Surgical Observations on Atelectasis of the Middle Ear in Children

Waarnemingen over atelectase van het middenoor bij kinderen

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Summary

Atelectasis of the middle ear, synonymous with that of the lung, is a variable collapse of the middle ear space, associated with retraction pockets formed by extreme atrophy of the tympanic membrane. It is a common condition in the paediatric patient population presenting to the Sophia Children's Hospital and though much controversy still surrounds the aetiology and progression, there is a clear association with the development of cholesteatoma. There is however almost always an associated otitis media with effusion (OME), though this may have cleared up by the time the patient is seen.

Observations and careful follow-up of the patients, though not the optimal method for elucidating the progression, does, in the absence of a suitable animal model, allow cautious estimates of possible aetiological developments.

The sequence of events appears to be the following, (though there are other possible explanations, and there is no consensus in the literature about this):

The middle ear fills up with secretions that become progressively thickened (synonyms: glue ear, otitis media with effusion (OME) or secretory otitis media (SOM). This results initially in a conductive hearing loss; occasionally as much as 40 or 50 dB and in the younger children this may cause a delay in speech development. After a variable length of time the middle ear secretions begin to be absorbed, drawing the thinned eardrum down towards the promontory and middle ear structures. At this stage the drum is not adherent to the middle ear structures, and may bulge out or be drawn in with varying Eustachian tube function. Older children often complain of clicking and popping of the ear, but otherwise it is a silent development. The drum may subsequently become adherent to the promontory or as is most frequently seen, to the long process of the incus, and may be gradually drawn into the round window niche, facial recess, sinus tympani and attic region around the ossicles. It seems likely that an intercurrent inflammatory process is required for an adhesion to form, and on surgery we often encounter fibrous bands fixing the drum to the middle ear structures or drawing it into the attic, towards the mastoid air cells. At each stage there is a possibility of spontaneous recovery, though this has not been reported once the drum has become adherent to the ossicles or promontory. There are then one or more retraction pockets of variable size held to the middle ear structures by adhesions or the negative middle ear pressures associated with underlying Eustachian tube dysfunction. As long as the desquamation process of the epithelial layer of the eardrum is not interrupted, and the epithelium progresses normally towards the external meatus, the situation may remain stable for years, though we have found that where the drum is fixed to the incus, there may be some degree of erosion of this ossicle in up to one third of the cases. Since the thin eardrum remains closely applied to the stapes, there is very little functional consequence even with complete interruption of the ossicular chain. Should the desquamation process be interrupted however, as frequently occurs even with the normal eardrum, following an intercurrent episode of acute otitis media (or possibly even otitis externa), epithelial debris will begin to accumulate in the retraction pocket, forming an epithelial cyst, or cholesteatoma.

The exact incidence or progression from retraction pocket to cholesteatoma is unclear and though in adults, many of the retraction pockets remain stable, and never progress to cholesteatoma, we have been unable to identify either in our population or in the international literature a reliable indicator in which patients to expect a progression and which retraction pocket will remain stable. Any retraction pocket must therefore be considered to be potentially unstable, with possibility of silent progression towards cholesteatoma.

Treatment may vary from early intervention with resection of the atrophic membrane to 'watchful waiting'. Some surgeons prefer to wait and see if the patient develops a cholesteatoma, though if they do there is

almost invariably damage to the ossicles, possibly to the inner ear and facial nerve, and the treatment will entail extensive, extended mastoid surgery with complex reconstructive procedures the results of which are never as good as prevention.

We have for this study examined a large group of patients with retraction pockets and atelectasis of the middle ear, to determine the efficacy and safety of earlier intervention, where possible, before cholesteatoma has had a chance to develop, or before it has grown beyond the middle ear and attic.

The surgical technique has gradually evolved, and a new classification was developed to indicate the extent of the disease, and the optimal procedure for each stage. As in so many studies, several unexpected discoveries were made; one of these about the rate of spontaneous healing of the eardrum after excision of the atrophic pocket. Postoperative earpacking was found to be unnecessary for this type of ear surgery.

For all the procedures reviewed, we analysed the effects of surgery on the function of the ear, to ensure there were no unexpected functional consequences or complications resulting from these modified procedures that might weigh the balance on the side of a more conservative policy. We hypothesised that in patients where the retraction pocket had developed a cholesteatoma would have poorer functional results than those where the intervention took place at an earlier stage.

Chapter One introduces the Erasmus classification of atelectasis of the ear. This is a surgical classification allowing comparison of the various stages of middle ear atelectasis. Stage I is an atrophic membrane without fixation to middle ear structures. In Stage II the atrophic drum is fixed to the promontory. In stage III the drum is fixed to the incus, but the base of the retraction can still be observed, while in stage IV the retraction is fixed to the incus and the depth is no longer observable, while in stage V there is evidence of accumulation of epithelial debris (cholesteatoma) in the depth of the pocket. The new classification is contrasted with previous classifications, and its practical implications are discussed.

Chapter Two describes the condition of the incus found during surgery for retraction pockets fixed to the incus (stage III and IV), but without evidence of cholesteatoma. Almost one third of the ears examined showed (under the operating microscope) some evidence of resorbtion of the Incus bone, varying from slight erosion to complete absence of the long process of the incus, and consequent disconnection of the ossicular chain.

Chapter Three describes the findings of a later group of patients where the atrophic eardrum was resected without any grafting procedures. Ninety four percent of the eardrums healed up completely within 6 weeks, obviating the need for grafting and thus simplifying the procedures considerably.

Chapter Four analyses a larger group of patients surgically treated for atelectasis, to confirm that surgical management could be shown to be a safe procedure at the various stages, and examine the percentage of ears progressing to higher stages. The group of patients with early cholesteatoma showed significantly worse hearing results than any of the other stages.

Chapter Five demonstrates that for a group of otological patients operated, ear packing after ear surgery proved, contrary to popular opinion, to be unnecessary. No complications occurred that could be attributed to the lack of ear packing, while operation time and patient anxiety were reduced.

Chapter Six describes the surgical techniques currently used for the management of retraction pockets and atelectasis of the ear in its various stages; the results distilled from the careful analysis and audits described in the earlier chapters.

This thesis attempts to describe, analyse and optimise the surgical management of a common paediatric otological problem, with the aim of preventing as far as possible the irreversible complications such as cholesteatoma formation and ossicular damage.

Samenvatting

Onder atelectase van het middenoor wordt verstaan de toestand waarin het trommelvlies zodanig naar mediaal is verplaatst dat het in contact is gekomen met andere middenoorstructuren en het middenoor nog slechts zeer beperkt lucht bevat. Het kan gepaard gaan met plaatselijke retractiehaarden die bekend staan als pockets. Het ziektebeeld gaat gepaard met een uitgesproken atrofie van het trommelvlies. Het komt veel voor bij kinderen.

Over de oorza(a)k(en) zijn de meningen verdeeld en ook over de mate- en de snelheid van optreden van complicaties zijn de boeken nog niet gesloten. Er bestaat een duidelijke relatie met het ontstaan van cholesteatoom. Er is meestal, zo niet altijd, een samenhang met otitis media met effusie (OME), ofschoon die bij het eerste consult van de arts reeds gedeeltelijk opgeklaard of volledig verdwenen kan zijn.

Doordat er nog geen diermodel bestaat dat volstrekt gelijk is aan het humane ziekteproces, is voorlopig de enige manier om oorzakelijke factoren en progressie van het ziektebeeld vast te stellen een regelmatige zorgvuldige observatie van de patient.

Van de verschillende mogelijke oorzaken die in de literatuur zijn te vinden menen wij dat het ziekteproces min of meer als volgt verloopt:

Het middenoor vult zich op een gegeven moment met vocht dat geleidelijk indikt en taaier wordt. In het verleden werden verschillende beschrijvende termen gebruikt zoals tubair catarrh, sereuse otitis media (SOM), lijmoor (glue ear) en - tegenwoordig - otitis media met effusie (OME). Dit stadium leidt in het begin tot een geleidingsslechthorendheid van soms wel 40 of 50 dB. Dat gehoorverlies kan bij jonge kinderen tot een vertraagde spraakontwikkeling voeren. Na een variabele periode kan het vocht in het middenoor worden geresorbeerd, waarbij het uitgerekte trommelvlies naar mediaal wordt getrokken in de richting van het promontorium en andere middenoorstructuren. In dit stadium is het trommelvlies nog niet verkleefd met middenoorstructuren, is daarmee in beginsel nog bewegelijk en kan - afhankelijk van de luchtdoorgankelijkheid van de buis van Eustachius - zowel naar buiten opbollen tot één of meer blazen (bullae) of toenemend naar binnen worden getrokken. Tijdens dat laatste proces kan het zich verder rond de gehoorbeentjesketen vouwen en in de monding van de buis van Eustachius en rond alle andere structuren van het middenoor (vide infra). Oudere kinderen kunnen soms klagen over lichte pijnklachten of klikken en ploppen van het oor, maar meestal klagen kinderen niet of weinig over de oren. In het angelsaksische spreekt men veelbetekenend wel over een silent aandoening. In het eindstadium is het trommelvlies uiterst dun geworden en volledig verkleefd met alle middenoorstructuren, waaronder ook (de nis van) het foramen rotundum, de stapes inclusief de m. stapedii, (de nis van) het foramen ovale, de recessus facialis, de sinus tympani, de atticus, de andere delen van de incus, het caput en collum mallei met de m.tensor tympani en tenslotte het antrum. Het lijkt waarschijnlijk dat een (steriel) ontstekingsproces (inflammatie) verklevingen veroorzaakt die tijdens een heelkundige ingreep als bindweefseldraden en banden kunnen worden tegenkomen. Deze fibreuze strengen strekken zich uit tussen middenoorstructuren en trommelvlies en zijn vermoedelijk verantwoordelijk door hun "elastiek-werking" dat het trommelvlies verder naar binnen wordt getrokken tot in de cellen van het mastoïd toe. Tijdens de vroege stadia is spontaan herstel nog mogelijk. Op het moment dat er verkleving is opgetreden met het promotorium en/of andere structuren van het middenoor is het proces onomkeerbaar. Meestal zijn er dan inmiddels retractie-pockets opgetreden door de adhesies en de onderliggende dysfunctie van de tuba Eustachii.

Zolang de migratie van de buitenste epitheellaag (stratum corneum) van het trommelvlies zich normaal verplaatst in de richting van de gehoorgang kan het zijn dat de patiënt - zelfs jarenlang - weinig of niets

merkt. Het gehoor kan nog heel lang (vrijwel) normaal zijn doordat het aambeeld (nog) intact is en nog niet door het contact met het trommelvlies is geërodeerd. Enige erosie hebben wij gevonden bij ongeveer een derde van de patiënten. Ook kan, nadat de processus longus incudis is verdwenen en het trommelvlies komt te rusten op de kraakbenige meniscus stapedii, hetgeen myringostapediopexie wordt genoemd, het gehoor nog nagenoeg normaal blijven.
Als echter de desquamatie van het trommelvlies abnormaal wordt, mogelijk ten gevolge van een otitis media of zelfs otitis externa, kunnen huidschilfers van het trommelvlies zich ophopen in een retractie-pocket. Daaruit kan een epitheliale cyste of cholesteatoom ontstaan.
De preciese incidentie van een retractie-pocket of cholesteatoom is niet duidelijk. Bij volwassenen kan een retractie-pocket jarenlang stabiel blijven en het nooit tot cholesteatoom brengen.

Noch in onze eigen patiëntengroep, noch in de literatuur hebben wij een betrouwbare parameter gevonden voor de mate van progressie. Wij beschouwen daarom elke retractie-pocket in beginsel als onstabiel en in potentie als een voorstadium van cholesteatoom.
Behandeling kan variëren van vroeg ingrijpen doormiddel van verwijderen van het atrofische gedeelte van het trommelvlies, tot zorgvuldig controleren.
Sommige oorartsen geven de voorkeur aan zorgvuldig controleren totdat zich een cholesteatoom heeft gevormd. Dat herbergt het gevaar van schade aan de gehoorbeentjesketen en - zelden - aan andere middenoorstructuren. Behandeling daarvan vereist tenminste uitgebreider, soms zelfs zeer uitgebreide chirurgie. Daarvan zijn de resultaten ten aanzien van het gehoor minder goed dan bij vroeg(er) operatief ingrijpen.
Wij hebben in ons onderzoek een grote groep patiënten met retractiepockets en atelectase van het middenoor gevolgd om de effectiviteit van vroege behandeling na te gaan op het voorkómen van cholesteatoom en het voorkómen van een retractie-pocket in die delen van het middenoor die niet met otoscoop of microscoop kunnen worden gevolgd, dat wil zeggen de atticus, het antrum, de recessus facialis en de recessus tympani.
Onze heelkundige techniek ontwikkelde zich geleidelijk en een nieuwe klassificatie van Stadia werd opgesteld op basis waarvan een optimale chirurgische procedure per Stadium kon worden vastgesteld.
Wij deden enkele onverwachte bevindingen. Eén daarvan was dat het trommelvlies na operatieve verwijdering van de atrofische pocket zich spontaan bleek te herstellen. Een ander was dat het onnodig bleek (bij dit soort ingrepen) de gehoorgang aan het einde van de operatie te tamponneren.
Voor elk operatietype hebben wij de resultaten van de behandeling nagegaan zowel wat betreft complicaties, als wat betreft postoperatief gehoor en recidief-frequentie.
Hoofdstuk 1 beschrijft onze Erasmus classificatie van atelectase van het middenoor. Dit is een chirurgische classificatie die de vergelijking van verschillende Stadia van middenooratelectase mogelijk maakt.
Stadium I is een atrofisch trommelvlies zonder verkleving met middenoorstructuren. In Stadium II is het atrofische trommelvlies verkleefd met het promontorium. In Stadium III is het trommelvlies verkleefd met het aambeeld maar de bodem van de retractie kan nog steeds in zijn geheel worden overzien. In Stadium IV is de retractie pocket verkleefd met het aambeeld en is de bodem van de pocket niet meer te overzien. In Stadium V is epitheliale debris dan wel cholesteatoom zichtbaar in de bodem van de retractie pocket. Deze nieuwe classificatie wordt vergeleken met andere, reeds eerder opgestelde classificaties.
Hoofdstuk 2 beschrijft de toestand van het aambeeld zoals gevonden tijdens de heelkundige ingreep van Stadia III en IV. Bij ongeveer een derde van de geopereerde oren van deze Stadia bleek sprake te zijn van

erosie van het aambeeld, zonder dat er sprake was van een cholesteatoom. De beschadiging kon gering zijn, maar ook kon het gehele lange been van het aambeeld volledig teloor zijn gegaan, waardoor er geen continuïteit meer bestond van de gehoorbeentjesketen.

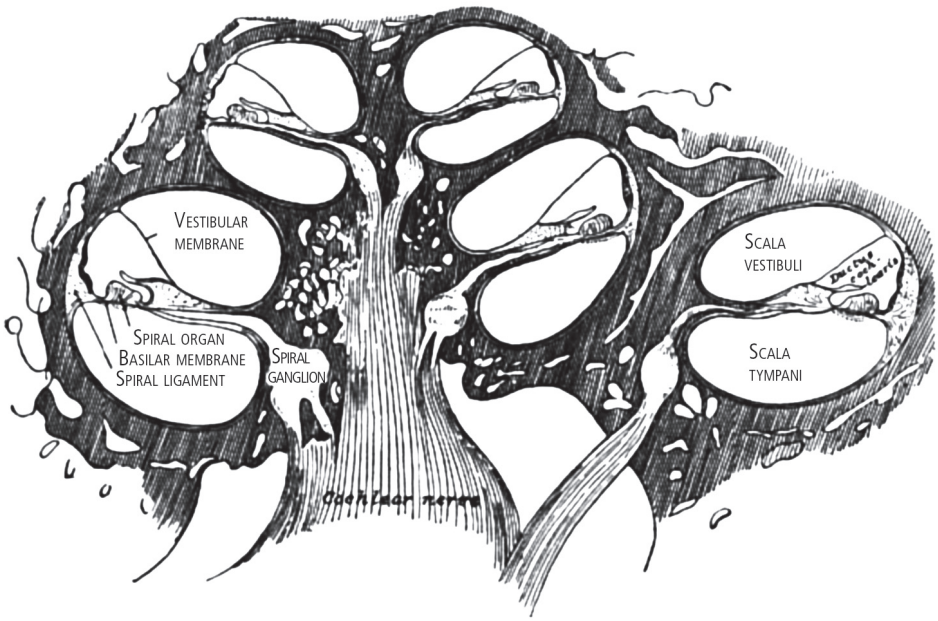
In hoofdstuk 3 worden de resultaten beschreven van een groep patiënten waarvan het atrofische trommelvliesdeel werd verwijderd zonder dat er enige poging werd gedaan dit te herstellen doormiddel van een trommelvliesplastiek. Vier-en-negentig procent van de trommelvliezen heelde - dus spontaan en zonder verdere interventie - binnen zes weken.

Hoofdstuk 4 beschrijft de resultaten van een groep patiënten die met een uitgebreider operatie werd behandeld voor hun atelectatisch trommelvlies. Het bleek dat deze operatie voor elk Stadium veilig was. De ontwikkeling van een bepaald Stadium tot een hoger Stadium van atelectase werd nauwkeurig vastgesteld. De groep patiënten die een vroege ontwikkeling tot cholesteatoom doormaakte bleek dit significant vaak te moeten bekopen met een minder goed gehoor dan elk ander Stadium.

Hoofdstuk 5 geeft aan in een groep oorpatiënten waarvan de gehoorgang aan het einde van de ingreep niet werd getamponneerd dat tamponneren onnodig is. Er trad geen complicatie op die aan het niet-tamponneren kon worden toegeschreven. In tegendeel; de operatieduur werd erdoor bekort en onze patiëntjes behoefden niet angstig te zijn of pijn te leiden doordat op enigerlei tijdstip na de operatie bij hen tamponmateriaal moest worden verwijderd.

Hoofdstuk 6 beschrijft de heelkundige technieken die momenteel in zwang zijn voor behandeling van retractie pockets en atelectase in de verschillende Stadia.

Ons onderzoek beoogde nauwkeurig te beschrijven wat werd waargenomen bij een veelvoorkomend pediatrisch oorprobleem, het waargenomene te analyseren en een optimalisatie van de heelkundige behandeling te formuleren. Ons doel daarbij was zoveel mogelijk voortschrijden van het ziekteproces tot een hoger stadium te voorkomen waardoor onomkeerbare beschadiging van de middenoorstructuren zou kunnen worden vermeden.


Vestibular membrane
Spiral organ
Basilar membrane
Spiral ligament
Spiral ganglion
Scala vestibuli
Scala tympani

Introduction

Research in surgical procedures is a difficult and controversial subject. Due to the nature of the surgical intervention, randomised trials are rare[1], and double blind surgery virtually impossible for the conscientious surgeon.

It may sound paradoxical to non-surgeons, used to the carefully nurtured myth of the detached and cold surgeon, to discover that the doctor patient relationship is of necessity very close; the patient must deposit a large amount of trust in his surgeon, and the surgeon may not betray that trust. If a patient on a medical trial does not feel well he can simply discontinue the medication. But a patient on the operating table is relying entirely on the trust he has placed in the surgeon, to look after his best interests and carry out the most effective procedure in the best possible way. The surgical patient has no choice once the procedure is under way. Any randomised procedure in surgery carries a risk independent of the type of surgical procedure, and the surgeon will have an opinion as to which of the options is in his hands the safest and most effective. Randomisation therefore carries an implication that some of the patients are receiving suboptimal treatment.

Placebo surgery has many of the risks and none of the benefits, submitting the patient to a lottery in which he could suffer serious complications or lose his life - somewhat reminiscent of Jorge Luis Borges' short story The lottery of Babylonia. A double blind study is one few conscientious surgeons would even contemplate. To justify submitting a patient to a lottery, by subjecting his well being to that of the 'greater good' is questionable, and becomes more so with increasing risks involved. The means do not justify the end if it may mean the end for the patient.

Research in surgery therefore is largely dependent on fortuitous observations and accidental occurrence; slow, gradual modifications of techniques, carefully monitored and always with the best interests of the patient in mind. Louis Pasteur always claimed that chance favours only the prepared mind[2], and surgery is full of unexpected incidents that must be recognised and interpreted.

In surgery we are faced with the arduous task of teaching established methods to residents, and innovating better methods for the patients, while working always within the widest possible safety margins. As with interventions in the ecology, or in the genome, we cannot afford to get it wrong.

This study started many years ago with a combination of a long-standing dissatisfaction with the unstructured nature of the treatment for atelectasis of he middle ear, (where 'watchful waiting' seemed to be the mainstay of management with surgery reserved for those patients that had developed a cholesteatoma) and a number of fortuitous observations, coupled to a careful and exhaustive analysis of the literature, to compare information, and wherever possible take advantage of the learning curve of other authors. This was followed by gradual modification and adaptation of techniques, and thorough audit of the results. In the course of the study, to be able to analyse the results more effectively we proposed a new (surgical) classification of the condition, discovered new facts, and analysed different aspects of the complications generally associated with the atelectasis. Many more observations were made that were not directly amenable to statistical analysis, and therefore not publishable at present, some of these have been included in the final discussion.

1 Jens Thomsen was harshly criticised for his placebo surgery study in 1985 [Thomsen J, Bretlau P, Tos M, Johnsen NJ. Placebo effect in surgery for Meniere's disease: three-year follow-up. Otolaryngol Head Neck Surg. 1983;91(2):183-6.]

2 Dans les champs de l'observation le hasard ne favorise que les esprits préparés.

Atelectasis of the middle ear, synonymous with that of the lung, is a variable collapse of the middle ear space, associated with retraction pockets formed by extreme atrophy of the tympanic membrane. It is a common condition in the paediatric patient population presenting to the Sophia Children's Hospital. Much controversy still surrounds the aetiology, and little has been published about progression. There is however almost always an associated otitis media with effusion (OME), though this may have cleared up by the time the patient is seen. OME is in itself a controversial subject about which far more studies have been published, without a clear aetiology emerging, so in essence we are examining the consequences and complications of another related problem, which is beyond the scope of this paper to analyse in further detail. Observations and careful follow-up of the patients, though not the optimal method for elucidating the progression, does, in the absence of a suitable animal model, allow cautious estimates of possible aetiological developments.
The sequence of events appears to be the following (though there are other possible explanations, and there is no real consensus in the literature about this):

The middle ear fills up with secretions that become progressively thickened. Synonyms are: glue ear, otitis media with effusion (OME) or secretory otitis media (SOM). This results initially in a conductive hearing loss; occasionally as much as 40 or 50 dB and in the younger children this may cause a delay in speech development. The eardrum, lying idle on top of this 'glue' becomes atrophic[3]; a disuse atrophy similar to that commonly seen in other tissues of the body. After a variable length of time the middle ear secretions begin to be absorbed, drawing the thinned eardrum down towards the promontory and middle ear structures. At this stage the drum is not adherent to the middle ear structures, and may bulge out or be drawn in with varying Eustachian tube function. Older children often complain of clicking and popping of the ear, but otherwise it is a silent development. The drum may become adherent to the promontory or as is most frequently seen, to the long process of the incus, and may be gradually drawn into the round window niche, facial recess, sinus tympani and attic region around the ossicles. It seems likely that an intercurrent inflammatory process is required for an adhesion to form, though we often encounter fibrous bands fixing the drum to the middle ear structures or drawing it into the attic, towards the mastoid air cells. At each stage there is a possibility of spontaneous recovery, though this is rare once the drum has become adherent to the ossicles or promontory. There are then one or more retraction pockets of variable size held to the middle ear structures by adhesions or the negative middle ear pressures associated with underlying Eustachian tube dysfunction. As long as the desquamation process of the epithelial layer of the eardrum is not interrupted, and the epithelium progresses normally towards the external meatus[4], there is little problem, and the situation may remain stable for years, though we have found that where the drum is fixed to the incus, there may be some degree of erosion of this ossicle in up to one third of the cases. Since the thin eardrum remains closely applied to the stapes, there is very little functional consequence even with complete interruption of the ossicular chain. We examined the correlation between hearing loss and stage of the atelectasis. Should the desquamation process be interrupted however, as frequently occurs even with the normal eardrum, following an intercurrent episode of acute otitis media (or possibly even otitis externa), epithelial debris will begin to accumulate in the retraction pocket, forming a cyst known as a cholesteatoma.
The exact incidence or progression from retraction pocket to cholesteatoma is unclear and though many of

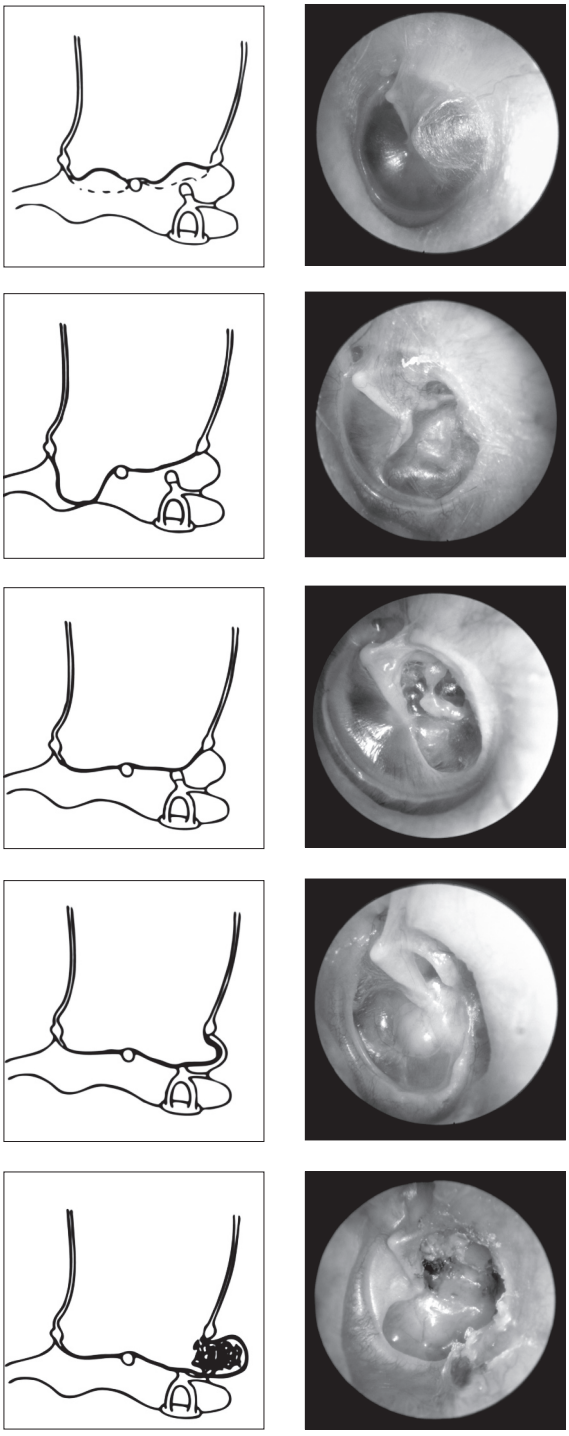
3 there is also a theory that the atrophy is caused by low middle ear pressure producing reduced circulation in the eardrum.
4 The skin of the normal eardrum and external meatus manifests a slow progression towards the outside, before desquamating, instead of the more usual direct desquamation of other skin areas that would rapidly result in a filling up of the external meatus with epithelial debris.

the retraction pockets in adults remain stable, and never progress to cholesteatoma, we have been unable to identify either in our population or in the international literature a reliable indicator of which patients may progress and which will remain with a stable retraction pocket. Any retraction pocket must therefore be considered to be potentially unstable, with possibility of silent progression to cholesteatoma.
Treatment may vary from early intervention with resection of the atrophic membrane to 'watchful waiting'. Some surgeons prefer to wait and see if the patient develops a cholesteatoma, though if they do there is almost invariably damage to the ossicles, possibly to the inner ear and facial nerve, and the treatment will entail extensive, extended mastoid surgery with complex reconstructive procedures the results of which are never as good as prevention, and entail considerable morbidity for the patients.
We have for this study examined a large group of patients with retraction pockets and atelectasis of the middle ear, to determine the efficacy and safety of earlier intervention, where possible, before cholesteatoma has had a chance to develop, or before it has grown beyond the middle ear and attic.
The surgical technique has gradually evolved, and a new classification was developed to indicate the degree of 'progression', but more importantly to determine the optimal procedure for each stage of the disease. As in so many studies, several unexpected discoveries were made; one of these about the rate of spontaneous healing of the eardrum has been described in detail in chapter 3. With the right instruments, and especially the right ear specula, most middle ear surgery can be carried out trans-meatally, without external incisions (not counting of course the tympanomeatal flap close to the annulus), thereby reducing the morbidity and discomfort of the patients, and especially in the younger patients, removing some of the fear inevitably associated with any surgical procedure, often compounded by anxiety about pack and suture removal.
Since pediatric patients, as they are waking up from surgery, occasionally removed the ear packs that otological tradition dictates must be inserted after every operation, without seemingly suffering any complications or consequences, we examined the consequences of not using postoperative earpacking in chapter 5.

For all the procedures reviewed, we analysed the effects of surgery on the function of the ear, to ensure there were no unexpected functional consequences or complications resulting from these modified procedures, that might weigh the balance on the side of a more conservative policy of watchful waiting.
We hypothesised that in patients where the retraction pocket had developed a cholesteatoma, would have poorer functional results than those where the intervention took place at an earlier stage, and these findings are set out in chapter 5.

It must be emphasised however that these studies do not set out to 'prove' anything, in so much as any biological study is able to provide a proof[5], for we can only attempt to show greater and lesser correlations and associations. The aim is thus merely to describe findings and interpret results. There are the inevitable problems associated with retrospective analysis, though they do avoid a possible observational bias that a prospective non-blinded study might be exposed to.
Cautious comparisons can be made between groups, between surgeons and between published studies, but individual differences are unavoidable, so comparisons may be meaningless at best and misleading at worst. Surgery remains a slow, evolutionary process, only rarely amenable to true revolutionary innovations. Paradoxically, though somewhat at odds with current statistical thinking, the final evidence is the patient sitting in front of us.

5 All scientific laws rest upon induction, which considered as a logical process, is open to doubt, and not capable of giving certainty. **Bertrand Russell** The Scientific Outlook. (Allen & Unwin, London 1931).



Chapter 1 **The Erasmus classification**

The Erasmus Atelectasis Classification: Proposal of a New Classification for Atelectasis of the Middle Ear in Children

Borgstein J, Gerritsma TV, Wieringa HM, Bruce IA

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Abstract:

- **Objectives:** Atelectasis presents a challenging, often progressive, problem in children. Because of the lack of a clinically practical classification, we introduce a new classification, which in our opinion is more useful in the pediatric age group. This alternative classification enables a more clinically relevant correlation between stage of disease and clinical sequelae and technical difficulty at surgery.
- **Study Design:** Observational study of patients seen and operated at the Sophia Children's Hospital in Rotterdam, The Netherlands between 1989 and 2005.
- **Methods:** Based on clinical appearance, each ear was placed into one of the five groups of the proposed classification and into one of the four stages of Sade's classification. Preoperative air and bone conduction thresholds and air-bone gaps (ABG) were calculated using the four-tone pure-tone (500, 1000, 2000, and 4000 Hz) averages for bone and air conduction.
- **Results:** Of the 248 ears in the study group, 72 were in stage I, with an ABG of 18.2 ± 12.3 dB. Twenty-two were in stage II, with an ABG of 12.9 ± 9.5 dB. In stage III, there were thirty-two ears, with an ABG of 11.6 ± 10.0 dB. Thirty-one ears were in stage IV, with an ABG of 16.1 ± 11.5 dB. Eighty-five ears were in stage V, with an ABG of 26.1 ± 13.3 dB. When grouped according to Sadé's classification, thirty-two ears could not be classified.
- **Conclusions:** We found the currently proposed classification more useful in that it follows the natural progression of the disease and is more practical in determining operative procedures at each stage.

Key Words: Atelectasis, classification, middle ear, cholesteatoma

Introduction

Atelectasis of the middle ear due to retraction of an atrophic eardrum is a common problem in pediatric otolaryngology and is associated with erosion of the long process of the incus and cholesteatoma[1,2]. Previous classifications are mostly based on the Sadé model for adult patients and do not accurately reflect the situation in children. Sadé classified retraction of the pars tensa into four stages[3] (Table I).

Table I. Classification of retraction pockets of the pars tensa proposed by Sadé

Stage	Description
I	Slight retraction of the tympanic membrane
II	Retraction of the tympanic membrane, touching the incus or the stapes
III	Tympanic membrane touching the promontory
IV	Tympanic membrane adherent to the promontory

In Sadé's classification, retraction towards the promontory seems to imply a worse situation than retraction towards incus or stapes. Stage I and II are called mild retractions and stage III and IV severe[1]. Another study has shown that stage I to III are reversible while stage IV is irreversible[4]. In practice, however, it is more difficult to lift the eardrum off the ossicular chain than off the promontory, as the ossicles should be manipulated as little as possible. Furthermore, incudopexy may lead to erosion of the incus and interruption of the ossicular chain[5,6], so that from the point of view of the patient, retraction to the promontory seems a milder stage than retraction onto the incus or stapes.

Sadé's classification is based on adult retractions without any residual OME[7], but it is also applied in studies with children, although this has to our knowledge never been validated. Cholesteatoma development is a logical progression of the process of atelectasis[1,2] that is encountered in some ears, we feel it should therefore be included in any classification.
We propose a new practical classification for atelectasis of the middle ear in pediatric patients (Table II).

Table II. Proposed new classification of retraction pockets of the pars tensa

Stage	Description
I	Tympanic membrane atrophic, but not adherent
II	Tympanic membrane adherent to the promontory
III	Tympanic membrane adherent to incus and/or stapes
IV	Adherent to ossicles with retraction pocket but without cholesteatoma
V	Retraction pocket with cholesteatoma and/or breakthrough

We feel this classification provides a more accurate indication of potential problems and management difficulty. Using this classification the earlier stages may be safely managed by less experienced surgeons or trainees, as opposed to stages III, IV and V that show a clear progression and require treatment by a more experienced otological surgeon.

The purpose of this study was to compare the proposed classification for atelectatic ears in pediatric patients with previous classifications.

Patients and Methods

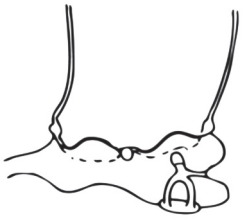
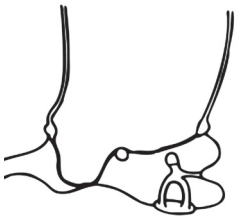
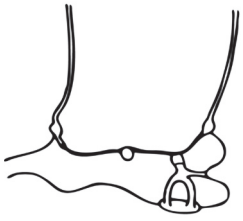
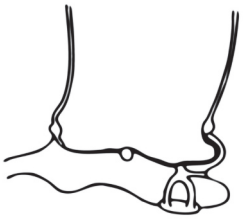
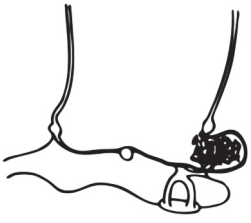
For this retrospective study we reviewed patients who had surgical intervention for atelectatic ears between 1989 and 2005 at the Erasmus MC Sophia Children's Hospital, Rotterdam, a tertiary referral centre for the south-western part of the Netherlands.
Patients were only included if they were no older than sixteen years at time of the first surgery. Of these patients the following data were collected: sex, age, operative appearance of the tympanic membrane, the type of surgery and the preoperative audiogram. Based on the appearance of the eardrum, each ear was subdivided into one of the four stages of Sadé[3]. To the classification of Sadé we added a 'non classifiable' group, for those ears we could not be readily allocated to one of the other stages. The ears were also subdivided according to the newly suggested classification.

The patients were treated according to the severity of the atelectasis. An atrophic tympanic membrane, which was not adherent (stage I of the new classification), was treated by ventilation tube insertion or simple excision of the pocket. When the tympanic membrane was adherent to the promontory (stage II), it was lifted off the promontory using a wax hook through a myringotomy incision, and where possible the atrophic part of the eardrum was excised. The resultant defect was either left to heal spontaneously or grafted. A ventilation tube was inserted. Adhesions to the incus or stapes (stage III) were removed via the middle ear, using a tympanomeatal flap to approach the adherent drum from the middle ear side and lifting it carefully off the ossicles, making every attempt to keep the atrophic drum intact. Once freed from the ossicles, the atrophic segment of the eardrum was excised and the eardrum was reconstructed with tragus perichondrium or temporal fascia. Where the incus was eroded, the gap was bridged by tragus cartilage, or an incus interposition was performed. Retraction pockets (stage IV) were also approached via a transmeatal approach with a tympanomeatal flap, and starting inferiorly, the retraction pocket was carefully eased out, and dissected off the ossicular chain and middle ear structures taking every precaution to avoid tearing the exceedingly thin epithelium. If the epithelium was unavoidably breached, a second look was always planned for approximately 12 months later. Cholesteatomas (stage V) were removed transmeatally where possible. Where the cholesteatoma had advanced too far into the attic or mastoid, a combined approach mastoidectomy was carried out via a retroauricular approach.
Preoperative air and bone conduction thresholds and air-bone gaps (ABG) were calculated according to the American Academy of Otolaryngology-Head and Neck Surgery guidelines, using the four-tone pure tone average (500, 1000, 2000 and 4000 Hz) for bone- and air conduction, if there were preoperative audiograms available.

Results

The study group consisted of 248 ears (181 patients; 84 male, 97 female) with retraction of the tympanic membrane. We found retraction of the pars flaccida in only 9 ears (3.6%). Ages ranged from 1 to 16 years, with a mean age of 8.8 ± 3.6 (standard deviation). A direct comparison of the two classification systems evaluated is given in tables III and IV.

Table III. Comparison between staging using the Sadé system and the proposed alternative

	Description	Proposed stage	Sadé stage
	Atrophic eardrum, not adherent	1	1 1 3
	Adherent to promontory	2	4
	Adherent to incus and/or stapes	3	2
	Deep retraction pocket towards attic	4	2
	Cholesteatoma in retraction pocket	5	NC

(NC = non classifiable)

Table IV. Further detailed comparison in our patient group between staging using the Sadé system and the proposed alternative classification.

		Stage of Sadé's classification					
		1	2	3	4	nc	Total
Stage of proposed classification	1	35	5	32			72
	2			22			22
	3		31		7		38
	4		6	11	7	7	31
	5					85	85
	Total	35	42	43	36	92	248

(NC = non classifiable)

Using the newly proposed classification:

- **Type I.** An atrophic but not adherent tympanic membrane was found in 72 (29.0%) of the 248 ears. In 50 ears there was a preoperative audiogram available. The mean preoperative ABG in this group was 18.2 ± 12.3 dB (range 0.0 to 43.8 dB).
- **Type II.** In 22 (8.9%) ears the tympanic membrane was adherent only to the promontory. There was a preoperative audiogram available in 17 ears. The mean ABG was 12.9 9.5 dB (range 0.0 to 28.8 dB)
- **Type III.** The tympanic membrane was adherent to the incus and/or stapes in 38 ears (15.3%). A preoperative audiogram was available in 31 ears. The mean ABG was 11.6 ± 10.0 dB (range 0.0 to 36.3 dB).
- **Type IV.** A retraction pocket without cholesteatoma was found in 31 ears (12.5%). There was a preoperative audiogram available in 29 cases. The mean ABG was 16.1 ± 11.5 dB (range 0.0 to 48.8 dB).
- **Type V.** In 85 ears (34.3%) a cholesteatoma was found. A preoperative ABG was available in 72 ears. The mean ABG was 26.1 ± 13.3 dB (range 0.0 to 57.5 dB).

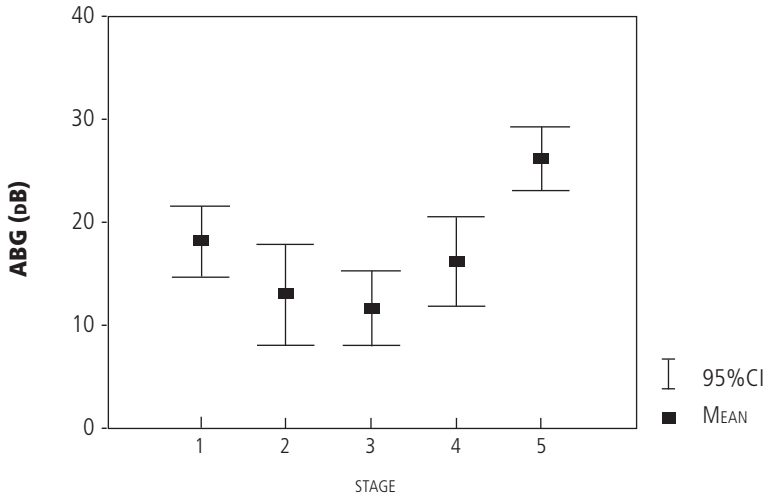
The mean preoperative air and bone conduction thresholds for each group are shown in table V.

Table V.

stage	Bone conduction	Air conduction
I	6.2 ± 5.9	25.7 ± 12.2
II	8.1 ± 5.0	20.8 ± 10.6
III	9.4 ± 7.1	21.5 ± 14.1
IV	9.2 ± 6.3	25.3 ± 13.2
V	10.2 ± 6.9	36.3 ± 15.5

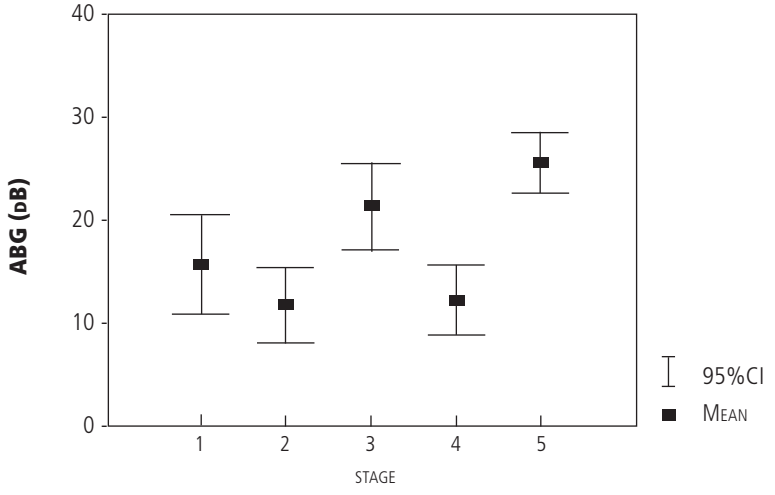
The mean preoperative air-bone gaps together with the 95% confidence interval (CI) for each group are shown in figure 1 and 2.

Figure 1. Mean preoperative ABG and 95% CI for each stage when arranged according to the proposed classification.



Group V is statistically significantly different from the other stages.

Figure 2. Mean preoperative ABG and 95% CI for each stage when arranged according to the Sadé classification.



Using the Sadé classification:

- **Sadé 1.** A slight retraction of the tympanic membrane was found in 35 ears (14.1%). Preoperative audiograms were available in 24 ears. The mean preoperative ABG was 15.8 ± 11.7 dB (range 0.0 to 43.8 dB).

- **Sadé 2.** The tympanic membrane was touching the incus or stapes in 42 ears (16.9%). There was a preoperative audiogram available in 34 ears. The mean preoperative ABG was 11.8 ± 10.4 dB (range 0.0 to 36.3 dB).
- **Sadé 3.** The tympanic membrane was retracted towards the promontory in 43 ears (17.3%). There was a preoperative audiogram available in 32 ears The mean preoperative ABG was 21.3 ± 12.0 dB (range 0.0 to 38.8 dB).
- **Sadé 4.** The tympanic membrane was adherent to the promontory in 36 ears (14.5%). Preoperative audiograms were available in 30 ears. The mean preoperative ABG was 12.1 ± 9.0 dB (range 0.0 to 28.8 dB).
- **Not classifiable.** There were 92 ears (37.1%) we could not classify into one of the stages of Sadé. This group included ears in which keratin was found to have collected in the retraction pocket (cholesteatoma) and those ears with a retraction pocket extending into the attic, antrum or sinus tympani. Preoperative audiograms were available in 79 ears and the mean preoperative ABG in this group was 25.5 ± 13.4 dB (range 0.0 to 57.5 dB).

Interestingly, attic (pars flaccida) retractions were found in our series in only 4% of ears, with the vast majority of pediatric retraction pockets originating in the pars tensa, as has also been described by Bluestone[5]. This is contrary to the findings described for adults, where pars flaccida retractions are most commonly found[1,3].

In 8 of our patients we found that there was a documented retraction in the past, which was not treated, and appeared to have progressed to a cholesteatoma. The time between the documentation of the retraction and the diagnosis of a cholesteatoma varied from 4 months to 42 months.

None of our patients suffered postoperative sensorineural hearing loss. There were no other complications found and no damage to the chorda tympani.

Discussion

Retraction of the drum and atelectasis of the middle ear has an uncertain aetiology and a high recurrence rate irrespective of the surgical technique used[6,8-10]. We have proposed a practical classification in children that indicates the severity of the condition from the perspective of long-term functional outcome and possible otological sequelae. In addition, this classification facilitates clear surgical planning, with the degree of difficulty of the operation again correlated to the stage of disease. Stage I and II are more amenable to simple procedures as compared to the higher stages which require progressively more complex and lengthy operations.

Recently, Pothier[11] evaluated the reliability of Sadé's classification in a study where otolaryngologists were asked to classify retraction pockets. He concluded that the value of this classification system may be limited. Overall inter-rater reliability was very low, with very high levels of variability. We have shown that it can prove to be difficult in children to classify some cases according to the stages of Sadé. We do not feel Sadé's classification is helpful in clinical decision-making. It is furthermore not always easy to differentiate between grades 3 and 4 clinically[12]. Other classifications found in literature are either modifications of the classification made by Sadé[13], or refer to retractions of the pars flaccida[14], which in our series occurs only very rarely in children.

The preoperative audiograms demonstrated, perhaps somewhat paradoxically, a better hearing in stages III and IV of our proposed classification. This difference may be explained by the poor acoustic characteristics

of the flaccid membrane in stage I, and the 'fixed' membrane in stage II, as compared to the situation in the higher stages where the atrophic drum is directly fixed to the incus or stapes and provides a good 'columellar effect' air conduction. It also emphasizes the fact that audiometry is not a reliable parameter for determining severity of disease in atelectasis, except where associated with cholesteatoma. Bone conduction is more difficult to measure in the younger children, so in some of these cases the bone conduction thresholds may be higher than normal.

While stage I may still be reversible, there is no evidence of reversibility once the atrophic drum has become adherent to the promontory or middle ear structures[3,15]. Sadé found that the milder stages (Sadé 1, 2 and 3) evidenced an amelioration in 45% of cases, but none of the 'adhesive stages' reversed themselves spontaneously[3], and that providing a retraction does not adhere to the deeper ear structures of the middle ear there is a chance that it may improve, either spontaneously or with the help of a ventilating tube[15].
We observed in the higher stages of our proposed classification, an almost constant finding of fibrous bands fixing the drum to parts of the promontory and ossicular chain, and pulling it into the sinus tympani or attic. In 8 of our patients we were able to find documented evidence suggestive of a clear progression from stage III to V; though the progression varied from as short as 4 months to as long as 42 months, implying that if a policy of watchful waiting is employed, the patients may need be reviewed every 3 months for many years.

Progression to cholesteatoma takes two possible routes[16]: The retraction pocket may accumulate epithelial debris due to altered desquamation patterns and forms an expansile lesion. Alternatively, the squamous debris becomes infected, leading to a breakdown of the atrophic epithelium in the depth of the pocket, and proliferation of mucosa, forming the well-known signal polyp. Once the epithelium has been breached in such cases the edges may grow inwards along mucosal planes and quickly extends to the attic, additus and mastoid.
We propose that the safest management strategy in atelectatic ears is excision of the atrophic section of the drum with either spontaneous healing (in our experience this occurs in the course of several weeks even with large resections, for the drum behaves as a traumatic perforation) or grafting. We generally use a simple graft of either tragus perichondrium, which is easily accessible from the transmeatal approach, or temporal fascia. The transmeatal approach, though technically more difficult, has the advantage of low patient morbidity. We found it helpful to use a ventilation tube while the graft was healing to prevent repeat retraction, but once the graft has healed, the ventilation tube may be removed, unless required for the treatment of intercurrent otitis media with effusion, to which this group of patients remained susceptible.
If a recurrent retraction is found on follow-up we treat the patient according to the same protocol, inserting ventilation tubes or freeing the retraction pockets as necessary. The final aim being to obtain a normal functional eardrum and prevent progression towards cholesteatoma.

Conclusion

We consider the currently proposed classification of middle ear atelectasis to be more useful than previously published classifications. We believe it follows the natural progression of disease more closely and provides a more practical guide to treatment planning.

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Postscript

The Sadé classification does not include cholesteatoma. We feel however that cholesteatoma may be a consequence of the disease, and not always clinically evident before surgery. Therefore we consider that these cases should not be excluded. Some of the patients included here would not have entered into the Sadé group and were therefore not classifiable in his classification.

It is sometimes difficult to distinguish with certainty before surgery that the drum is adherent to the incus or the promontory, so the final classification can only be made after surgery.

The order of the classification has been altered from that of Sadé in such a way that it follows more naturally the sequence of surgical difficulty: type I requires little more than a ventilation tube, with or without excision of the atelectatic part of the drum, type II may be approached via a myringotomy and does not require a tympanomeatal flap, type III, IV and V are progressively more difficult and as a consequence require greater expertise and experience in their management.

In eight of the patients from group V we found earlier documented evidence that a retraction pocket had been recognised. Although this does not indicate how long the atelectasis had already been present, it provides an indication that the progression or development of a cholesteatoma in the retraction seems to be variable from as short as four months to well over forty months

Though large differences have been recorded for recurrence rate of atelectasis, no surgical technique has succeeded in eliminating recurrence entirely. Irrespective of technique there is a possibility of recurrence and all patients require long follow up.

Audiometry is not a satisfactory measure for the extent of the atelectasis. The persistence of glue in the ear will produce a marked conductive loss, and an entirely eroded ossicle may, due to the columella effect, show virtually normal hearing.

Chapter 2 **Erosion of the incus**

Erosion of the incus in pediatric posterior tympanic membrane retraction pockets without cholesteatoma

Borgstein J, Gerritsma TV, Bruce IA

Int J Ped ORL 2008;72:1419-23

Abstract

- **Objective:** To analyse a group of pediatric patients operated for atelectasis with incudopexy, to determine the incidence of damage to the incus. Associated hearing loss was determined and a comparison was made between the patients with and without incus erosion.
- **Methods:** Observational study of patients seen and operated at the Sophia Children's Hospital in Rotterdam between 2002 and 2005. All patients who had undergone surgery for retraction pockets with pre-operative evidence of fixation of the tympanic membrane to the incudo-stapedial complex were identified for the study. Patients with evidence of cholesteatoma (epithelial debris within the pockets) were excluded from the study. Pre- and postoperative air and bone conduction thresholds and air-bone gaps were calculated using the four-tone pure-tone average for bone- and air conduction.
- **Results:** In this study of 46 ears with posterior retractions contacting the incus, 30% were found to have some degree of damage of the incus associated with incudopexy. In the group with incudopexy without erosion the preoperative and postoperative air-bone gaps were 10.0 ± 9.8 dB and 5.9 ± 8.3 dB respectively. The pre-and postoperative air-bone gaps in the incus erosion group were 20.1 ± 13.3 dB and 13.8 ± 9.1 dB respectively. The audiological differences between the erosion group and the non-erosion group and between pre- and post-operative air-bone gaps were statistically significant.
- **Conclusion:** In this group of patients we found, per-operatively, a high incidence of erosion of the incus associated with posterior retraction pockets adherent to the incus. The audiometric data confirms that early surgery does not adversely affect the postoperative hearing where there is no erosion of the incus, and likewise the improvement in air-bone gap post-operatively was statistically significant in the erosion group. On the basis of these findings we conclude that watchful waiting may not be the best strategy in these patients.

Key words: incus erosion, posterior retraction pockets, atelectasis

Introduction

Erosion of the incus as a complication of retraction pockets and atelectasis of the postero-superior quadrant of the eardrum is a frequently observed but rarely discussed problem[1-5]. The incidence in paediatric patients has not been clearly examined in the literature. In many centres there is a policy of watchful waiting in such cases were the retraction pocket is suspected to be adherent to the long process of the incus. Subsequent incus damage is then usually attributed to erosion resulting from cholesteatoma.

Retraction pockets of the posterior and postero-superior section of the eardrum are common findings in pediatric otology. Some ears recover spontaneously after ventilation tube insertion, but once the flaccid drum has become fixed to the incudo-stapedial complex it is often associated with erosion or aseptic necrosis (osteitis) of the long process of the incus even where there is no sign of cholesteatoma[3,4].

The purpose of this study was to examine the incidence of erosion of the incus in association with pars tensa retraction and fixation to the incus, in a pediatric study group. It is our departmental management policy to intervene early in pars tensa retractions and the possibility of this strategy having a negative effect on hearing outcome was determined.

Methods

An observational study was undertaken of patients seen and operated upon between 2002 and 2005 at the Sophia Children's Hospital in Rotterdam, a tertiary level referral hospital for the south western part of The Netherlands. It forms part of a larger atelectasis study currently being conducted at our hospital.

We have reviewed the case notes of all children operated upon for atelectasis with clinical suspicion of tympanic membrane fixation to the incudo-stapedial complex. None of the patients had undergone any previous middle ear surgery, apart from ventilation tube insertion. Patients with evidence of cholesteatoma at operation were not included in this study, so that we could examine the incidence of damage to the incus purely associated with an atrophic tympanic membrane. For similar reasons, re-operations in cases of recurrent atelectasis were not included. All patients were under 16 years of age at time of surgery. We have restricted our observations to patients under 16, as atelectasis in adults generally has a far slower progression. Patients were only included in this study if the preoperative suspicion of tympanic membrane fixation to the incudo-stapedial complex could be confirmed at surgery.

All patients were operated by the same otologist, transmeatally, using a posterior tympanomeatal flap. The retraction pocket was dissected free and off the ossicles and the ossicular chain was carefully inspected. The retraction pocket was then excised and the resulting drum defect grafted with tragal perichondrium. Evidence of erosion was documented at the time of surgery. If the thin adherent epithelium was torn during the procedure it is our practice to carry out a 2nd look tympanotomy after 10 months. A long-term ventilation tube was inserted in all the operated ears and left in place for approximately 1 year. Where there was complete interruption of the ossicular chain, this was reconstructed using tragal cartilage to bridge the bony gap between residual incus and stapes.

The incidence of incus damage was calculated and all ears were subdivided into 'no erosion' and 'total or partial erosion' groups for further analysis. Pre-operative and post-operative (6 months) air and bone conduction thresholds were determined and air-bone gaps (ABGs) were calculated using the four-tone pure-tone average (500, 1000, 2000 and 4000 Hz) for bone- and air conduction.

For the statistical comparison between the preoperative and postoperative findings the paired-samples t-test test was used. For the statistical comparison between the non-erosion and the erosion group, the independent-samples t-test was used.

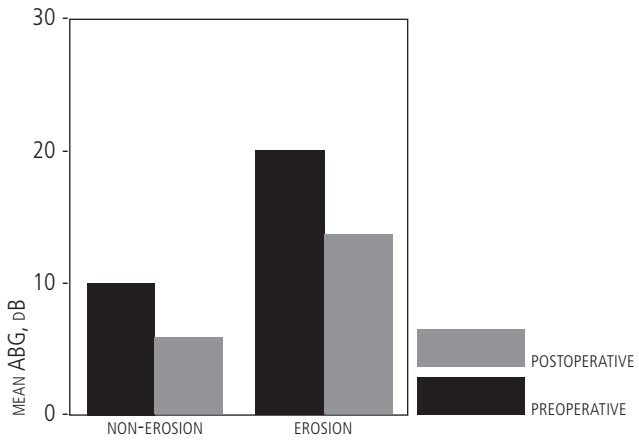
Results

Two patients were suspected clinically of incudopexy that was not confirmed at surgery and were thus excluded from the analysis. The remaining study group consisted of 46 ears (42 patients; 16 male and 26 female). Ages ranged from 3 to 15, with a mean age of 10.4 ± 3.4 (standard deviation). Preoperative audiograms were available in 43 ears and postoperative audiograms were available in 45 ears. The preoperative ABG varied from 0.0 dB to 48.8 dB, with a mean of 13.3 ± 11.9 dB. The postoperative ABG ranged from 0.0 to 33.8 dB, with a mean of 8.3 ± 9.2 dB.

Non-erosion group: In spite of fixation of the retraction pocket to the incus being confirmed at surgery, there was no microscopic evidence of damage or resorbtion of the incus in 32 ears (69.9%). The ages in the non-erosion group varied from 3 to 15 years, with a mean of 9.8 ± 3.5.

In this study group the preoperative air-bone gap varied from 0.0 to 32.5 dB, with a mean of 10.0 dB ± 9.8 dB. The postoperative ABG varied from 0.0 to 33.8 dB, with a mean of 5.9 ± 8.3 dB. The improvement seen between the preoperative and postoperative ABG was statistically significant ($p < 0.05$) (Figure 1).
($p = 0.045$)

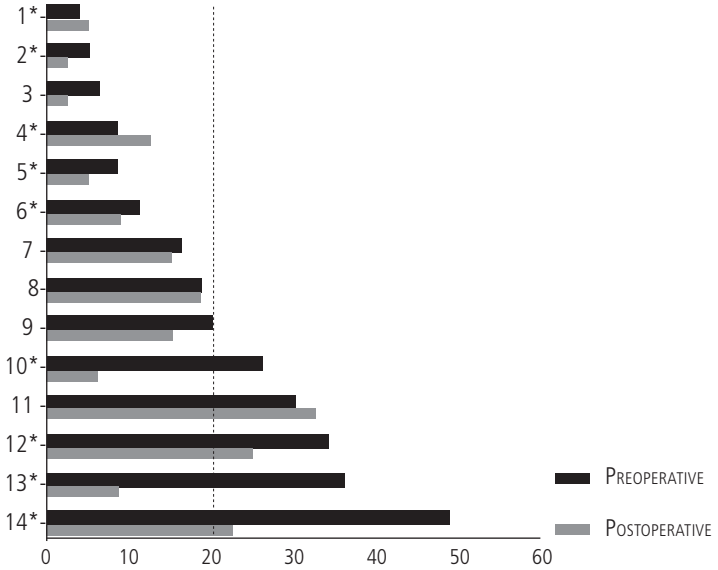
Figure 1. Mean air-bone gap pre- and postoperatively for non-erosion group and erosion group.



Erosion group: At intra-operative microscopic inspection we found evidence of erosion of the long process of the incus in 14 ears (30.4%) of 12 patients (5 male, 7 female). The nature of any such erosion varied from absent lenticular process or substitution of the lenticular process by a fibrous band, to complete absence of the long process. The age range in the erosion group ranged from 5 to 15 years, with a mean age of 11.8 ± 2.6 years. The preoperative air-bone gap in the erosion group varied from 3.8 dB to a maximum conductive loss of 48.8 dB, with a mean of 20.1 ± 13.3 dB. The postoperative air-bone gap ranged from 2.5 to 32.5 dB, with a mean of 13.8 ± 9.1 dB. The difference between the preoperative and postoperative ABG was statistically significant ($p < 0.05$) ($p = 0.029$). The preoperative air-bone gap together with the postoperative air bone gap for the erosion group is shown in Figure 2. In 8 ears (57.1%) the preoperative ABG remained under 20 dB. Postoperatively 11 ears (78.6%) had an ABG under 20 dB.

The mean preoperative and postoperative ABG in the erosion and non-erosion group are shown in figure 2.

Figure 2. Air-bone gaps in the 'erosion group'. Patients who underwent ossicular chain reconstruction are marked with an asterisk.



The difference between the preoperative ABG in the erosion group and the preoperative ABG in the non-erosion group was statistically significant ($p < 0.05$) ($p = 0.007$). There was also a significant difference between the post-operative air-bone gaps of both groups ($p < 0.05$) ($p = 0.006$). The mean preoperative and postoperative bone and air conduction thresholds in the erosion group and the non-erosion group are shown in Table 1.

Table 1. Air and bone conduction four frequency thresholds (mean ± standard deviation)

	Non-erosion group		Erosion group	
	Preoperative	Postoperative	Preoperative	Postoperative
Bone conduction	9.2 ± 6.9	11.5 ± 7.6	11.2 ± 7.3	11.7 ± 6.3
Air conduction	20.8 ± 13.9	15.8 ± 10.7 * (P = 0.016)	31.3 ± 14.6	24.7 ± 12.8 * (P = 0.033)

* = statistically significant difference between preoperative and postoperative threshold

In both groups the postoperative air conduction thresholds were significantly lower than preoperatively ($p<0.05$). The bone conduction threshold did not change significantly after surgery. There was a statistical significant difference in the pre- and postoperative air conduction thresholds between the erosion and non-erosion groups. We observed in our patients no incidence of damage to the other ossicles and no evidence of erosion of the incus when the tympanum was not adherent to the ossicular chain. There was no incidence of sensorineural hearing loss complicating surgery.

Discussion

Cholesteatoma is frequently associated with damage to the ossicles, especially the long process of the incus. This study suggests that a posterior retraction pocket adherent to the long process of the incus, without cholesteatoma, may also lead to erosion of the incus in approximately a third of cases. There are generally few symptoms associated with this form of atelectasis, though some children will indicate occasional discomfort and pain in the ear, and some of the older children may notice mild hearing loss. The problem is otherwise insidious, and hearing tends to remain surprisingly close to normal limits. Surprisingly good thresholds, even in the presence of complete ossicular discontinuity, may be explained by the stapedopexy (columellar) effect.

Erosion of the incus ranged from resorbtion of the lenticular process, via substitution of the end of the long process by a fibrous band, to complete separation of the incus and stapes. Surgery involved exceedingly careful dissection to free the atrophic section of the drum from the ossicles, as any epithelium left behind may develop into a cholesteatoma, and excessive manipulation of the ossicles themselves may lead to sensorineural hearing loss, which was not encountered in this group. The retraction pocket was then excised and the resultant defect closed with tragal perichondrium. No cartilage was used to strengthen the graft. The audiometric findings in the 14 ears with erosion of the incus indicate that surgical intervention did not have adverse effect on the hearing. Only where there was a complete interruption of the ossicular chain, was an ossicular reconstruction carried out with tragal cartilage to bridge the discontinuity. We generally reserve Titanium ossicular prostheses for revision surgery in patients with a persistent air-bone gap. In our unit patients are normally followed up with six monthly microscopy in clinic and audiometry until the tympanic membrane is considered to be stable. We saw no evidence of late progression of hearing loss in any of these patients, except a variable conductive loss in those with recurrence of their atelectasis and those with recurrent otitis media.

That the atrophic eardrum retracting onto the ossicular chain is associated with a considerable incidence of erosion to the incus has been previously documented in adults. Several explanations for the pathogenesis of incus damage have been suggested. These include erosion from an osteitis similar to that seen in a cholesteatoma, interruption of blood supply due to pressure of the thin tympanic membrane on the small vessels running along the length of the long process, or deviation of the blood supply towards the tympanic membrane and away from the distal part of the incus[6]. Erosion of the incus as a rule does not occur before incudopexy, and the lenticular process generally seems to be the first part of the incus to become resorbed, leading to a medialisation of the incus and consequently the malleus. In all our patients the head of the stapes could be clearly defined, and surprisingly we saw no evidence of damage to the stapes itself even in longstanding stapedopexy. Upon initial analysis all patients found to have stapedial damage had evidence of cholesteatoma and were therefore excluded from the final study group.

Once the atrophic posterior segment of the drum becomes adherent to the incudo-stapedial complex spontaneous recovery is rare[7]. While in adults this situation may remain stable for many years, it is our experience that a high proportion of pediatric patients progress rapidly towards damage to the incus and cholesteatoma formation. Our policy of early intervention in pars tensa retractions is aimed at preventing damage to the ossicular chain and possible progression to a cholesteatoma.

In summary, in this group of paediatric patients we found, per-operatively, a high incidence of erosion of the incus associated with posterior retraction pockets that were adherent to the incus. On the basis of these findings we conclude that watchful waiting may not be the best strategy in these patients. The audiometric data confirms furthermore that careful early surgery does not adversely affect the postoperative hearing where there is no erosion of the incus, and likewise the improvement in air-bone gap post-operatively was

statistically significant in the erosion group.
Based on our findings we conclude that surgical treatment of posterior retraction pockets in children should be undertaken early in the disease process, in order that the risk of subsequent incus erosion may be minimized.

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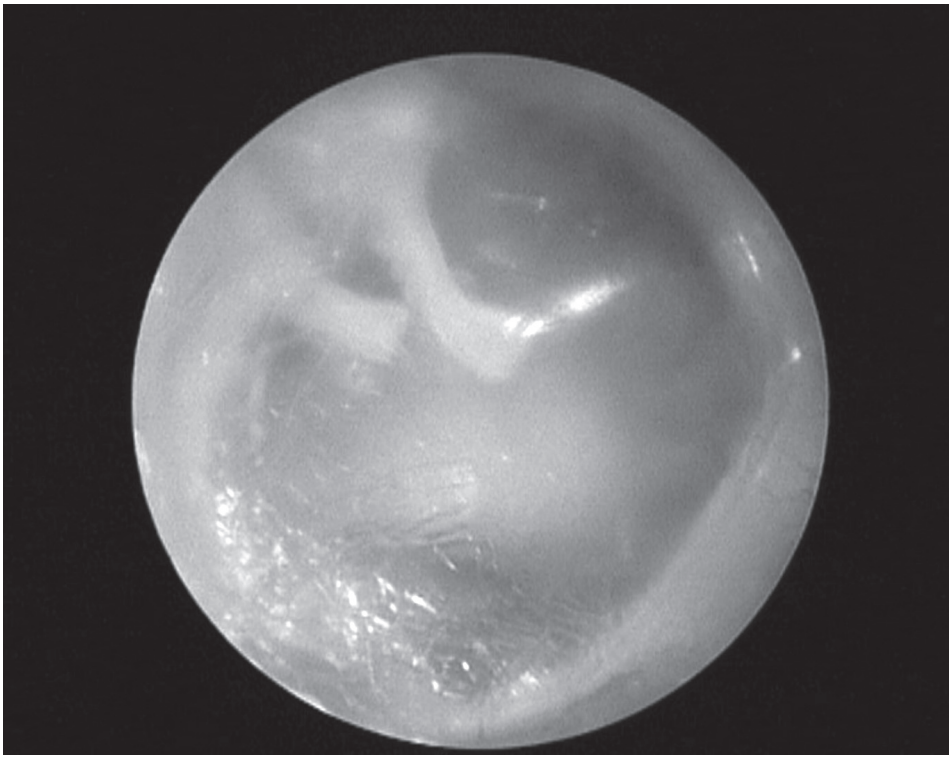
Postscript

This is an observational study of those patients operated for type III and IV atelectasis. During the time of the study the patients' indication for surgery was atelectasis. As commented in the last chapter there is not a good correlation between the extent of the atelectasis and the hearing.
Diagnosis of fixation of the eardrum to the incus is fairly reliably made, by the way the rest of the eardrum is draped over the ossicles; though we have not yet completed the prospective correlation studies between clinical and surgical observations.
Cartilage grafts were used early in these studies, but gradually abandoned after the evidence of chapter 4 began to emerge. Recurrence rates for atelectasis are dependent on many factors (including persistent otitis media with effusion) that have not yet been fully analysed. Spontaneous healing is covered in the next chapter, but since this leads to essentially a normal eardrum it was considered preferable to other grafting methods. Also incomplete excision of the atrophic drum segment may result in rapid recurrence as soon as the ventilation tube has been removed.
While this is not a longitudinal study, we have on occasion found evidence of cholesteatoma development while the patient was on the waiting list. These cases will need further analysis, but it remains difficult to be hundred percent sure about cholesteatoma in the deep retraction pockets without surgery. Erosion of the incus has been documented in the next chapter, and like cholesteatoma seems better prevented than treated. Possibly endoscopy may offer an option of direct observation, even in the deep retraction pockets, but this kind of endoscopy is on the whole not well tolerated by the younger children, and the follow-up would need to be as frequent as every few months.



final result of spontaneous healing on discharge of patient

Chapter 3 **Spontaneous healing of the Tympanic membrane**

The extraordinary healing properties of the pediatric tympanic membrane

a study of atelectasis in the pediatric ear

Borgstein J, Stoop E, Halim A, Feenstra L

Int J Ped ORL 2008;72:1789-93

Summary

- Objectives: Traumatic perforations of the eardrum are generally treated conservatively as they tend to heal spontaneously. Retraction pockets of the eardrum, leading to atelectasis of the middle ear and often ultimately though unpredictably, to cholesteatoma formation, are treated in a variety of ways including complex grafting procedures. On the premise that a surgically resected retraction pocket is in essence a traumatic perforation, we examined the results of spontaneous healing of the resected retraction pocket.
- Methods: retrospective case note study
- Patients: a group of 86 ears in 62 patients who had undergone simple excision of the atrophic segment of the eardrum and who had no grafting procedure of the resultant defect, were followed at 6 days, 6-7 weeks and then every 6 months to determine the incidence of spontaneous healing of the eardrum. Audiograms were taken preoperatively, at 7 weeks and between 7 to 15 months post-operative.
- Results: 94.2% of the eardrums (81 out of 86 ears) healed spontaneously without any form of grafting within 7 weeks. Air bone gap showed improvement in 53 patients. Only one of the 4 ears that failed to achieve closure had post-operative ear discharge. There were no other complications. In 17 ears (19.8%) there was a recurrence of the atelectasis.
- Conclusion: Excision of retraction pockets in pediatric ear atelectasis, in principle does not require grafting, as the great majority will heal spontaneously. The spontaneous healing in this study is comparable to reported studies of spontaneous healing of traumatic perforations.
  Irrespective of the size of the atrophic part of the membrane, recurrence rates for the atelectasis after simple excision is similar to that described in other studies. Retraction pockets may be excised and allowed to heal without risk to the hearing.

Introduction

Retraction pockets of pediatric eardrums remain a controversial subject, with treatment varying between conservative management (unless a cholesteatoma develops)[1-3], insertion of ventilation tube, and excision[4-6]. There are some reports of spontaneous healing of resected retraction pockets[4], but in most studies, careful grafting of the resulting defect with a wide range of materials are performed[7]. Temporalis fascia, conchal and tragal perichondrium and both conchal and tragal cartilage[8-12] have all been described. Blaney[4] described a simple excision of pediatric retraction pockets with a healing rate of 87%. In 1992, Sharp[6] similarly described simple excision of retraction pockets though his reported rate of healing was only 65%, for a mixed group of patients.

On the other hand, there seems to be a consensus amongst most otologists that traumatic perforations of the ear drum should not be treated surgically unless they fail to heal spontaneously within a given time[13]. Kristensen has made an elegant and exhaustive analysis of more than 500 papers on the management of traumatic perforations published over the past century[14]. The closure rate is reported to vary between 0 and 100 %, though the lower incidences were often associated with heat trauma. For the remaining traumatic perforations he calculated a spontaneous healing percentage of 78.7%. Similar rates have been described elsewhere.

On the premise that excision of atrophic retraction pockets is tantamount to producing a traumatic perforation under surgical conditions, it has been our policy over the past years to leave the defect to heal spontaneously. In this study we examine retrospectively the results of all these procedures, to determine closure rate and hearing thresholds. Since we do not pack the operated ears it was possible to carefully observe the healing process during the first weeks.

Methods

The case files of all patients who had undergone resection of atrophic retraction pockets for atelectasis of the middle ear between 2004 and 2007 were examined to determine closure rate and hearing thresholds. The first author or a senior resident carried out all surgery, and all operations were carried out trans-meatally. Where the eardrum was not fixed to the promontory or middle ear structures a simple excision using micro-scissors could be carried out, while a fixed eardrum requires careful separation of the eardrum from underlying structures via a tympanomeatal flap. Once the eardrum is entirely free from underlying structures it is completely resected, leaving a free margin of non-atrophic drum. A ventilation tube ('T'-tube) was placed through the perforation resulting from the excision, to ensure adequate middle ear ventilation after healing; the drum heals around the ventilation tube. No ear packing of any sort was used[15]. The ventilation tube was generally removed after one year if it had not extruded spontaneously before then, though it may be left in longer; it is our policy to remove all T-tubes after two years to prevent tube perforations and granulations. After removal of the T-tube, the ear is treated as any other ear, and should there be evidence of recurrent otitis media with effusion, a new ventilation tube may be inserted. The perforations resulting from resection of the atrophic segment were divided into small (one quadrant or less) medium (two quadrants) and large (subtotal), to determine if size of perforation was important for healing. The patients were followed up at 6 monthly intervals until the ears are considered to be stable. Audiograms were done one day preoperatively, and at 6 weeks and 7 - 15 months post-operative. The 4-frequency (500, 1000, 2000, 4000 Hz) average of air conduction and bone conduction thresholds as well as the air bone gap was calculated. In order to investigate the general post-operative effect on bone conduction in all

patients, the median of the best available post-operative bone conduction threshold was calculated.
All patients were classified and treated according to the Erasmus classification for pediatric atelectasis (table 1), as has been described in some detail elsewhere[16].

Table I: Erasmus Classification of Pediatric Atelectasis of the Middle Ear

Stage	Description
I	Tympanic membrane atrophic but not adherent
II	Tympanic membrane adherent to the promontory
III	Tympanic membrane adherent to incus or stapes
IV	Adherent to ossicles with retraction pocket but no cholesteatoma
V	Retraction pocket with cholesteatoma or breakthrough

Recurrence of the atelectasis was documented, though re-operations were not included in this analysis. Small pockets of type I and II were managed by simple myringotomy and excision of the pocket. All type III, IV and V retraction pockets were operated via a transmeatal approach and tympanomeatal flap, with cautious separation of the thin adherent membrane off the middle ear structures, where necessary teasing it carefully out of the hypotympanum, round window niche, facial recess and attic, to attain a complete eversion of the pocket before excising it.
The 6 weeks and 7-15 months post-operative bone conduction thresholds and ABG were compared with that of the preoperative audiogram, using the paired nonparametric test (Wilcoxon Signed Rank Test).
The patients were then arbitrarily sub-divided into 2 groups: <12 years and ≥ 12 years. Twelve years being considered as an age when Eustachian tube dysfunction has improved in most patients. We compared the success rate and the incidence of recurrent atelectasis in both age groups using the Chi-Square test. All statistical analysis was performed in SPSS 16.0 and we considered a p value of ≤ 0.05 as significant.

Results

Patients ranged from 4 to18 years of age, with a median of 9.0 years, and a male to female ratio of 1:1.2 (28 boys and 34 girls). Of the 86 ears (62 patients) operated, 94.2% healed within 6 weeks, the drum initially closing neatly around the ventilation tube that was inserted to prevent recurrence of otitis media with effusion (OME) in this pediatric group of patients. The size of the resultant defect after atelectasis resection varied from small to subtotal and is shown in table 2.

Table 2: Number of patients per size of the defect (after atelectasis resection)

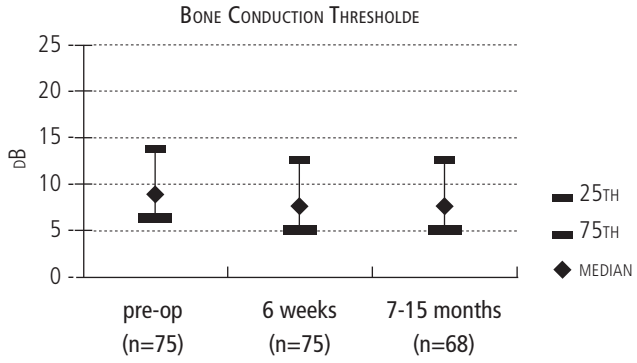
Defectsize	Closure	Failure
Small ($\leq$1 quadrant)	20	0
Medium (2 quadrants)	31	3
Large (subtotal)	30	2
Total	81	5

Postoperative discharge from the operated ear was seen in 8.1% (7 out of 86) of the ears at one-week follow-up. There was no problem with early extrusion of the T-tube, though one tube was inadvertently removed while removing a blood coagulate.

Two patients were too young for preoperative audiometry, but had postoperative audiograms done, while 11 patients missed postoperative audiograms at either 6 weeks or 7-15 months. Among the 86 operated ears, the 6 weeks and 7-15 months post-operative hearing thresholds were available in respectively 75 and 68 ears. The median of the overall post-operative bone conduction thresholds was 6.88.

The 6 weeks and 7-15 months post-operative bone conduction thresholds were each compared with the preoperative threshold. The p values were 0.27 and 0.92 (graph 1).

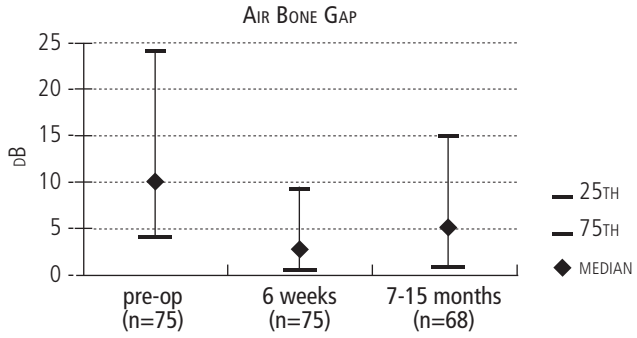
Graph 1. Medians of preoperative, 6 weeks and 7-15 months post-operative bone conduction thresholds with their 25th and 75th percentiles.



There was no incidence of facial nerve problems attributable to surgery, though one patient presented with a preoperative facial paralysis. He had a grade V atelectasis with a small cholesteatoma in the oval window niche, and his facial paralysis recovered completely within 2 weeks of surgery.

There was a significant improvement in the 6 weeks and 7-15 months post-operative ABG in comparison with that of preoperative, since all p values were < 0.01 (graph 2).

Graph 2. Medians of preoperative, 6 weeks and 7-15 months post-operative Air Bone Gap with their 25th and 75th percentiles.



When the two age groups were compared with each other, the younger group (<12 years, 66 ears) had a success rate of 95.3%, while in the older group (≥ 12 years, 22 ears) healing was successful in 90.9% of the cases, with a p value of 0.45. Furthermore, the incidence of recurrent atelectasis was found to be 20.3% (13 out of 66) in the younger group and 18.2% (4 out of 22) in the older group, with a p value of 0.83. After removal or extrusion of the ventilation tube, recurrence of atelectasis subsequently developed in 19.8% (n=17) of the ears. Three of these 17 patients (17.4%) developed a further recurrence of the atelectasis. Of the 5 patients whose eardrum did not heal completely 2 had improved hearing thresholds and the remaining 3 had increased ABG compatible with the size of the perforation. None of the patients had a change in the bone conduction threshold after surgery.

Discussion

The incidence of spontaneous healing in resected retraction pockets of atelectasis in pediatric patients in this study is 94.2%, somewhat higher than spontaneous healing of traumatic perforations, as reported in the literature[14]. It should however be considered that these perforations were created under aseptic surgical conditions and may be expected to have a higher closure rate than the traumatic perforations of heterogeneous origin. Grafting of resected pockets is probably unnecessary, as reported closure rates of tympanoplasty lie between 54.5 - 94%[17,18]. Furthermore, not having to graft the resected defect considerably shortens operating time as well as diminishing patient discomfort from a graft area. Under the operating microscope, the healed eardrum is indistinguishable from the normal eardrum, generally showing no signs of scarring or tympanosclerosis in the regenerated area. Table 2 indicates that the size of the defect is relatively unimportant, and the chance of complete closure of the defect after resection is very similar for retraction pockets of two quadrants and those leaving a subtotal perforation, though pockets comprising less that 25% of the eardrum (one quadrant or less) all healed completely. It does seem important wherever possible to maintain a clear rim of tympanum around the periphery so that it may heal cleanly without again becoming adherent to the underlying structures. Having established the uniform healing independent of the size of the perforation it would be useful to find a suitable control group for a randomised prospective study. There were no significant changes in the post-operative bone conduction thresholds, indicating no incidents of perceptive hearing loss following surgery. As it was not always possible to obtain hearing thresholds in the younger children, the median of the best available post-operative bone conduction thresholds in all patients was calculated. This value was not higher than the preoperative value. The two patients who were too young for preoperative bone-conduction audiograms were during the follow up period found to have normal bone conduction thresholds.

The median of 7-15 months post-operative ABG seemed to increase slightly, probably referring to the incidence of recurrent atelectasis.

We found in 17 patients (19.8%) a recurrence of the atelectasis once the ventilation tube had been removed, or after it had extruded spontaneously, but these patients could be treated in the same way as the original group, by repeating a simple careful excision of the atrophic membrane. These secondary procedures were not included in this analysis for the sake of clarity, since this second group is small, but there are no discernable differences with the first group; the drum continues to heal well after a second or even third resection should this be necessary. The underlying pathology is still uncertain, but other studies indicate recurrence rates of between 8 and 19%19. Our recurrence rate is similar to that described by Yung[9] (19%) for the smaller retraction pockets. However, he found a recurrence rate of 67% for the completely

atelectatic membrane. In our study we found no difference in the recurrence of larger (subtotal) retraction pockets, indicating that complete excision of the atrophic membrane and allowing it to heal spontaneously may be a better treatment option. The regenerated membrane is clearly more physiological than a cartilage graft, gives a clearer indication of the condition of the middle ear, and makes it easier to identify recurrent atelectasis. Since in the younger patients OME continues to be a problem, where necessary a new ventilation tube may be inserted as with any normal drum, something that is far more difficult through a cartilage or palisade graft. During the follow up period, we found further recurrent atelectasis in 3 of these 17 patients (17.6%), but this may be seen not as a deterioration of the problem but a repetition of problem itself, due to underlying pathology as yet not clearly defined.

Of the 5 patients with persistent perforation, 3 had an increased ABG, compatible with the perforation size, while 2 had an improved ABG. There is no recurrent atelectasis in this group, since the perforation in effect provides adequate ventilation for the middle ear. These eardrums are to be closed by simple transmeatal tympanoplasty, when the ear and Eustachian tube function are considered to be stable.

The only complication encountered was postoperative ear discharge encountered at the one-week follow-up, in 7 ears (8.1% of the ears), that was treated with antibiotic eardrops. Among those who failed to achieve closure of the tympanic membrane however, only 1 patient had post-operative ear infection, so a postoperative ear discharge in this group did not prevent healing at 6 weeks, and failure to heal could not be attributed to postoperative infection as is often assumed in tympanoplasty or traumatic perforations, though early treatment of an infection may be important, and this is one of the reasons we see these patients after one week. The remaining group of 79 ears had clinically normal eardrums at the end of the follow up period.

We found a small but not significant difference in the success and recurrence rate in children under12 years when they were compared with those who were 12 years and older. This suggests that the age of the patient may not have a significant role in the success and recurrence rate. However, the total number of unhealed eardrums was very small (n=5), similar in fact to persistent perforations described for long term ventilation tubes[20]. In older patients and adults it is perhaps not necessary to insert the ventilation tube at the time of the excision, but many of the younger patients continue to have recurrent otitis media.

Conclusion

If several techniques may be shown to have similar results, it would then be useful to apply Occam's Razor and adopt the simplest technique.

Excision of retraction pockets in pediatric ear atelectasis, in principle does not require grafting, as the great majority will heal spontaneously. The spontaneous healing in this study is comparable to reported studies of spontaneous healing of traumatic perforations.

Irrespective of the size of the atrophic part of the membrane, recurrence rate for the atelectasis after simple excision is similar to that described for other techniques, in other studies.

Retraction pockets of pediatric eardrums in this study could be safely excised without grafting, and most of the eardrums regenerated spontaneously with a resultant virtually normal drum. Whether adult pockets may be treated in the same way would require a further study. However, the incidence of spontaneous healing in the older children was not significantly different to the younger ones, so we speculate that the adult eardrum will respond similarly. This study also confirms that it is correct to treat (even large) traumatic perforations conservatively

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Postscript

All patients operated for atelectasis during the study period were included. Stage V included.
Progressive recurrence rates are mentioned only as a possible trend. The groups however are too small for significant comparison. A longer follow-up will be required to determine exact figures of recurrence. This entire group is under long-term observation.
Indications for surgery remain debatable. We have made the suggestions towards early intervention only very cautiously, after extensive debate and literature reviews, and with continued monitoring of functional and anatomical evidence, of which the results are presented here. Our aim is to prevent erosion of the incus and cholesteatoma while leaving the patient with an eardrum that is as close to anatomically normal as possible. Prevention is only acceptable if the cure is not worse than the disease, and by these various audits our first aim has been to confirm this for ourselves.

Chapter 4 **Safety of surgical intervention**

Atelectasis of the Middle Ear in Pediatric Patients: Safety of Surgical Intervention

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Intl J ped ORL 2009;73:257-261

Abstract

- **Objective:** There is no consensus amongst clinicians regarding the best treatment strategy for pediatric atelectasis of the middle ear. It is the policy in our pediatric otolaryngology department to intervene early in the disease process. In an attempt to provide evidence regarding the safety of early intervention we have analysed the audiological outcome following surgery in different stages of the disease.
- **Study design:** Retrospective case note review
- **Methods:** We undertook a retrospective study of children with atelectasis treated surgically at a Dutch tertiary referral centre. Disease severity was classified according to the Erasmus Classification of Pediatric Atelectasis, and pre- and post-operative 4 frequency ac and bc thresholds were compared.
- **Results:** The study group consisted of 169 ears in 127 patients. The mean age at surgery was 9.6 years. There was an improvement in the average airbone gap for all stages. No deterioration in mean bone conduction thresholds was found following surgical intervention and there were no dead ears post-operatively.
- **Conclusion**: This study demonstrated that surgical intervention had a favourable effect on hearing level across all stages, though hearing was markedly worse in stage V, and that a policy of intervention early in the disease process cannot be rejected on the grounds of risk of iatrogenic sensorineural hearing loss.

Introduction

Atelectasis of the middle ear due to atrophy and retraction of the tympanic membrane is a common and frustrating problem in pediatric otolaryngology. However, there is no consensus as to the best treatment strategy[1-11]. There are several options, varying from watchful waiting, via surgical intervention in the form of ventilation tube insertion, to simple excision and ventilation tube insertion, myringoplasty and tympanoplasty (with or without cartilage support and pallisades), or cortical mastoidectomy in an attempt to improve middle ear ventilation. Due to the columella effect of the atrophic membrane draped over the ossicular chain, hearing levels are a poor indicator for the severity of the disease. As Dornhoffer[10] has stated in a previous study, there is also a dilemma about the most suitable moment for intervention. Some clinicians prefer watchful waiting, with their rationale being to avoid the potential risk of iatrogenic hearing loss in an ear that is often otherwise relatively asymptomatic. Others prefer early intervention in order to limit the chances of incus erosion or progression of disease towards cholesteatoma formation.
In an attempt to provide evidence regarding the safety of early intervention we have used a new classification of pediatric pars tensa retractions to analyze the audiological outcome of early surgical intervention in atelectasis[12] (Table 1).

Table 1. Erasmus classification of pediatric atelectasis

Stage	Description
I	Tympanic membrane atrophic, but not adherent to middle ear structures
II	Tympanic membrane adherent to the promontory only
III	Tympanic membrane adherent to incus and/or stapes
IV	Adherent to ossicles with deep retraction pocket but without cholesteatoma
V	Retraction pocket with cholesteatoma and/or breakthrough

Patients and Methods

For this retrospective study we reviewed those children who had undergone surgical intervention for atelectatic ears between 1989 and 2005 at the Erasmus MC, Sophia Children's Hospital, Rotterdam, a tertiary referral centre for the southern part of the Netherlands. Patients 16 years or younger were included in this study. From the case notes the following data were collected: sex, age, operative findings of the tympanic membrane, the number and type of surgeries, pre- and postoperative audiograms and length of follow-up. Based on the clinical appearance of the tympanic membrane, and the findings at surgery, each ear was subdivided into one of the five groups of the Erasmus classification (Table 1)[12]. For parametric data, the mean was calculated together with the standard deviation (SD) and for statistical comparison a t-test was used.
The patients were treated according to the severity of the atelectasis. It has been our departmental policy when presented with an atrophic tympanic membrane, which is not adherent, or adherent only to the promontory (stage I and II), to either leave this untreated, or where indicated treat by ventilation tube insertion, with or without simple excision of the pocket.
When the tympanic membrane was adherent to the incus or stapes (stage III), the collapsed segment was removed via a transmeatal approach, using a tympanomeatal flap; lifting the tympanic membrane

carefully off the ossicles prior to excision of the collapsed segment. This dissection is started inferiorly, both avoiding excessive manipulation of an intact ossicular chain, and the risk of incomplete resection of thin membrane attached to the ossicular chain, or in the depth of the pocket where it is retracted into the facial recess or attic. The tympanic membrane was reconstructed with tragal perichondrium, or temporalis fascia. Where the incus was eroded, the gap was bridged using tragal cartilage. Stage IV retraction pockets were also removed via a permeatal approach taking every precaution to avoid tearing the exceedingly thin membrane. If the epithelium was unavoidably breached, a 'second look' was always planned for 10 months later. Retraction pockets filled with epithelial debris (Stage V) were removed permeatally where possible, providing the pathology was limited to the middle ear and attic. Disease extension into the mastoid antrum was cleared using a combined approach tympanomastoidectomy, via a postauricular approach.
Audiometry was routinely carried out one day preoperatively at 6 weeks and 7 to 15 months postoperatively. The air and bone conduction thresholds and air-bone gap (ABG) were calculated, using the four-tone pure-tone average (500, 1000, 2000 and 4000 Hz) for bone and air conduction. The difference between the preoperative ABG and the postoperative ABG after the latest surgery ('closure of the air-bone gap'), was used to determine whether there was an improvement in hearing. Audiometry, even in the younger patients, was considered to be reliable, reflecting the extensive experience in pediatric audiometry of the audiological staff in our tertiary referral centre.

Results

Overall Outcomes

The 'surgical intervention' study group consisted of 169 ears (127 patients; 57 male, 70 female) with atelectasis of the pars tensa. Ages ranged from 1 to 16 years, with a mean age of 9.6 ± 3.4 (SD, standard deviation). The time between surgery and the audiogram had a median of 12.5 months (25th and 75th percentiles were 9.4 and 16.3 respectively). The pre- and post-operative mean bone and air conduction thresholds for each stage of disease are shown in Table 2. The mean pre- and postoperative ABGs together with the 95% confidence interval are shown in Figure 1.

Figure 1. Mean pre- and post-operative thresholds for differing stages of disease

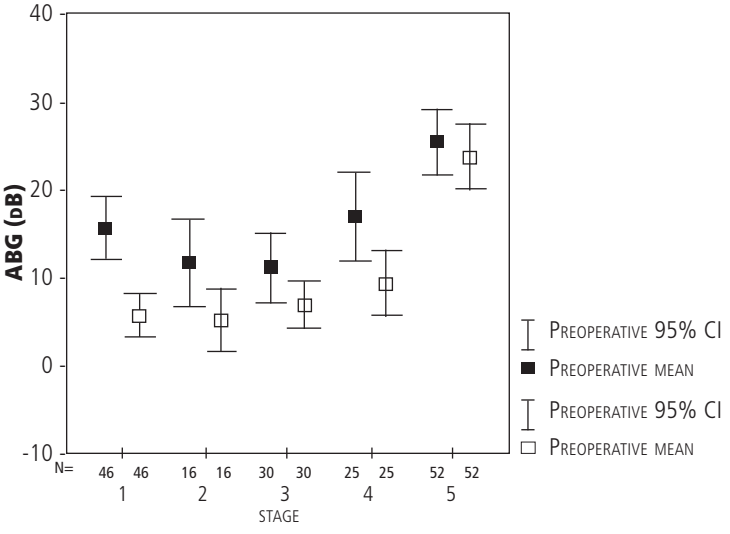

Table 2. Mean 4 frequency pre- and postoperative bone and air conduction thresholds for the different disease stages

	Bone conduction (dB)		Air conduction (dB)	
Type	Preoperative	Postoperative	Preoperative	Postoperative
I	9.6 ± 7.7	9.4 ± 7.0	24.1 ± 11.0	15.2 ± 10.5 *
II	8.6 ± 6.5	9.1 ± 7.0	20.8 ± 10.4	13.4 ± 7.9 *
III	10.7 ± 7.3	11.4 ± 7.5	22.3 ± 14.3	17.6 ± 10.2 *
IV	9.0 ± 6.7	10.6 ± 5.9	26.0 ± 13.9	20.6 ± 12.9
V	10.1 ± 6.2	12.6 ± 6.0 *	36.0 ± 14.4	36.0 ± 15.2

* = statistically significant difference between preoperative and postoperative value

Outcomes for each stage of disease

- **Stage I.** An atrophic but not adherent tympanic membrane was found in 46 (27.2%) of the 169 ears at first surgery. In 30 ears (65%) no other surgery was performed after the first intervention. Despite intervention (usually a ventilation tube) ten ears (22%) progressed to a higher stage, of which 2 developed a cholesteatoma (4% of 46 ears). The average preoperative ABG was 15.7 ± 12.2 dB (minimum 0.0 and maximum 38.8 dB). The postoperative ABG after the last surgery was 5.8 ± 8.4 (min 0.0 and max 31.3 dB). The difference between the preoperative and postoperative ABG was statistically significant ($P < 0.05$).

- **Stage II.** In 16 (9.5%) ears the tympanic membrane was adherent only to the promontory. No further surgery was performed in 10 ears (63%), with the other six ears requiring further surgery. In 3 ears (19%) the atelectasis subsequently progressed to a higher stage. The average preoperative ABG was 11.6 ± 9.4 dB (min 0.0 and max 28.8 dB). The postoperative ABG after the last surgery was 5.2 ± 6.6 dB (min 0.0 and max 23.8 dB). The difference between the preoperative and postoperative ABG was statistically significant ($P < 0.05$).

- **Stage III.** The tympanic membrane was adherent to the incus and/or stapes in 30 (17.8%) ears. Of these 17 ears (57%) did not progress to a higher stage while 6 (20%) did. In 4 ears (13%) a cholesteatoma was found at later surgery. The preoperative ABG was 11.2 ± 10.0 dB (min 0.0 and max 36.3 dB). The ABG after the latest surgery was 7.0 ± 7.1 dB (min 0.0 and max 27.5 dB). The difference between the preoperative and postoperative ABG was statistically significant ($P < 0.05$).

- **Stage IV.** A deep retraction pocket without cholesteatoma was found in 25 (14.8 %) ears. Eleven ears (44%) did not require further surgery, the other 14 ears did. Six ears (24%) progressed to a higher stage and became cholesteatomas. The preoperative ABG was 17.0 ± 12.1 dB (min 0.0 and max 48.8 dB. The ABG after the latest surgery was 9.4 ± 9.0 dB (min 0.0 and max 25.0 dB). The difference between the preoperative and postoperative ABG was statistically significant ($P < 0.05$).

- **Stage V**. In 52 ears (30.8%) cholesteatoma was found at initial surgery. In this group no second operation

was required in 9 ears (17%). In 43 ears more surgery was required, including 'second look' surgery and clearance of recurrent cholesteatoma (28 ears; 54%). The preoperative ABG was 25.5 ± 13.5 dB (min 0.0 and max 57.5 dB). The postoperative ABG after the latest surgery was 23.7 ± 13.4 dB (min 0.0 and max 55.0 dB). The difference between the preoperative and postoperative ABG was not statistically significant ($P > 0.05$).

None of the patients required exteriorization of the mastoid, and none had injuries to the facial nerve or iatrogenic sensorineural loss postoperatively.

Discussion

We have analyzed the audiological data following surgical intervention in pediatric atelectasis using a practical clinical classification of middle ear atelectasis in children[12]. In our opinion this classification provides a useful indication of the severity of the condition and possible complications, to which the outcome of intervention can be compared.

In general, it has been our policy in Stage I and II disease to treat conservatively, with intercurrent otitis media with effusion (OME) and hearing loss prompting ventilation tube insertion. Towards the end of the study period we began to excise the retracted atrophic segment, in addition to ventilation tube insertion. In stage II, where the retraction is fixed to the promontory, the atrophic tympanic membrane may be carefully dissected off the promontory by inserting a St. Barts blunt wax hook through a simple myringotomy, prior to excision.

In stages I to IV, the preoperative audiograms did not show a large conductive hearing loss. In all these stages the mean ABG remained below 20 dB. There was paradoxically a better preoperative hearing threshold in those stages associated with incudopexy (stage III), which could be explained by the poor acoustic characteristics of the flaccid membrane in stage I, and tethering of the ossicular chain by the membrane fixed to the promontory in stage II, as opposed to the situation in the higher stages, where the atrophic tympanic membrane is directly fixed to the incus, or stapes, producing 'columellar-effect' air conduction. The stages of the disease show poor correlation with audiometry, which conversely is an unreliable measure for advancing disease. Postoperatively, the hearing was shown to have improved (for each stage there was a statistically significant difference between the preoperative and postoperative ABG), which we consider to be partly due to better ventilation of the middle ear after surgery; remembering that many of these patients had intercurrent otitis media with effusion. As expected, the characteristics of Stage V disease were significantly different to the other stages, as this stage was frequently associated with ossicular damage by the cholesteatoma, especially of the incus and stapes. The preoperative hearing was much worse than the hearing thresholds in stages I to IV. Although there was a significant improvement in hearing postoperatively, it remained worse than in the other stages. Where necessary, the ossicular chain was reconstructed using tragal cartilage or a titanium partial or total ossicular prosthesis, so the pre- as well as post-operative hearing in stages IV and V shows a wider spread.

Many of the patients required multiple surgeries and if the atrophic drum was torn during the removal of a pocket (or retracted segment), from the ossicular chain or deeper structures, a revision ('2nd Look') surgery was carried out after 10 months, as is our practice in cholesteatoma surgery.

There also appears to be in this group, a direct correlation between the incidence of re-operations and disease severity. Stage I atelectasis required reintervention in 35% of cases (mostly as reinsertion of a ventilation tube), but a small percentage (4%) progressed to cholesteatoma, indicating that careful long-

term follow up is essential. Of Stage II 63% of the patients did not require further intervention, while in stage III this has dropped to 57%. More than half of the patients in stage IV and 83% of those in stage V requiring further surgery. Most of the patients in stage V required a second look, with the exception of those cases where the cholesteatoma could be entirely inverted and resected, without breaching the thin epithelial lining.

Opponents of early intervention contest that surgery carries a significant risk of iatrogenic sensorineural hearing loss. However the data presented in this article refutes this, with the results in all disease stages up to where there is erosion of the incus, having comparable postoperative hearing result. Therefore we think surgery should be performed early in the disease process, in order to offer the patient the best possibility of a good result, and the lowest chance of re-intervention. The tendency to develop re-atelectasis seems to decrease with age, with older patients tending to more stable pockets, as seen in some adult patients, though older patients are in no way immune to the retraction pockets developing cholesteatoma.

Conclusion

Although this study shares the generic problems of retrospective studies, it does demonstrate that early intervention does not have a negative impact on hearing thresholds. On the grounds of risk of surgical intervention, we suggest that 'watchful waiting' is not necessarily the most appropriate strategy, in all but the earliest stages of the disease. Obviously a much larger, prospective randomized study would be required in order to demonstrate the presence of a positive impact of early surgical intervention on the natural history of the disease. This study demonstrates that a policy of intervention early in the disease process cannot be rejected on the grounds of risk of iatrogenic sensorineural hearing loss.

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Postscript

This group of patients is far more heterogeneous than the other study groups, and consists of all patients with documented atelectasis and retraction pockets operated in the department between 1989 and 2005 The aim is to confirm that irrespective of the classification, functional results are not impeded by surgery.

The seemingly high rate of revision surgery of group V includes second look operations where there was a breach of the cholesteatoma during removal (these pockets are frequently deep into the facial recess or attic, and many show 'breakthrough of the pocket with exposed mucosa or signal polyps). Only where the cholesteatoma and retraction pocket could be removed intact did we consider revision surgery unnecessary.

The additional advantage of spontaneous healing described in chapter 3 is that the new eardrum usually remains translucent, and not opaque as in cartilage support, so even late recurrence of cholesteatoma may be noticed. This group also reflects a number of the earlier patients who did not have follow up revision or were for a time lost from follow up, and subsequently developed recurrent cholesteatoma. Where we have any doubt about the integrity of the retraction pocket, independent of the stage, a revision is always planned after 10 - 12 months.

Chapter 5 **Ear packing**

Ear packing after ear surgery: is it really necessary?

Borgstein J, de Zwart G, Bruce IA

J L O 2008; 122: 253-254

Abstract

- Objective: We question the need for packing of the ear canal after ear surgery. It has not been the first author's standard practice to use postoperative ear packing for several years. During this period few problems, or complications, have been encountered.
- Setting: Tertiary Referral Academic Paediatric Hospital
- Materials and methods: A retrospective review of all children who had undergone major ear surgery in our unit over the last one year was carried out. They reflect a full range of otological procedures. Postoperative complications and infections in the first 6 postoperative weeks were recorded.
- Results: A total of 135 ears were operated upon in 107 patients ranging in age from 11 months to 19 years (mean 9.5 years). During this time period 8 children (7.5%) developed a postoperative ear infection. No cases of tympanic or meatal granulations, problems with the tympanomeatal flap or meatal stenosis were encountered. All infections were successfully managed with topical antibiotics.
- Discussion: We conclude that packing after ear surgery may be safely abandoned, saving not only valuable operating time, but obviating the need for pack removal that is always a source of discomfort and anxiety. This is especially important in children who may subsequently require a further general anaesthesia in order to remove the pack.

Key words: ear surgery, ear packing, ear packs, infection, complications.

Introduction

Packing of the external auditory meatus after major ear surgery is an established practice in most hospitals. The type of packing varies between departments, with a wide scala of individual preference more tradition than evidence based. Some research has been reported investigating the different types of packing material, antibiotics, or antiseptic materials, used to cover the packs,[1,2] and some adverse reactions have been described[3] However, the fundamental need for packing has not been established to the authors' knowledge. The subsequent removal of the pack is, especially in the paediatric age group, an important source of anxiety and discomfort. In addition, the pack produces a temporary conductive hearing loss until removed; a point particularly relevant where there is already a hearing loss in the unoperated ear, or when considering bilateral surgery.

Prompting our change in practise was the initial observation that the surgical outcome, in those patients who removed their packing inadvertently whilst recovering from general anaesthetic, did not seem to be adversely effected. This led to a gradual reduction in the use or ear packing, until it was abandoned entirely 3 to 4 years ago. This study aimed to investigate outcome when ear packing was not used following middle ear and mastoid surgery.

Methods

All children who had undergone open middle ear or mastoid ear surgery during 2006 were included in this retrospective study, reflecting the full range of otological procedures. Grommets, Examination Under Anaesthetic and foreign body removal were excluded from the study. All patients were operated on personally, or by a junior surgeon under direct supervision, by the first author. Postoperative complications and infections in the first 6 postoperative weeks were recorded for this study, though because of the nature of the underlying otological problems, most patients required and received long term follow-up.

No ear packing of the external meatus was used for any of the patients, except for a few small pledgets of gelfoam soaked in antibiotic and steroid solution applied directly to an exposed graft after myringoplasty, on occasion. Where necessary, a dry gauze swab was loosely taped over the ear to absorb any postoperative bleeding. The patients were instructed to observe strict water precautions for at least 6 weeks post-operatively.

Patients were routinely seen one week postoperatively and 5 weeks later, at which time a postoperative audiogram was carried out. Patients were instructed to return in the interim period if they experienced any discharge, bleeding or pain. Where infections, or other complications were found, the patients were reviewed as often as was deemed necessary to successfully manage the problem. The patients did not receive routine antibiotic treatment postoperatively unless there was evidence of infection during surgery.

Results

During 2006, 135 ears in 107 patients were operated upon, ranging in age from 11 months to 19 years (mean 9.5 years). Eight of the 107 patients had a postoperative infection (7.5%), with one child developing bilateral infections. Of the total of 135 ears there were 9 ear infections (6.7%). All infections presented as ear discharge and were successfully treated with antibiotic and steroid ear drops. None had persistent discharge after antibiotic drops and in only one child was the graft placed at myringoplasty subsequently found to have failed resulting in a residual perforation.

There was no documented evidence of flap necrosis, or granulations affecting the grafted tympanic membrane or tympanomeatal flap. There was no evidence of meatal stenosis. One patient had an infection at the site where a tragal perichondrium graft was harvested, but this was not considered to be associated with lack of ear packing. No other problems were found.

Discussion

Though ear packing seems to be an established practice in many, if not most, otological centres, we have been unable to find the rationale, or evidence base, for this practice. In fact, there is a paucity of work published on ear packing, except for comparisons of various types of ointment used with the packs. Curiously, in the case of a traumatic perforation, or damage to the meatal skin, the recognised teaching is to leave the perforation alone, avoid all packing and eardrops and await spontaneous healing. Our rationale is that surgical intervention can be considered analogous to ear trauma, and may be managed in the same way with respect to ear packing.

There are a number of clear advantages to not packing the ear after surgery. Firstly, the patient avoids the anxiety and pain of pack removal. This is especially important in children who may subsequently require a further general anaesthesia in order to remove the pack. Any bleeding after surgery runs out of the ear instead of accumulating under the pack, so there is less risk of accumulated blood and secretions becoming infected. The patient's hearing is close to optimized immediately after surgery, whereas a pack confers a considerable hearing loss until removal. In addition, there is no risk of inadvertently disturbing a graft during the packing process or its subsequent removal. Finally, operating time is reduced, as is the first outpatient visit. We consider that packing after ear surgery may be safely abandoned, saving not only valuable operating time, but obviating the need for pack removal with its attendant anxiety and discomfort.

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Postscript

This study includes all the major ear operations carried out by the first author in 2006 within the Sophia Children's Hospital. It includes atelectasis surgery, middle ear and ossicular chain reconstructions, combined approach mastoidectomy and radical mastoidectomy as well as revision surgery.
Most of the surgery was carried out transmeatally, but the retroauricular approach was used for mastoid surgery. The variation used for retroauricular surgery was described in an earlier publication: Borgstein J. Prevention of Meatal Stenosis After Aural Surgery in Children. Laryngoscope 2001;111(5): 928

Chapter 6 **Surgical technique**

How I do it: Surgical management of atelectasis of the middle ear.

Borgstein J

Submitted: Laryngoscope

Atelectasis; collapse of middle ear due to atrophy of the tympanic membrane may be managed surgically in a variety of ways depending on the extent of the problem. This is not a "why I do it", so we will not here discuss the rationale for operating the various stages of atelectasis, but describe the method used.
After an analysis we carried out of the healing rates of excised retraction pockets, we now favour complete excision of the atrophic part of the eardrum, with placement of a ventilation tube (T-tube) directly through the resultant perforation. No attempt is made to graft the perforation, as it will heal completely around the T-tube within 6 weeks in 95% of the cases. Stage I and II, if combined with normal hearing may be simply observed, but where ventilation tubes are indicated for conductive hearing loss it is convenient to excise the entire atrophic segment of the drum. Where there is clinical suspicion of fixation of the drum to the incus, and therefore risk of erosion of the incus, or where there is an deep retraction pocket whose base cannot be observed, and therefore risk of cholesteatoma, surgery may be the safest option.
The technique used for the resection varies with the stage of the problem, and preoperatively we stage the atelectasis using the Erasmus classification. At the start of the procedure a needle or myringotomy knife is used to make a small myringotomy in the eardrum so that any glue may be suctioned off. It is then possible by lifting the atrophic segment carefully with the suction cannula, to determine if the drum has become fixed to the promontory and/or ossicles.

Where the drum has not become fixed to the ossicles or promontory (stage I) the atrophic section of the drum is simply excised with micro scissors and needle.

If the drum has become fixed to the promontory (stage II), a wax hook may be inserted through the myringotomy incision and used to carefully separate the drum from the promontory, after which it can be excised.

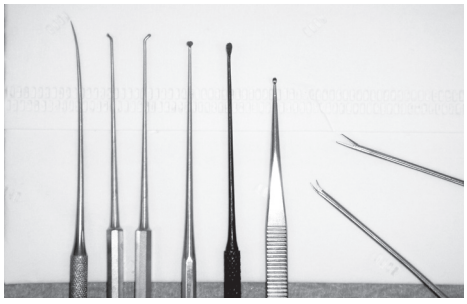
Once the drum has become fixed to the ossicles (stage III) we approach the middle ear via a tympanomeatal flap. It is important to keep the entire pocket intact so it can be everted before excision, for if the pocket tears near the ossicles of in the depth of a retraction towards the attic, the epithelial cells left behind may result in a cholesteatoma.
Using a Rosen dissector we make an incision in the meatal skin approximately 0.5 mm from the annulus. The meatal skin and even the annulus are also often atrophic to a variable degree, so great care should be taken to avoid tearing the skin and especially the annulus. The dissection must be carried beyond the annulus, taking care to remain behind the retraction pocket that is often retracted onto the promontory. It is often possible to locate the middle ear space inferiorly near the hypotympanum. Once the middle ear space has been identified, the retraction pocket is followed superiorly, and gently lifted off the promontory to which it may have become fixed. Working gently superiorly, the retraction is lifted out of the round window niche, and followed up towards the ossicular chain. The stapedius is then identified and the stapes and incus. No attempt is made at this point to dissect the eardrum off the ossicles, but the chorda and scutum are followed round towards the malleus, until the middle ear has been identified between the incus and malleus. The chorda tympani is generally retracted against the scutum by the retraction pocket, and the pocket must be separated from the chorda. Once the superior limits of the pocket have been found the pocket is very gently teased off the ossicles. It will almost always be fixed to the distal part of the incus, and present a varying degree of erosion of the incus, but the pocket may lie against the stapes or even run between the crura. Using the Fish dissector it is separated from the ossicles with the utmost care, to avoid tearing the drum on the one hand, and to avoid unnecessary manipulation of the ossicles on the other.

Once the drum has been completely freed from the middle ear structures, it is inverted and inspected for tears. Then it is excised completely with needle and micro-scissors, using the suction cannula to hold the atrophic drum. Once the atrophic segment has been excised, a free margin of eardrum should be visible around the resultant perforation. A T-tube is placed directly through the perforation onto the promontory, one of the legs towards the Eustachian tube and the other towards the round window; the end of the tube may be leaning against the external meatus. Unless the patient partakes in very violent exercise, the T-tube will remain in place, while the drum heals tightly around it. No ear packing is used. We generally review the patient after one week to ensure there is no infection, as this should be treated early to avoid interference with the healing mechanism. The drum will heal within two to three weeks, the excised atrophic drum being replaced by an eardrum of entirely normal aspects.

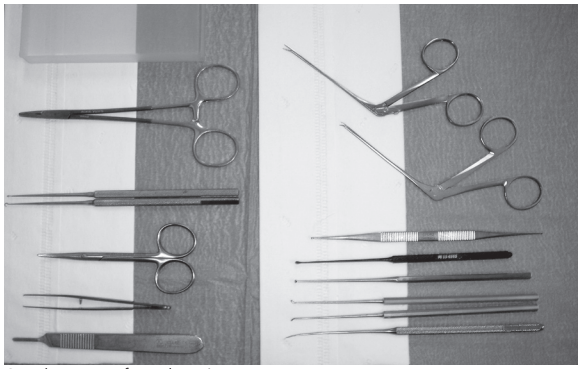
Deeper retraction pockets (stage IV) are managed in the same way, though it becomes increasingly difficult to lift the entire pocket out of the hypotympanum, sinus tympani, facial recess and attic, this is still possible with the careful use of the fish dissectors. Often there will be fibrous bands holding the drum into the attic, and these need to be cut before the pocket can be everted.

The surgery is carried out transmeatally using a suitable set of ear specula, and generally no external or retroauricular incisions are necessary. We do not use any form of postoperative ear packing, and review the patient at 6 or 7 days and 6 weeks postoperatively, at which time an audiogram is carried out, and 95% of the ear drums have healed completely. The T-tube is left in place for approximately one year, sometimes longer if the opposite ear manifests signs of recurrent OME.

Set of graduated ear specula



Detail of middle ear instruments



Complete ear set for atelectasis

Chapter 7 **General Discussion**

Occam's razor states: Entia non sunt multiplicare praeter necessitatum
- do not make things more complicated than necessary
The simpler, more elegant and harmonious of solutions to a problem is likely to be the better one... conversely an inelegant and complex solution is likely to prove the inferior eventually and will be replaced sooner or later.

Every surgical procedure and every part of every surgical procedure carries its own inherent risks and consequences independent of the general risks of surgery and anaesthesia. In surgery there is no such thing as no gain - no harm, for some harm is inherent in every surgical procedure. Even the length of the procedure may be important, for the longer the operation the greater the risk of infections, tissue trauma and complications, so it is important not to extend a procedure unnecessarily. On the other hand, delaying surgery for too long may also carry consequences in advance of the disease, and increasing degree of difficulty of the procedure when it eventually becomes inevitable. Therefore it becomes important to be constantly vigilant; to analyse each step and decide if it is necessary for this particular situation, and for this operation in general, and to find the optimum timing of an operation. Many surgical procedures have evolved slowly over time and are passed on in an apprentice system that has served us well for many millennia. Some of these procedures may be centuries old, and the traditions do not always take into consideration the tremendous surge in technology and research over the past years. We have methods at our disposal now that were undreamed about, and effective ways of evaluating our results. Every operation should be assessed not only as a whole, but also to see if its components are all still required. Many procedures can be effectively simplified, without compromising the results.

Where several options exist, and it is rare for surgical procedure not to have multiple options, and as long as the results are comparable, Occam's razor dictates that it is the simplest, fastest, cheapest alternative that should be used, as it has inherently less chance of producing a complication. There are fewer steps that can go wrong, a shorter operating time and anaesthetic time during which fate can strike, and less instruments that can fail. Even the surgeon is less stressed and less likely to commit a mistake. The difference in results may sometimes be very subtle, and the problems difficult to analyse, but common sense indicates that there must be a difference.

It is therefore useful to analyse any procedure to try and separate the essential components from the unnecessary embellishments. Is that pack really necessary? Do we need three sutures or is one sufficient and gives an equally good result? Is there perhaps an alternative like staples or glue? Is that operation really necessary or is there a good chance or spontaneous recovery. If surgery is delayed will this lead to a unacceptable rate of complications? Does the whole procedure need an endoscopic approach or can a well camouflaged incision give a faster, more direct approach with better results, shorter operating time and lower costs (financially or in terms of patient suffering)?

Does the patient need to stay in hospital, where the discomfort, risks of infections and other problems (not to mention the costs) persist, or may he be safely sent home to recover in his own trusted environment. Can this be shown to affect the healing? Traditions and 'protocols' that kept patients in hospital a specific number of days may no longer exist; the reasons may not even have existed in the first place, or may be effectively substituted by changing technology. We need to look not only at every procedure, but also at the components of every procedure, to see where it can be made simpler, faster, more effective. Obviously it is not possible to carry out an adequately documented double-blind-randomised-controlled-trial for every variation; it is often impossible even to predict which parts of which procedure may be unnecessary or incorrect. But it is possible to be alert for every eventuality, every accidental variation, and observe if it made a difference. To examine critically the operating sets and weed out unused instruments. To trawl the literature for reports of alternative procedures for similar problems, and alternative techniques used by other specialties for solving comparable problems. None of us of course will modify a technique simply because an unknown surgeon claims to have better results, but if we know that an alternative has been tried it gives us an extra arrow for our bow - to keep in mind as a useful bit of information, possibly to be used at an opportune moment.

We may not completely believe the other surgeons results, and we are always slightly suspicious of his statistics, but it does offer a possible alternative at an awkward moment.

This series of observations, and they are no more than observations, provide nonetheless a wealth of accumulated information that may be used to simplify the management of the awkward problem of aural atelectasis. In many ways it provides a continuum of developments that may pave the way to a more effective, less uncertain and certainly a faster surgical management of the entire range of atelectasis problems, There is some indication that it may be better to intervene before stage V is reached, though as yet we have insufficient information to be able to predict when an atelectasis is likely to develop cholesteatoma, and why. Inevitably this will lead either to a percentage of unnecessary operations, or to a percentage of advanced and difficult problems due to the development of a cholesteatoma, or the erosion of an incus.

The procedure for resecting a retraction pocket may vary from several minutes for stage I and II, but rarely takes more than 30 minutes, for the later stages. Once the excised atrophy has healed, it leaves a neatly regenerated eardrum of normal appearance[6] and has no demonstrable consequences for the hearing thresholds of the patient, neither air nor bone conduction. We were fortunate to have an almost complete audiological documentation in the majority of the cases, and though it must be recognized that the underlying problem of secretory otitis media may persist, and that the atelectasis may recur, the regenerated eardrum may be treated as a normal one and requires no special considerations. Where necessary the middle ear may be ventilated with grommets in the usual way (this is far more difficult where cartilage has been used to support the drum), while a recurrent atelectasis is effectively treated in the same way as the earlier procedure. Careful excision of the retraction pocket and atrophic eardrum appears from these studies and in this group of patients to be a simple and effective and safe method of dealing with the problem.

The important, and unexpected finding of these studies was the extraordinary healing capacity of the tympanic membrane after excising - this has been described before in a few sporadic publications, but with lower overall closure rates. In our study, 95% of the eardrums healed around the ventilation tube within 6 weeks; most within two or 3 weeks if the patient was seen earlier. We were fortunate to have an almost complete follow-up of our patients; few were lost to follow-up. It is difficult to identify exactly the differences between this and other earlier studies. There are several points where our technique may differ from previous studies:

- The complete excision of the atrophic membrane, leaving a freestanding rim of normal drum, from which healing may take place. Any remaining atrophic segments may develop new retraction pockets.
  The eardrum is an extraordinary structure, and unique in the human body, it heals in all three layers at once - epithelium, fibrous mesothelium and mucosa.
- A ventilation tube (T-tube) is inserted in every case, simply through the resultant perforation after excision of the atrophic drum segment.
  Initially we would try to find a segment of remaining eardrum through which to place the ventilation tube, but this proved unnecessary.
  The ventilation tube was used to counteract any dysfunction of the middle ear gas exchange mechanisms during healing, but may not be necessary in older and adult patients.

6 Ideally we would need to carry out a full histological analysis of the new eardrum but this is ethically difficult to justify.

- Applying no ear tampons prevents accumulation of blood and secretions, and may contribute to a faster healing process;
  It is generally accepted that traumatic perforations should be left alone, to heal without interference, eardrops or packing, and certainly the incidence of postoperative infection in the operated group was lower than that found in our department after simple grommet insertion (unpublished data from a parallel study).

We feel that the proposed Erasmus classification has proved useful in analyzing results and classifying pathology in a more effective way than earlier classifications based on the Sadé system. It must be reiterated that this classification is primarily a surgical classification, as only during surgery and generally only after making an initial myringotomy can one be certain whether the drum is adherent or not. The Erasmus classification has proved useful for analysing results, and a cautious start has been made to correlate clinical pre-operative findings with operative confirmation, so that the operating time can be more accurately assessed, as well as the skills and experience required of the operator for each stage. Here inter-observer and intra-observer reliability also needs to be evaluated, but we feel it is unlikely that this will bring greater clarity, for the earlier stages (I and II). These would normally only be eligible for surgery if there was an important conductive hearing loss, either due to OME or due to tethering of the ossicles by the retracted drum.

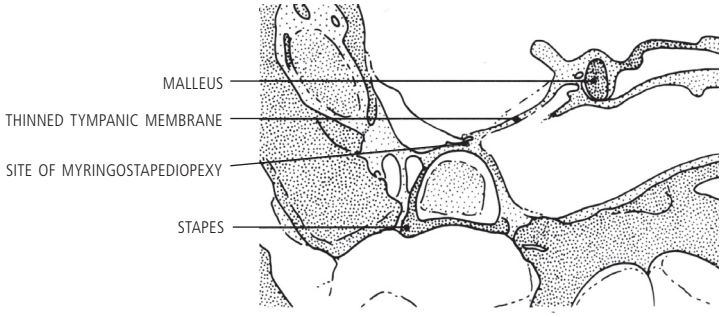
With the higher stages (III and IV) we found that, incudopexy may generally be identified with some confidence in the outpatient setting, though inter and intra-observer studies still need to be completed. We use a system of pre- and postoperative sketches to identify the problems, for it has so far proved unpractical to attempt preoperative photography in the younger patients, who often find the aural endoscope threatening.
The presence of cholesteatoma where it emerges from a retraction pocket presents few diagnostic problems, though the extent of the deep retraction pockets and the extension of cholesteatoma may only be discernible during surgery.
Whether the proposed classification may also be applied to adults we cannot state with confidence, though if extrapolation from older teenage children in these studies, and from traumatic perforations is to be permitted, there is little reason to believe adult ears would respond differently.
With certain reserve then, surgical planning may be based on an initial classification, though the classification may need to be adjusted with surgical findings. Stage I and II may be excised or observed. Where there are audiological indications for ventilation tube insertion (a conductive hearing loss) it is perhaps as well to resect the atrophic segment of the drum, for it takes only a few minutes to excise the atrophic drum if it is still non-adherent, or adherent partly only to the promontory. Stages III and IV where the atrophic drum is adherent to the ossicles and other middle ear structures, will need to have a tympanomeatal flap approach to the middle ear, and this usually requires fifteen to thirty minutes, depending on the degree and depth of the retraction, and the structures it is adhered to. This allows the adherent drum to be carefully dissected off the ossicles and other middle ear structures from below, thereby avoiding unnecessary manipulation of the incus and stapes, and minimising the risk of tearing the exceedingly thin drum and leaving epithelium behind in the middle ear where it may grow out to a cholesteatoma under a healed eardrum. It has been our policy to revise after ten months any ear where the drum has torn inadvertently.
Stage V will need to be planned as a possible combined approach tympano-mastoidectomy (CAT), though

frequently may require little more time than stage IV. It is often possible to remove the retraction pocket in its entirety with the contained cholesteatoma, but intercurrent infection (otitis media or 'otitis externa' within the pocket requires great care, as the epithelium then becomes more friable. We have insufficient cases at present for a more detailed analysis of this group. Where there is any doubt as to the integrity of the atrophied drum, the patient should be programmed for revision surgery after approximately ten to twelve months (possibly earlier in younger children).

The impression, gathered from a number of separate observations, is that the thin drum may on occasion break down spontaneously and perforate, allowing polypoid swollen middle ear mucosa to protrude through into the base of the retraction pocket, producing what is known as a 'signal polyp', and generally considered to be an indication of cholesteatoma.

Ideally the ear is operated before stage V is reached, for cholesteatoma introduces an unpredictable element into the equation, and may quickly progress to fill the entire middle ear or attic, frequently destroying the middle ear structures in its way towards the attic and additus, and into the mastoid air cell system. Surgery for group V is frequently more extensive than anticipated.

Erosion of the incus was reported separately, for stages III and IV where the eardrum has become fixed to the incus and - stage V atelectasis is more frequently associated with ossicular damage, and this is well known to occur with cholesteatoma. We found at surgery, some degree of ossicular damage in approximately 30% of the stage III and IV ears, varying from limited erosion of the angle of the LPI or the lenticular process with continuity maintained, to almost complete absence of the long process of the incus (LPI). This has been previously reported in adults but not in children as far as we know. Erosion has a direct consequence for the eventual conductive hearing status of the patient. Once the incus has been eroded sufficiently to lose continuity with the stapes, an ossicular chain reconstruction will be required, with a far lower success rate than may otherwise be achieved by preventive or pre-emptive measures, and another indication that it may be better not to delay surgery for too long. Though the LPI may be completely eroded, the hearing is surprisingly good in many of these patients, for the thin drum of the retraction pocket becomes fixed to the head of the stapes and results in a 'columella effect' with direct sound transmission to the stapes and inner ear. Hearing therefore is not well correlated with the extent and advancement of the problem.



In principle, once the eardrum has healed, the T-tube may be removed as soon as the chance of intercurrent OME is deemed to be lower. Generally for our group of patients, the tube is removed after one year, but the patient is carefully monitored for several more years to guard for recurrence. Recurrence of glue ear or a retraction pocket merits the placement of a new ventilation tube.

The retrospective analysis of the results describes the same population as the incus erosion, and the

classification paper, but antedates the spontaneous healing analysis and the ear packs group.
Many of the earlier patients still had grafting of the defect with fascia, cartilage or perichondrium grafts, a practice that was later abandoned when it became clear that spontaneous healing gave equally good or better results than grafting, and this may have reflected on the postoperative hearing results, for a graft may not yet be completely incorporated a six weeks, while a regenerated drum is essentially normal by then. Once the eardrum has healed and the ventilation tube has been removed or has extruded, the drum closes and the aspect of the healed drum is normal or close to normal. Since the ventilation tubes were generally removed within two years, we experienced no problems with persistent tube perforations.

Early intervention therefore takes away a large part of the uncertainty and frustration of having to keep the patient under long term observation. Where a cholesteatoma developed in our series, from a previously noted retraction pocket, this occurred between four and forty months (though with longer follow-up of retraction pockets this interval may extend to many years, as not all retraction pockets develop a cholesteatoma, and some may remain silent for years, especially in older and adult patients). In younger children, the incidence of complications is higher, possibly due to more frequent episodes of otitis media or otitis externa. If predictive factors can be identified it may be possible to avoid some of the surgery, but from these studies is seems clear that certainly any retraction pockets at stage III and higher should have surgery, for it has not been reported or observed that once a drum has become fixed to the ossicles it will ever spontaneously correct itself.
If similar results may be expected in adult patients cannot be directly extrapolated from these observations, but from what is known about spontaneous healing of traumatic perforations, it seems likely that the adult eardrum will respond favourably to excision. Conversely, the results of spontaneous recovery indicate that the currently accepted policy of treating all traumatic perforations conservatively is justified.
In this study we did not analyse the various methods described in the literature for 'stenting' the atrophic membrane with cartilage and fascia grafts. For the earlier patients we have on occasion used these techniques, only to find that the opacity of the grafted drum precluded adequate inspection of the middle ear, made ventilation tube insertion considerably more complicated, and on occasion a new retraction pocket would develop near the edges of the cartilage graft. Some very good results have been reported for the various stenting techniques, but they require more skill, and never result in a normal looking eardrum.
No patient has so far been operated more than twice for simple excision (cholesteatomas obviously frequently require revision surgery (second look) and may have multiple recurrences). Further and longer analysis is needed to confirm these findings.

Packing after ear surgery may also be unnecessary, as indicated by the analysis of all ear surgery carried out in 2006, and includes retroauricular approach to the mastoid for mastoidectomy. We were unable to identify any complications attributable to the practice of not packing an ear after surgery, and in our series no incidence of meatal stenosis (the most feared complication) has occurred.

A search of the literature revealed that spontaneous healing found for excised retraction pockets is in a similar range, though slightly higher than the spontaneous healing of traumatic perforations (though this includes mixed causes). In retrospect it is logical to consider a surgical excision as an optimally produced traumatic perforation, the healing in our series seemed irrespective of size of the excision, with subtotal excisions healing as well as small retraction pockets. All but 5% of eardrums were healed within six weeks.

chapter 8 **Conclusions**

As stated in the beginning of this thesis, we did not set out to 'prove' anything, merely to analyse the results of different management strategies for middle ear atelectasis. Several cautious conclusions may be drawn from these trends and associations, always bearing in mind that they may only be valid for the particular group of patients examined.

- The Erasmus surgical atelectasis classification system seems useful for comparing operation results in the group of paediatric patients examined.
- The classification system seems promising also for planning the type and extent of surgery required to eliminate the problem.
- The tympanic membrane regenerates at an extraordinary rate and with high reliability, so after excising an atrophic segment there is rarely any need for grafting.
- After healing, the new tympanic membrane is indistinguishable from a normal eardrum, and the middle ear function may be expected to return to normal unless ossicular erosion has occurred.
- Ossicular erosion is seen in up to 30% of ears where the retraction pocket was found to be fixed to the incus (incudopexy) during surgery.
- Packing of an ear after ear surgery proved in our series to be unnecessary.
- Surgical management of the various stages of atelectasis is fast and safe, but the higher stages require considerable surgical skill to avoid tearing the thin membrane.
- Watchful waiting may be wishful thinking - it is currently not possible to predict when a retraction pocket may develop cholesteatoma, or result in erosion of the incus. Waiting too long may result in unnecessary destruction of middle ear structures, and a more complex operation. Operating too soon may result in unnecessary surgery, though the operation is faster and simpler. A suitable balance will need to be found between these alternatives.

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Professional Degree: 11 May 1978, Medical Doctor - University of Groningen

Specialist Registration:

Consejo Mexicano de Otorrinolaringologia y Cirugia de Cabeza y Cuello (Mexican Council of Otorhinolaryngology, Head and Neck Surgery), 26 February 1988

Medische Specialisten Registratie Comissie (European Medical Specialization Registration Committee). Specialist of Otorhinolaryngology. 1 August 2001, 2006

Registered / Licensed:

Netherlands, 11 May 1978, Nº 0939 04 8

BIG Register June 2000, Nº49052693901

Malawi, August 1979, Nº 776

England, 25 May 1982, GMC Nº 2559362

Mexico, 2 September 1988 Ced. Prof. 1281016

BIG Register (otolaryngology) 2 May 2002

Fellow Royal Society of Medicine, London - 1st June 1993

Specialist in Otorhinolaryngology EU 1st August 2001, recertified 2006

Professional Experience:

Resident in General Surgery at the Queen Elizabeth Central Hospital, Blantyre, Republic of Malawi (1978 to 1980)

District Medical Officer and Director Thyolo District Hospital, Thyolo, Malawi (1980 to 1982)

Resident in Otolaryngology at Warwick Hospital, Warwick and Radcliffe Infirmary, Oxford, England (1982 to 1986)

Resident in Otolaryngology at the Royal National Throat Nose and Ear Hospital, London, England (1986)

Specialist in Otorhinolaryngology and Head and Neck Surgery, Department of Otorhinolaryngology National Respiratory Diseases Institute (Instituto Nacional de Enfermedades Respiratorias), Mexico City (1988 to 1994)

Investigator/Researcher in Otorhinolaryngology, National Respiratory Diseases Institute (Instituto Nacional de Enfermedades Respiratorias), Mexico City (from September 1994 to 2002)

Lecturer in Surgery at the National Autonomous University of Mexico (Universidad Nacional Autonoma de

Mexico (Nov 1993 to July 1994)

Professor of Surgery at the National Autonomous University of Mexico (Universidad Nacional Autonoma de Mexico (from 13 July 1994)

Coordinator of Surgical Education and Teaching at the National Autonomous University of Mexico (Universidad Nacional Autonoma de Mexico) (from 1 June 1996 to 1 March 1998)

Lecturer in Otolaryngology (Undergraduate Course) at the National Autonomous University of Mexico (Universidad Nacional Autonoma de Mexico) (from 1 September 1997 to 2001)

Dean of Medicine - Medical School Project Westhill Institute, Mexico City (March to November1998)

Professor of Otorhinolaryngology Panamerican University, Mexico City (Universidad Panamericana) (From June 1999 - to date)

Professor of Otolaryngology University of Malawi - College of Medicine (from March 2000)

Specialist in Pediatric Otorhinolaryngology Erasmus University of Rotterdam, Sophia Children's Hospital (from 1 August 2000)

Member of the Council for Tropical Medicine (COTG) (from 2005)

Editor Netherlands Journal for Tropical Medicine Medicus Tropicus (from 2006 to 2006)

Chief editor Medicus Tropicus (since 2008)