. They have nevertheless been recorded as qualified failures, since the hearing has not improved, as have the two cases in which the perforation was closed yet the hearing was worse. If the successful cases amount to a clear 54.9% it is nevertheless legitimate to say that another 14.5% have gained some benefit from the operation in having their perforations completely closed, and that some overall benefit may be expected, as judged from this series, in 69.4% of operations.

Complete failure to close the perforation associated with unchanged hearing occurred in six cases, and with worse hearing, as recorded audiometrically, in 13 cases. But in the 13 worse-hearing cases only two patients complained that the hearing seemed worse; 10 thought there had been no change and one maintained he heard better.

Table II is the chronological expression of the result groups, and may be read in conjunction with Table III, which is an analysis of causation of the 19 unqualified failures. No clear pattern of predictability emerges. There would not seem to be an inherent tendency for any temporal attrition to occur. The failures are closely bound up with the incidence of upper respiratory infections, and susceptibility to this is tied to the individual's resistance to chance exposure. A regular previous

history of more than three upper respiratory infections a year would harden the prognosis. But many such individuals are excluded from operation anyway, because of difficulty in obtaining a thoroughly dry ear for a long enough period.

Table IV is a simple summary of results in terms of advantages as seen from the viewpoint of the otologist and the patient. Even though the subjective advantages

TABLE IV.—Summary of Results

	Objective	Subjective
Advantage	43 (69.4%)	27 (43.9%)
No advantage	6 (9.4%)	32 (51.3%)
Disadvantage	13 (21.2%)	3 (4.8%)
Total cases ..	62 (100%)	62 (100%)

from operation appear below 50%, there is less discouragement here than seems apparent. Nine patients asserted absence of advantage in which the audiometric gain was clear and associated with a completely closed perforation, including one patient with 100% closure of air-bone gap.

In discussing the anticipated benefit from myringoplasty with a patient it is reasonable and fair to predict 70% measurable advantage, 10% no advantage, and 20% measurable disadvantage from this operation.

Discussion

The most important consideration in the successful application of myringoplasty is undoubtedly the selection of cases. Thorburn (1954) had already predicted, in the infancy of the operation, that this might be difficult. Zöllner (1955), reporting 22 cases, in which seven re-perforated and the hearing was totally or partially lost, stressed that operation should be attempted only when the ear had been dry for some time. Beales (1961), describing six years' experience with 87 cases, stressed the need for a six-months pre-operation period without discharge. In this series an arbitrary dry period of two months was the allowable minimum, and, since in 19 unqualified failures the cause of re-perforation in 14 could be traced to reactivation of otitis media in association with an infection of the upper respiratory tract, it is thought that this period is probably too short. Pre-operative observation should be able to estimate the behaviour of the ear under the conditions of an upper respiratory infection.

Some flexibility is desirable, as it would not be reasonable to wait unduly to observe an upper respiratory infection in a patient whose rate of incidence was low. But in the average person developing an infection perhaps twice a year it would be an advantage to know, apart from the information derived from the history, how the middle ear behaved under these circumstances. Reactivation of otitis media would be taken as an adverse prognostic sign for long-term survival of the graft. In a patient who gave a regular history of recurrent otorrhoea in association with colds myringoplasty would, in the light of our experience, probably not be thought worth while.

It is recommended *in the first instance*, therefore, that a case should not be considered for myringoplasty unless there has been complete absence of discharge for six months and unless the history indicates a more than 50% probability of the middle ear surviving an upper respiratory infection without involvement.

TABLE II.—Results of Follow-up

Objective Results	No.	Followed Up				
		1 Year	2 Years	3 Years	4 Years	5 Years
Unqualified success	6	4	0	1	0	1
Qualified	28	8	7	2	6	5
“ failure”	9	2	6	0	0	1
Unqualified “	19	3	1	8	6	1
Ears operated	62	17	14	11	12	8

TABLE III.—Cause of 19 Unqualified Failures

Failed take (early slough)	..	..	..	5 cases
Reperforation	..	..	..	14 “
Upper respiratory infection	..	..	11	
Blew nose too hard	..	..	1	
Graft removed with dressing	..	..	1	
Not known	..	..	1	

In the second instance the selection of cases is governed by the audiological principles controlling restoration of middle-ear function. Portmann and Claverie (1955) enumerated four anatomical indispensables for good functional results. (1) A vibrating intact membrane (the purpose of myringoplasty). (2) A free, air-containing tympanic cavity in communication with the atmosphere by a patent eustachian tube. (3) A columella effect—for example, intact mobile ossicles, or membrane at least in solid contact with mobile stapes (sound pressure transformer). (4) Two functioning inner-ear windows, one in contact with tympanic membrane (oval window) and one free, open to tympanic cavity (round window), allowing a sound pressure gradient.

Pre-operative estimation of these anatomical-functional necessities is desirable.

(1) Occlusion of the perforation. Cigarette paper or Japanese silk may be cut to suitable size and, after having been moistened with sterile paraffin, placed over the perforation. A gain in hearing on pure-tone audiometry indicates satisfactory function of the other three categories, and a good result from operation may be anticipated.

(2) If there is absence of improvement on (1), the patency of the eustachian tube may be investigated by catheterization.

(3) Ossicular function may be estimated by a vibrating (acoustic) probe connected with a bone-conduction output of the pure-tone audiometer.

(4) In large perforations with ossicular discontinuity but freely mobile inner-ear membranes a sound pressure gradient may be induced by loading the round window with a small pledget of cotton-wool soaked in sterile paraffin. In a patient in whom improved hearing is obtained by this manoeuvre, but not by occluding the tympanic membrane perforation, a poor functional result is to be anticipated as it implies absence of essential columella effect at the oval window.

In cases where these investigations suggest discontinuity of the ossicular chain, myringoplasty must be approached with caution. The hearing cannot be expected to improve and may even be made worse. The only gain to be anticipated from operation is a closed middle ear. This may be considered worth while by some patients who are particularly desirous of being relieved of the necessity to remain on precautions, or by others in competition for posts involving a medical examination, or for life-insurance purposes.

Where the eustachian tube is thought to be hopelessly impassable neither myringoplasty nor other forms of middle-ear reconstructive operations—for example, tympanoplasty—are likely to improve the hearing. A combination of ossicular discontinuity and eustachian blockage is a discouragement to any operation not otherwise required for the cure of active disease.

In the third instance the selection of cases is governed by the principle of safety, already considered. This means in effect that myringoplasty may be applied only to those ears which have been dry and inactive for six months and in which study, including radiography, has excluded the presence of cholesteatoma in the attic, antrum, mastoid, or stapes area. Some will maintain that cholesteatoma cannot be excluded without surgical inspection and will condemn simple myringoplasty as unsafe without previous removal of bone to allow access to these areas for inspection. Such an attitude, however, should logically lead to the advising of an inspection operation in every case of perforated eardrum, since the presence of a perforation of the pars

tensa cannot in itself render an ear safe from the activity of a cholesteatoma. On the whole, otological opinion has subscribed to the view that there are safe perforations which do not need exploratory operations, and it is in these classical instances that myringoplasty is thought to be safely applicable. In the cases in this series followed up for three years and over there have been no complications attributable to the enclosing of undetected disease.

The results of myringoplasty are perhaps disappointing in that such an apparently simple defect can be dealt with to advantage by this operation in only 70% of cases. The disadvantageous consequences of operation, moreover, have been high at 20%. At the same time the experience gained must lead to an even more stringent selection of cases, which should improve the overall results. In the long run an unclosed perforation carries an inherent risk of a greater ultimate hearing loss than does an intact ear, and is always "at risk" as regards reinfection via the meatus. On balance the plastic repair of perforations by skin-grafting is regarded as an improvement upon previous methods of treatment, provided the selection of cases is carefully made and a good micro-surgical technique employed. This agrees with the experience of other workers in this field. While the results are unspectacular the operation is thought to be very worth while.

Since the completion of this study the method of internal onlay grafting with portions of vein has given promise of a higher proportion of satisfactory results than at first anticipated. The surgical restoration of hearing in conductive deafness due to all causes is engaging the attention of otologists the world over, and further developments in this field may be expected.

Summary

The results of five years' experience in 62 cases of perforated tympanic membrane repaired by skin-grafting are presented.

Selection of cases and careful technique are of overriding importance and are discussed in detail.

Measurable advantage in 70%, no advantage in 10%, and measurable disadvantage in 20% have resulted from this operation.

The operation is regarded as an improvement on previous methods of treatment. While the results are unspectacular it is concluded that myringoplasty is very worth while.

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