Experimental incus transposition

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Experimental autogenous incus transposition

Tympanoplasty has now been practised for over 20 years, though to an extensive degree for a time considerably less than this. Many changes have occurred during this period, reflecting the dissatisfaction with various materials originally used: examples are skin proposed by Wullstein (1953) and later universally rejected for reasons given by Guildford (1965). Similarly replacement of ossicles by synthetic prostheses was widely popularized in the early sixties (Austin and Shea, 1961; Tabb, 1963; Guildford, 1964) but later rejected (Smyth *et al.*, 1967; Farrior, 1973). These changes of opinion show the initial optimism destroyed by the poor results after only a few years. In each case the use of materials in humans was undertaken before experimental studies had shown their long-term fate.

Ossicular transposition has been practised since Zöllner (1955) described the method. Though previously known it was not really a recognized procedure. After initial infrequency, ossicular transposition was described often in the literature, though there were few cases until Guildford (1965, 1966) described a larger series. In spite of this there are still only a few reports of extensive series in man (Wehrs, 1967; Hough, 1970; English *et al.*, 1971; Cody and Taylor, 1973).

In contrast to the number of ossiculoplasties performed using ossicular transposition there are only few reports of studies of human ossicles which have been removed some time after transposition (Hall and Rytzner, 1960 and 1961; Kley and Draf, 1965; Linthicum, 1966; Kerr and Smyth, 1971). There were problems of interpretation because of the very small number of specimens, the fact that they were all from failed tympanoplasties, the differences in appearances, and the different interpretation given of the findings. It is indeed hazardous to make dogmatic statements on the findings without the use of collateral evidence. Since the long-term results of ossiculoplasty may depend to some extent on the behaviour of the transposed ossicle; and since ossiculoplasty by transposition is still a widely practised procedure, it is necessary to continue to evaluate the behaviour of ossicles experimentally (Békésy, 1961).

Previous experimental studies have been performed. Stengl and Hohmann (1964) performed stapedectomy and incus transposition in cats and primates. In cats, there was found a layer of new bone on the surface

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though the rest of the bone was dead. Fibrosis was quite prominent, and there was ankylosis with the malleus. One incus was replaced by fibrous tissue. In the primates the process was slower and similar. The marrow spaces were filled with connective tissue, but nevertheless the appearance was of death of the incus but with some remodelling. Wilson, Pulec and Van Vliet (1966) used homografts and autografts in cats. Though the process with autografts was slower than homografts the changes were similar, there being large areas of resorption and later remodelling. Van den Broek and Kuijpers (1967), replacing incudes in rats, found varying cell death in autografts with evidence of revitalization, while homografts and denatured autografts were totally dead with evidence of much slower change—the reverse of the findings of Wilson *et al.* (1966) with cats. Any revitalization, rapid initially, appeared later to cease. Winter and Hohmann (1967) also used cats. They studied tetracycline fluorescence, which was not significantly different in autografts and homografts, implying that both were initially dead. Smyth, Jones and Kerr (1967) could likewise find no significant difference between autografts and homografts in cats. Benitez and McIntyre (1968) described the behaviour of orthotopic homografts in cats with tetracycline uptake, showing cessation of activity in one year. A further observation was that the incudes were of normal shape but fixation to the walls of the tympanic cavity was not infrequent. Taggart (1969) using monkeys noted similar fibrous adhesions.

The overall picture is confusing. Cats, rats and primates have been used. In cats there appears to be some belief that the transposed ossicle is initially mainly dead. That there should be differences between homografts and autografts is not unexpected, but there is dispute, and differences in findings between studies. Fibrosis and ankylosis is a not uncommon finding in cats, and, as will be shown, may have some bearing on the findings. Rats appear to suffer less from fibrosis but some parts of replaced incudes appear to survive.

In a clinical situation the detailed behaviour of a transposed ossicle is important. A dead ossicle may generate a reaction whether in the tympanum or on the drumhead. An ossicle fixed with fibrous or bony adhesions may not function. Ossicles may be used, potentially viable, as immediate autogenous transplants, or as dead or denatured autografts, or as 'homografts', though as used at present these are not homografts in the real sense in that treatment with alcohol or other preservatives has removed any antigenic behaviour which would promote a homograft reaction.

This study was proposed to add to the available information, both experimental and clinical, concerning the behaviour of transposed autogenous incudes, and was conducted using the rat as the experimental animal. The choice of animal was partly because previous work (van den

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Broek and Kuijpers, 1967) has shown the behaviour of *replaced* incudes, and partly because of cost (low cost permits the use of large numbers, thus allowing better and more reliable observations). In addition, the behaviour of the incus in rats seems to be most similar to those few observations of transposed incudes in humans.

Method

The experimental study involved 88 rats of 100–200 grams (Wistar), anaesthetized by ether followed by oxygen and halothane. Only one ear was operated upon, whereupon a tympanotomy was performed from above. The incus was removed and returned to the tympanic cavity in various ways. After surgery the animals were kept for various periods from one week to six months. No antibiotics were used. The segment of skull containing the ear was removed, fixed, decalcified, serially sectioned, and stained.

Six rats were rejected as unsuitable or because of technical operative or histological failures. Eighty-two rats were studied in the following groups:

(A) 1. Incus removed and replaced orthotopically (5 cases)
2. Incus removed and replaced orthotopically after boiling (4 cases)
3. Incus removed and replaced orthotopically with gelatin sponge (5 cases)

(B) 4. Incus removed and transposed free into tympanum (7 cases)
5. Incus transposed between malleus and stapes (35 cases)
6. Incus transposed between malleus and stapes with scarification of the related mucosa (10 cases)
7. Incus transposed between malleus and stapes after boiling (10 cases)
8. Incus transposed between malleus and stapes with gelatin sponge (6 cases)

Results

Groups (A) 1, 2, 3. Replaced incudes (Figs. 1, 2).

In these groups the incus was replaced orthotopically. The purpose was to ensure that the findings correlated with previous studies where the incus was replaced in its natural position (van den Broek, 1967).

1. The replaced incudes had all formed vascular adhesions and attachments to related structures. The malleolo-incudal joints were obliterated with fibrous tissue. Viability of articular cartilage was universal while bone adjacent to attached areas was often viable. The remainder of the ossicles was largely dead, though all haversian systems were filled with connective tissue, sometimes with viable bone in relationship. Specimens at two months and six months were not significantly different, suggesting that whatever viability is retained or regained, it is achieved in the early stages.

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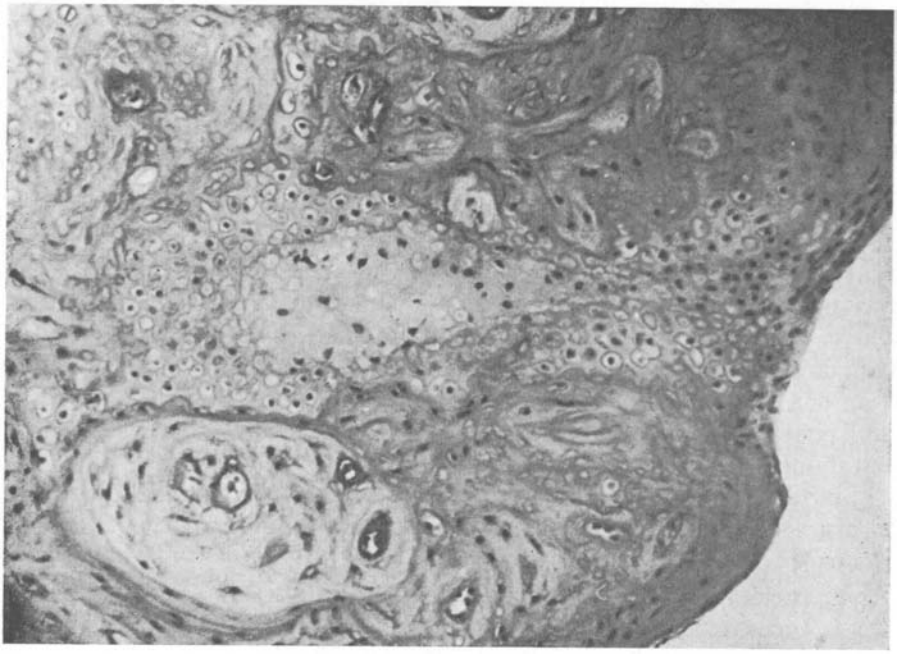


FIG. 1.
Replaced, after 175 days.

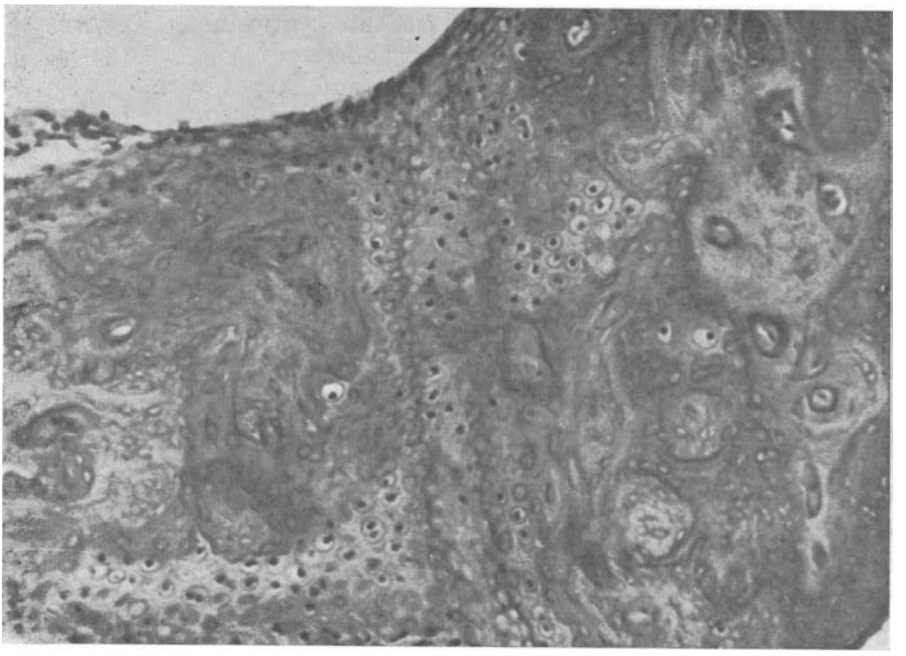


FIG. 2.
Replaced after boiling, 175 days.

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2. These boiled replaced incudes differed from the untreated ones in that there was very much less viability. There were a few layers of bone deposited on the surface and the haversian systems were filled with connective tissue. There was no inflammatory response or rejection. The result was an ossicle essentially dead. There was negligible change between two months and six months.

3. Incudes replaced with gelatin sponge behaved in a manner similar to untreated incudes (Group 1) but there were prominent vascular adhesions involving the associated gelatin remnants. Though less at six months, fibrosis was still excessive.

Groups (B) 4, 5, 6, 7, 8. Transposed incudes (Figs. 3–9).

4. A few incudes transposed to a site distant from ossicles were found not dissimilar to those transposed between the malleus and stapes. The degree of viability was variable, but appeared to be related to the site and extent of vascular adhesions. Haversian vascularization was universal, and occasional internal bone deposition was seen. Parts of the ossicle such as the long and short processes standing away from the tympanic wall were dead. There was no significant difference between two and six months. Bony ankylosis was seen in some.

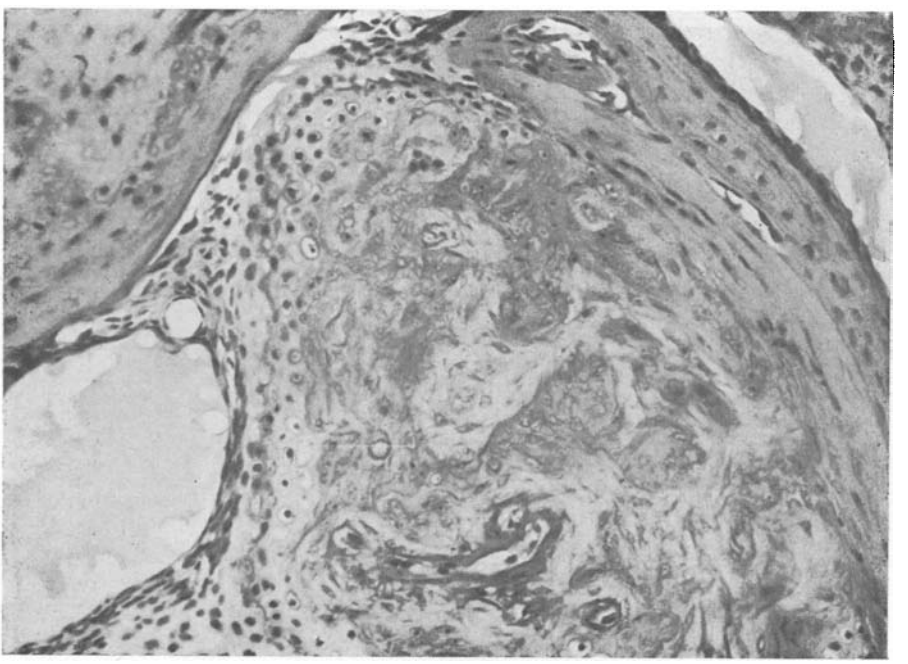


FIG. 3.
Transposed, after 13 days.

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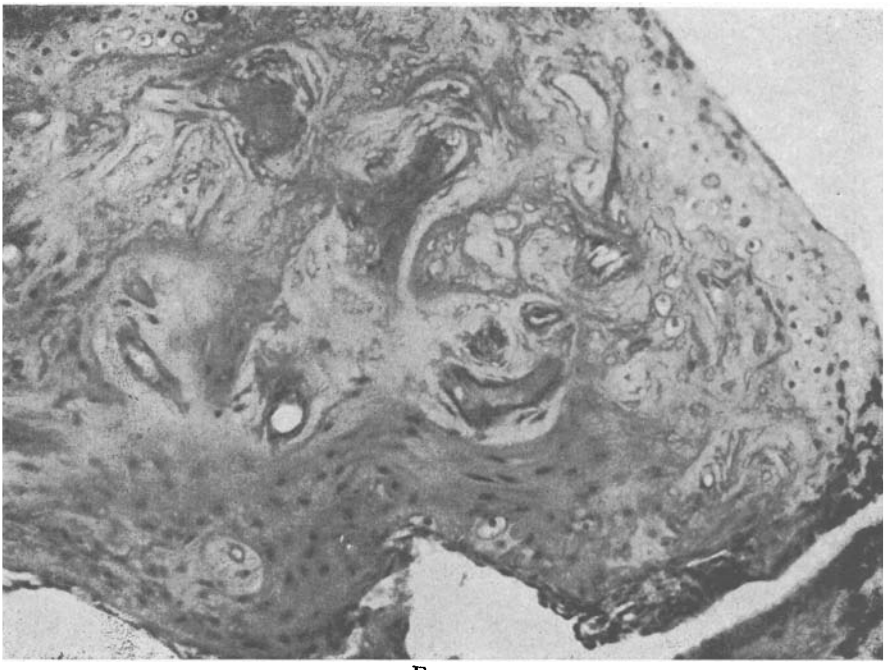


FIG. 4.
Transposed, after 35 days.

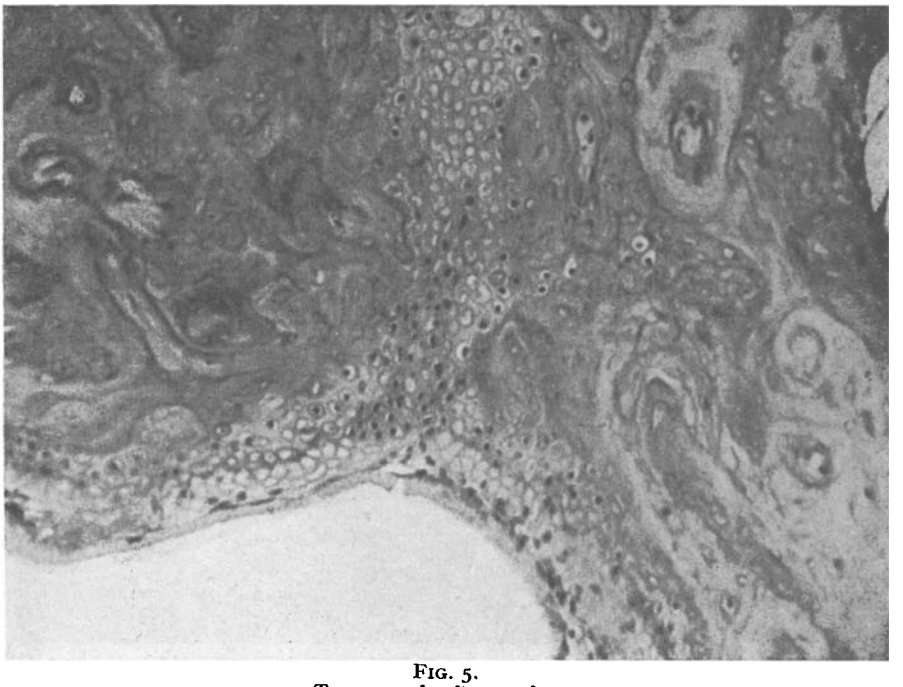


FIG. 5.
Transposed, after 95 days.

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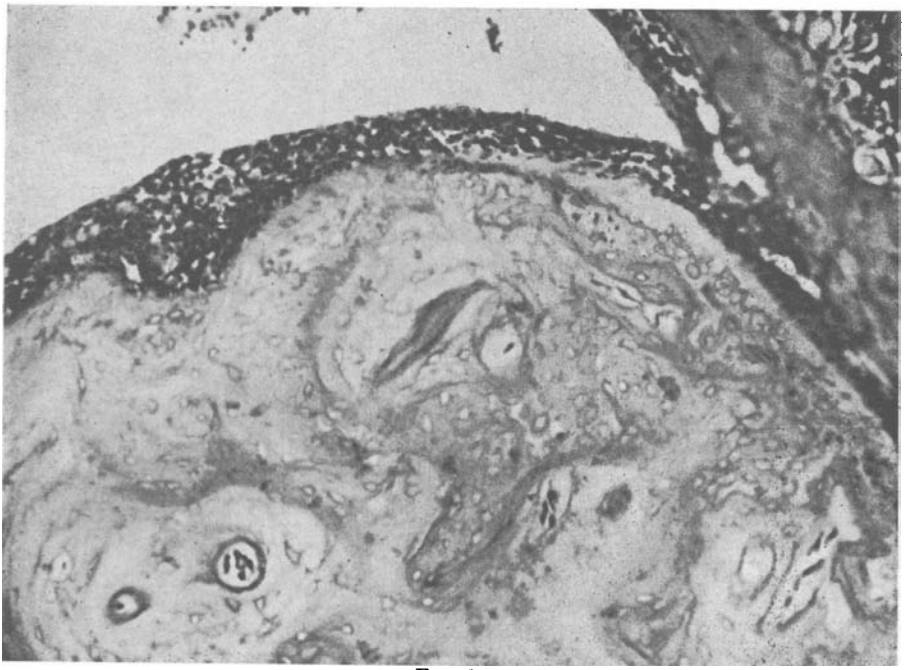


FIG. 6.
Transposed, after 202 days.



FIG. 7.
Transposed, with mucosal scarification, after 173 days.

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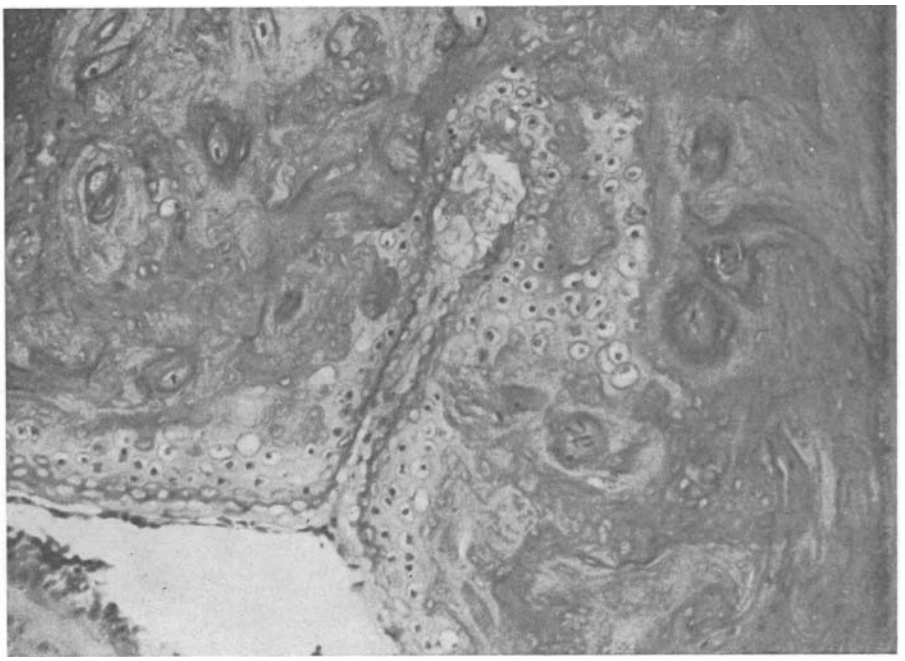


FIG. 8.
Transposed, boiled, after 55 days.

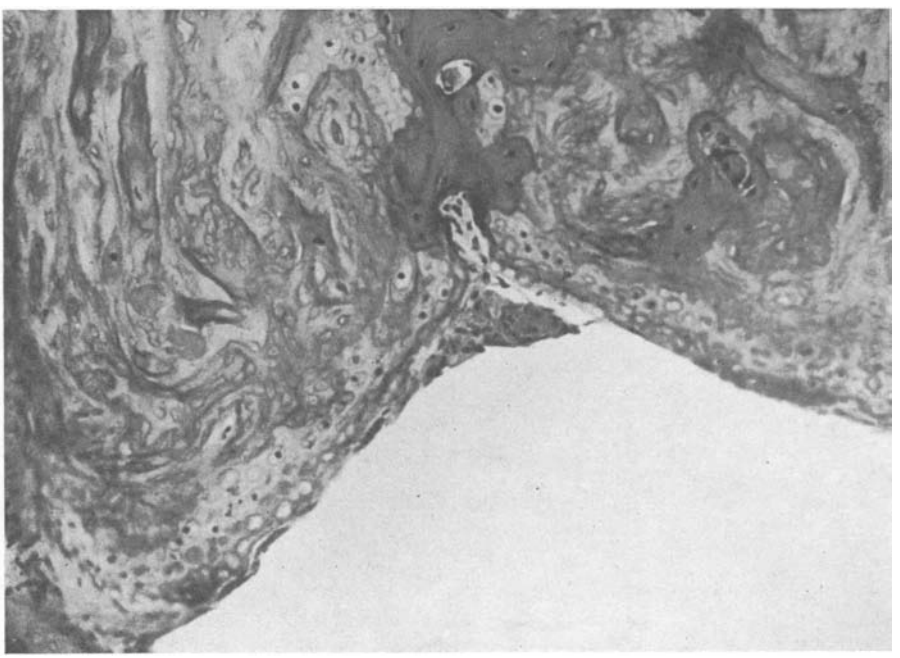


FIG. 9.
Transposed, boiled, after 175 days.

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5. In this major group replants were studied at all stages. During the first few days there was an inflammatory exudate though cells were scanty. This was interpreted as post-traumatic. The ossicle was surrounded by immature connective tissue with intense cellular activity and plump mesenchyne cells and osteocytes. There were areas of erosion and resorption though osteoclasts were never seen. The major (central) parts of the ossicles were dead though vascularization of the haversian canals was obvious and cartilage appeared normal. After two weeks the appearance was similar but now in some areas deposits could be seen—they were either osteoid or cartilage. The central areas were still, of course, dead. Over the next two months all inflammatory exudate disappeared, while the tissue over the ossicles thinned into a less active covering. The ossicles varied a little in the degree of viability—all had at least a thin viable layer on some surface. The cartilage was almost invariably normal in appearance and beneath it was often a deep subarticular wedge of viable bone or osteoid. Elsewhere viability was more in relation to vascular adhesions wherever they happened to be. This applied to long and short processes as well as the bodies of the ossicles. There was never inflammatory rejection.

Over the period two to six months there was little change though the size of the adhesions did seem to diminish slightly; and probably there was a little reduction in bone cellularity as well as in the deeper layers of cartilage. Otherwise the situation remained static unless otitis media, spontaneous in older rodents, were to supervene. Some loss of osteocytes may also occur with age in bone in the walls of the tympanum.

6. Scarification of the mucosa did not induce significant change in transposed incudes when compared with the previous group. Since many of the previous group developed adhesions to the promontory it could not even be stated that scarification induced adhesions here more often than when scarification was avoided.

7. Incudes transposed after boiling were found to be similar to those replaced after boiling. There was less evidence of viability, and periosteal deposition seemed minimal. Even though fibrous or even bony ankylosis occurred, there was relatively little associated viable bone. At one week activity was very much less than unboiled specimens, and the same was apparent at one, two and six months.

8. Gelatin sponge surrounding transposed incudes was associated with the presence of fibrosis greatly in excess of that normally found. The viability of the incudes was similar to other unboiled specimens, and though there was a suspicion of more viability it could not be regarded as significant.

In brief, transposed incudes did not change macroscopically and retained or regained viability to some limited degree, though viability

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seemed to be broadly related to the site and size of vascular adhesions. Adhesions developed fortuitously at points of contact, and could not be shown to be significantly induced by scarification or injury to the mucosa. Boiled (i.e. killed) incudes regained relatively little viability. All incudes had their haversian systems filled with connective tissue though this could not be regarded as revitalization. Only post-operative inflammation was seen, apart from the spontaneous otitis of increasing age.

Changes in the drumhead were observed. A few perforations were found but had the character of rupture during processing of the specimen. The superior part of the drumhead was often thickened and vascularized, especially when related to the ossicle, and in some cases it appeared a good vascular source. Desquamative or destructive reaction of the drumhead in relation to the ossicle was not seen.

Transplanting of bone has been the subject of experiment over many years. Bashkirtzew and Petrow (1912) showed that free autogenous bone lost its osteocytes except for a few favoured ones, and also observed the relative advantages of autografts as opposed to homografts or even dead bone in the rapidity of revitalization and incorporation. Brown and Brown (1913) showed in dogs that bone needed contact with bone to survive and remained viable only in a functional situation. Hutchinson (1952) using mice, and Ray and Tawfik (1963) did not differ substantially, and their experiments confirmed that free autogenous bone may have viable cells which then contribute to viability and subsequent activity.

Transplants of free bone into the tympanum of animals have been studied by Guildford *et al.* (1966), Beck and Franz (1961), Musebeck and Falck (1963), and Benitez *et al.* (1971) using dogs, guinea-pigs and cats. Bone chips in general survived or revitalized while retaining their shape, though ankyloses and adhesions were frequent while resorption did sometimes occur (Musebeck and Falck, 1963).

Ossicles may differ. Bellucci and Wolff (1961) replaced stapes in cats. Stengl and Hohmann (1964) performed experimental stapedectomy and incus transposition in cats and monkeys. While viability was observed, massive fibrosis and ankylosis was almost the rule. Revitalization in monkeys was slower and less extensive. Wilson *et al.* (1966) described one autogenous incus transposition in cat—the result was similar. Smyth *et al.* (1967) performed ten experiments with cats with autogenous ossicles and observed initially dead ossicles revitalized—again with extensive ankylosis. Taggart (1969) used autograft incudes in monkeys, and found limited revitalization, together with ankyloses.

Van den Broek and Kuijpers (1967) described autogenous incus replacement in rats. Their findings were paralleled in this series—that is limited, mainly surface vitaility but generally cell death. Even after nine months large areas of dead bone remained. Boiling ensured a dead bone

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replant and considerably less revitalization. Kastenbauer's (1972a and b) rabbits were similar.

Studies summarized above differ to some extent. It seems that revitalization in cats is rapid and nearly complete but associated with gross adhesions and ankylosis. Monkeys revitalize less and though ankyloses are less they appear to be considerable. Rats revitalize relatively little, particularly if the size of the ossicle is taken into account. Fibrosis is less.

This present study adds a little more to the overall picture. Transposition (as opposed to replantation in its natural position) of the incus in rats is similar to repositioning except that revitalization is orientated to points of contact with vascular structures. It confirms that ossicles do not behave like bone chips which, it is claimed, fully revascularize, but remain partly non vital—at least in rats.

Boiling delays and reduces the revitalization process considerably, though whether there is an advantage in less adhesions is not certain. Certainly boiling is likely to simulate the so-called homografts (suitably denatured) that are currently used. The changes during the period of these experiments suggest that whatever revitalization occurs, takes place rapidly and then progresses only slowly or not at all—a static state is reached rapidly in the rat (though probably less rapidly in cats and even less in monkeys). There is no evidence of inflammatory rejection. Overall there is the appearance of a partly viable static and more or less inert ossicle in an uninflamed tympanum, presumably at least potentially functional, its function modified by the degree of adhesion. While the functional (hearing) result has not been assessed, all the evidence from this work points to continuing stability in the middle ear. Nevertheless evidence derived from this work is derived from incudes which were normal in normal ears. Whether such findings can be projected to the situation in the chronic ear depends on what collateral evidence can be derived from human material. This is a subject under separate study.

Summary

Incus replacement or transposition was performed in 82 rats. Findings were similar in that a degree of vitality was retained or regained, though more slowly in boiled implants. Gelatin sponge induced fibrosis. Activity rapid at first ceased later. Generally replanted incudes seemed stable.

Acknowledgements

I am grateful to Mr. R. J. Bennett, who inspired this work. Many thanks are due to Miss C. Holden, who typed the script; and to Mr. Tom Dee and Miss J. McCulloch who assisted with the illustrations.

https://doi.org/10.1017/S0022215100081032 Published online by Cambridge University Press

REFERENCES

AUSTIN, D. F., and SHEA, J. J. Jr. (1961) *Laryngoscope*, **71**, 596–611.

BASHKIRTZEW, N. J., and PETROW, N. N. (1912) *Deutsch Zeitzchrift für Chirurgie*, **113**, 490–531.

BECK, C., and FRANZ, H. (1961) *Archiv für Ohren-Nasen und Kehlkopfheilkunde*, **179**, 111–21.

VON BEKESY, G. (1961) *Laryngoscope*, **71**, 367–76.

BELLUCCI, R. J., and WOLFF, D. (1961) *Annals of Otology, Rhinology and Laryngology*, **70**, 64–80.

BENITES, J. T., and MCINTIRE, C. L. (1968) *Journal of Laryngology and Otology*, **82**, 23–7.

———, BEJAR, I. R., and MCINTIRE, C. L. (1971) *Journal of Laryngology and Otology*, **85**, 1177–82.

VAN DEN BROEK, P., and KUIJPERS, W. (1967) *Archives of Otolaryngology*, **86**, 287–93.

BROWN, W. L., and BROWN, C. P. (1913) *Surgery, Gynaecology, and Obstetrics*, **17**, 681–9.

CODY, D. T. R., and TAYLOR, W. F. (1973) *Laryngoscope*, **83**, 853–64.

ENGLISH, G. M., HILDYARD, V. H., HEMENWAY, W. G., and DAVIDSON, S. (1971) *Laryngoscope*, **81**, 1434–47.

FARRIOR, J. R. (1973) *Archives of Otolaryngology*, **97**, 55–7.

GUILDFORD, F. R. (1964) *Archives of Otolaryngology*, **80**, 80–6.

——— (1965) *Laryngoscope*, **75**, 236–42.

——— (1966) *Laryngoscope*, **76**, 709–18.

———, SHORTREED, R., HALPERT, B. (1966) *Archives of Otolaryngology*, **84**, 144–7.

———, WRIGHT, W. K., and HALPERT, B. (1965) *Archives of Otolaryngology*, **82**, 503–5.

HALL, A., and RYTZNER, C. (1957) *Acta Otolaryngologica*, **47**, 318–24.

———, ——— (1960) *Acta Otolaryngologica*, Supp., **158**, 335–40.

———, ——— (1961) *Archives of Otolaryngology*, **74**, 22–6.

HOUGH, J. V. D. (1970) *Laryngoscope*, **80**, 1385–413.

HUTCHINSON, J. (1952) *British Journal of Surgery*, **39**, 552–61.

KASTENBAUER, E. R. (1972a) *Archiv für Klinische und Experimentelle Ohren-Nasen-und Kehlkopfheilkunde*, **203**, 58–69.

——— (1972b) *Archiv für Klinische und Experimentelle Ohren-Nasen-und Kehlkopfheilkunde*, **203**, 70–80.

KERR, A. G., and SMYTH, G. D. L. (1971) *Journal of Laryngology and Otology*, **85**, 337–47.

KLEY, W., and DRAF, W. (1965) *Acta Otolaryngologica*, **59**, 593–603.

LINTHICUM, F. H. (1966) *Laryngoscope*, **76**, 1232–41.

MUSEBECK, K., FALCK, P. (1963) *Archiv für Ohren-Nasen-und Kehlkopfheilkunde*, **181**, 279–90.

RAY, R., and TAWFIK, Y. S. (1963) *Journal of Bone and Joint Surgery*, **45A**, 337–43.

SMYTH, G. D. L., JONES, J. H., and KERR, A. G. (1967) *Journal of Laryngology and Otology*, **81**, 1325–35.

STENGL, T. L., and HOHMANN, A. (1964) *Archives of Otolaryngology*, **80**, 72–9.

TABB, H. G. (1963) *Laryngoscope*, **73**, 363–83.

TAGGART, J. P. (1969) *Archives of Otolaryngology*, **90**, 445–8.

WEHRS, R. E. (1967) *Archives of Otolaryngology*, **85**, 371–9.

WILSON, D. F., PULEC, J. L., and VAN VLIET, P. D. (1966) *Archives of Otolaryngology*, **83**, 554–9.

WINTER, L. E., and HOHMANN, A. (1967) *Archives of Otolaryngology*, **86**, 44–8.

https://doi.org/10.1017/S0022215100081032 Published online by Cambridge University Press

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WULLSTEIN, H. (1953) *Proceedings of the 5th International Congress of Otorhinolaryngology*. Congress Abstracts, Amsterdam, 1953. Ed. P. G. Gerlings, W. H. Struben, publ. Assen-van Gorcum, 1955.

ZOLLNER, F. (1955) *Journal of Laryngology and Otology*, **69**, 637–52.

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