The Journal of Laryngology and Otology
January 1980. Vol. **94.** pp. 15–23

Evaluation of Eustachian tube function

By J. HOLMQUIST and L. OLÉN

Introduction

IT is widely accepted that disorders of the Eustachian tube contribute to the development and course of middle ear diseases such as different kinds of chronic otitis media (Miller, 1965; Holmquist, 1970; Bluestone *et al.*, 1979). Adequate function of the Eustachian tube is also considered one prerequisite for re-establishing a closed aerated tympanic cavity in tympanoplasty. Controversy exists when it comes to measuring this function and to whether the testing methods available are capable of giving useful clinical information (Sharp, 1970; Andreasson and Harris, 1979). Before discussing different testing techniques it seems appropriate to review some functional aspects of the Eustachian tube.

The functions normally attributed to the Eustachian tube are:

1. To maintain air pressure equality over the tympanic membrane by transport of air through the tube.
2. To drain mucus, normally produced in the tympanic cavity, through the tube into the nasopharynx.
3. To protect the middle ear from nasopharyngeal air and sound pressure changes.

Even though these functions are interrelated a single simple measure has not yet been designed which reflects the state of Eustachian tube function. There is also a lack of basic quantitative information on Eustachian tube physiology, which may account for the current state of testing function, i.e. its questionable validity and frequent unreliability.

The purpose of this paper is to present those tests of Eustachian tube function which the authors have found useful in the clinical routine.

Testing air transport through the Eustachian tube

The absorption of gases from the tympanic cavity into the surrounding tissues is the basis for the need of air transport through the Eustachian tube during typical physiologic conditions. It has been shown that the gas absorption is approximately 0·8 ml/24 hours (Riu *et al.*, 1966; Ingelstedt and Jonsson, 1967; Elner *et al.*, 1971). This amount of gas then has to be replaced by air through the Eustachian tube. It is commonly accepted that this gas is moved through the tube on swallowing. This may be accom-

Supported by grants from the Swedish Medical Research Council B79–17X–5435–01.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

plished in two ways: by a complete separation of the tubal walls along their entire length, or by allowing air bubbles to move through the tube in the same way that a bolus is forced through the oesophagus. There is support for both these theories.

As the volume of air moving through the tube on swallowing is extremely small (less than 1 mm^3), clinically useful measures of volume have not yet been designed. Therefore, indirect measures, which hopefully reflect the capacity of the tube to transport air, must be used.

1. *Tympanometry* measures intratympanic air pressure. As air pressure equivalency across the tympanic membrane indicates adequate air passage through the tube, this method is useful in ears with a mobile intact tympanic membrane. In tympanometry the ear canal air pressure is continually altered while recording the impedance change. Descriptions of the equipment and procedures used are published elsewhere (Lidén *et al.*, 1970; Holmquist, 1973). Fig. 1 illustrates a tympanometric recording from a case with sub-atmospheric air pressure in the middle ear. Recordings from ears with retracted tympanic membranes consistently show negative middle ear pressures, indicating dysfunction of the Eustachian tube.

2. *Sonotubometry* is a measure of sound transport through the Eustachian tube. In this procedure a pure tone is delivered into the nasopharynx and the sound pressure level in the ear canal is monitored continuously. When the tube opens, as during swallowing, the sound pressure in the ear canal reaches a peak. It is assumed that when the results of sonotubometry indicate opening of the tube on swallowing they also indicate that air may pass through the Eustachian tube. A schematic illustration of the set-up is shown in Fig. 2.

This method was described 40 years ago by Perlman (1939), but has not been extensively used in clinical routine. Virtanen (1978) modified the

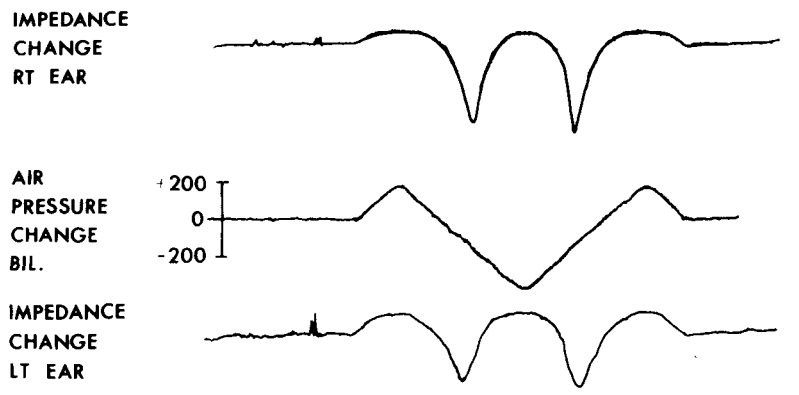


FIG. 1

Tympanometric recording from a case with otoscopic signs of bilateral retraction of the tympanic membranes. Tympanometry reveals sub-atmospheric air pressure in both ears.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

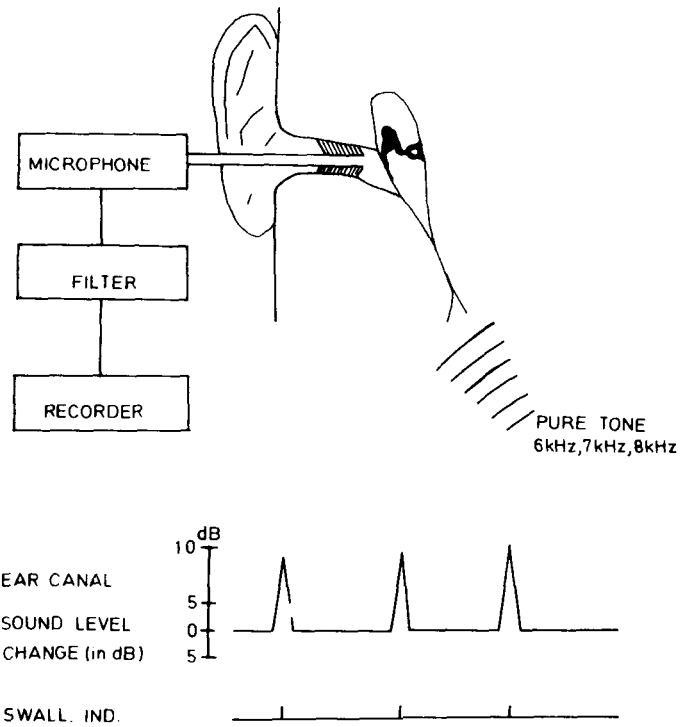


FIG. 2

Schematic illustration of sonotubometry. Sudden sound-pressure change in the ear canal synchronously with swallowing indicates tubal opening.

technique by using higher frequencies for the sound source in the nose. This eliminates disturbances due to swallowing, thus making the interpretation of the results easier. We have reproduced Virtanen's modified technique but have been unable to attain such a high percentage of positive results as he did (Table I). This may be explained by using different criteria for the selection of normals. We do, however, find the technique

TABLE I

SONOTUBOMETRIC RESULTS IN NORMALS

Investigator	Number of Eustachian tubes	Positive response %	Frequency of test tone
Virtanen, 1977	106	90	6, 7, 8 kHz
Olén and Holmquist, 1979	182	67	6, 7, 8 kHz

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

simple and reliable for evaluating tubal opening, and interpret our results as follows:

When sonotubometry indicates tubal opening, this means that air may pass through the Eustachian tube during the usual conditions. On the other hand, when sonotubometry fails to show tubal opening, this does not necessarily indicate insufficient tubal function. Despite negative sonotubometry in 33 per cent of our normal individuals, they all had an aerated tympanic cavity. This might mean that in these individuals the air passes through the tube without a complete separation of the tubal walls on swallowing.

Beside the need to function as a passage for small air volumes, as mentioned above, the Eustachian tube must also transport air in atypical situations when the ambient air pressure changes, as in flying or diving. The demands on the Eustachian tube to transport air will then increase. It has also been suggested that this capacity to transport air at high air pressure gradients over the tube may be a useful clinical measure of Eustachian tube function (Flisberg *et al.*, 1963; Miller, 1965; Holmquist, 1969).

Testing the ability of the Eustachian tube to function in these extreme situations may be accomplished by the 'Air pressure equalization technique' (Holmquist, 1969; Münker, 1972; Holmquist, 1977).

The testing procedure is divided into two steps:

(a) to establish an air pressure gradient over the tube, and
(b) to record the equalization pattern upon swallowing.

In ears with a tympanic membrane defect, establishment of an air pressure gradient over the Eustachian tube may be accomplished by using an air pressure pump with an airtight seal in the ear canal. The established air pressure may also be recorded on a manometer. The pattern of equalization upon swallowing is then studied. In ears with an intact tympanic membrane the establishment of an air pressure gradient is more complicated. For this purpose it may be necessary to use a pressure chamber, but for routine clinical use the manoeuvres of Toynbee, Valsalva or simple 'sniffing' can be used. The equalization pattern is then recorded by impedance measurement and by observing impedance changes with swallowing.

The standardized testing procedure in ears with a tympanic membrane defect is illustrated schematically in Fig. 3. When testing normal individuals it has been found that the opening air pressure is around 400 mm H_2O and the Eustachian tube closing pressure is then normalized by swallowing. A negative air pressure is then created in the ear and the equalization pattern upon swallowing recorded. Fig. 4 illustrates the mean values of the equalization patterns for different groups of ears.

From what has been said above, the air pressure equalization test

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

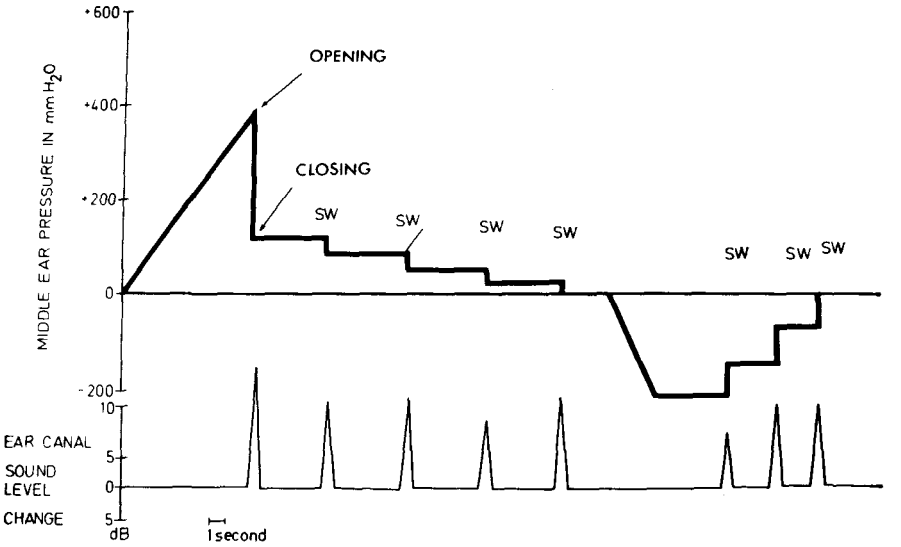


FIG. 3

Schematic illustration for the testing procedure in the 'air pressure equalization technique'. Simultaneously sonotubometry is shown on the lower section.

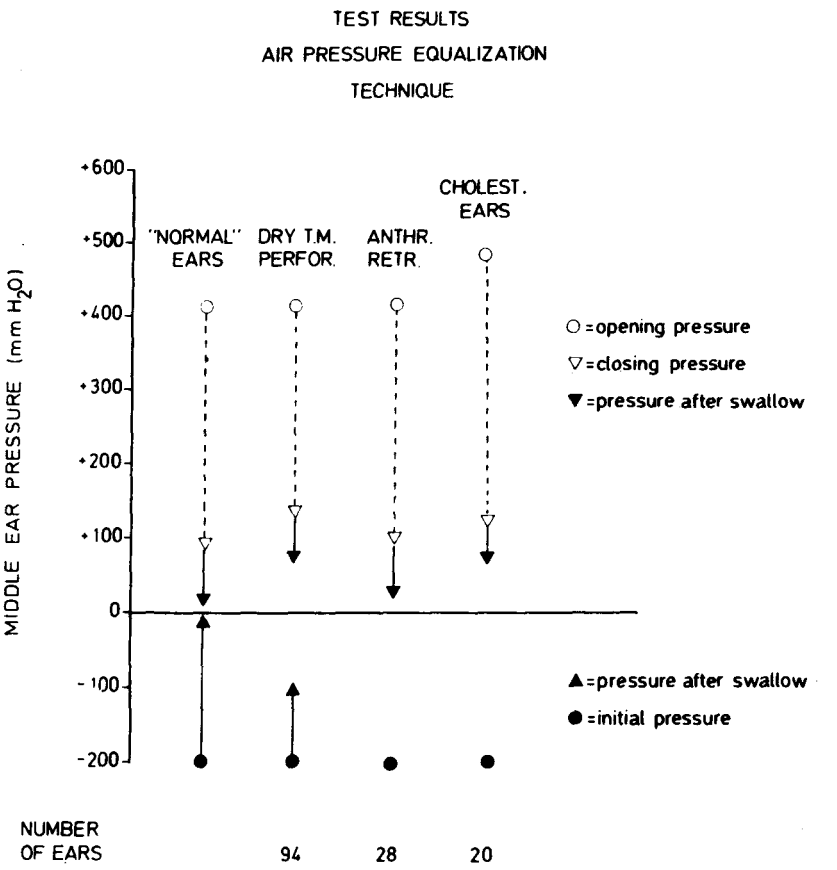


FIG. 4

Mean values of testing Eustachian tube function in different groups of ears.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

evaluates the capacity to normalize high air pressure gradients over the Eustachian tube. As argued previously this test may be useful in predicting the outcome and long-term success in tympanoplasty (Miller and Bilodeau, 1963; Holmquist, 1968; McKinnon, 1970; Niwa, 1972; Bluestone *et al.*, 1979). For the past 15 years we have been using this test for the pre-operative evaluation of tubal function. We interpret the test as follows:

Surgery is never refused only on the basis of poor testing results. In ears with poor pre-operative tubal function the surgical procedure always includes exploration of the tympanic orifice to exclude anatomical occlusion by polyps, adhesions, etc. which may be easily corrected. Further, in the post-operative follow-up, ears with poor function are observed more closely than those with good function. Retraction pockets, middle ear effusion and other complications are more common in these ears as compared to those with good function (Ekvall, 1970; Tos, 1978; Blatnik *et al.*, 1977).

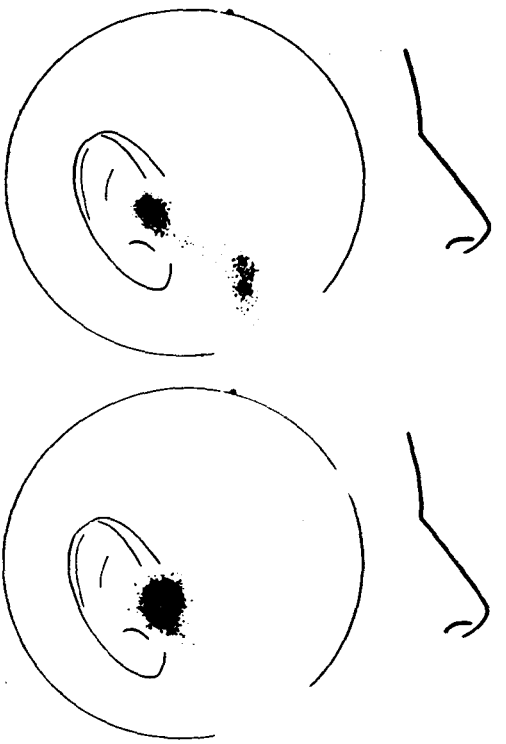


FIG. 5

Scintigraphic pictures from two cases. Upper section illustrates good function, lower section poor clearance.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

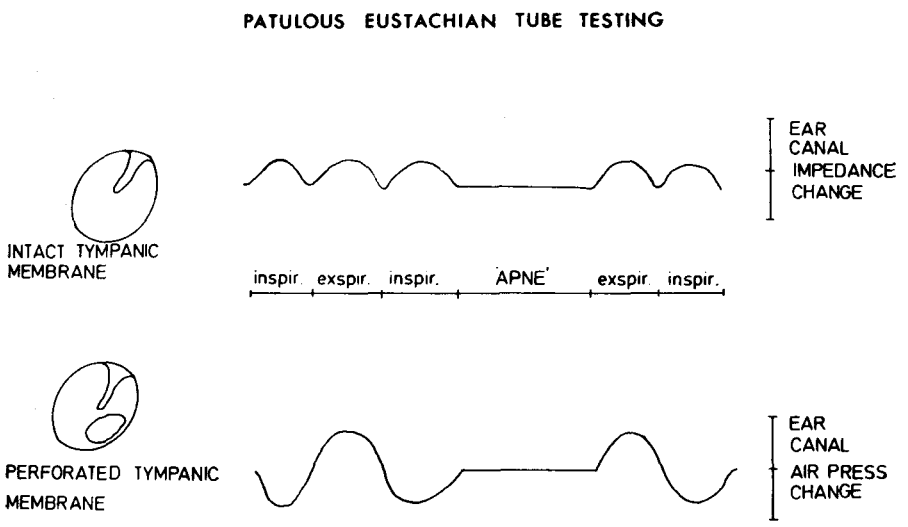


FIG. 6

Recordings from ears with patulous tubes. Upper section using impedance measure in the ear with an intact tympanic membrane. Lower section using air pressure measure in the ear canal in a case with tympanic membrane perforation.

Testing drainage function of the Eustachian Tube

The anatomical basis for considering the Eustachian tube as a drainage tube is the presence of secretory cells in the middle ear as well as in the tube itself. These secretory cells provide the lining with a mucous blanket which, as a result of ciliary action, moves towards the nasopharynx. The capacity of the tube to drain mucus is influenced by many factors: cilial activity, gravity, air pressure gradients along the tube, viscosity and other characteristics of the fluid as well as of the tubal walls. The testing of drainage function is therefore time-consuming, and simple clinical measures have not yet been developed. The technique we are using includes the instillation of a technetium-marked albumin solution into the tympanic cavity and the observation of clearance capacity with a scintigraphic camera. Further details of the procedure have been presented elsewhere (Holmquist, 1977; de Collogny *et al.*, 1977). Fig. 5 illustrates the normal scintigraphic picture on the upper and a pathologic one on the lower section. This technique has certain merits but its clinical value has not yet been proved.

Testing protective function of the Eustachian Tube

The normal Eustachian tube is closed most of the time. In this state it protects the ear from changes in air and sound pressure. Appreciation of this function is an integral part of the evaluation of Eustachian tube function.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

TABLE II

SUMMARY OF EUSTACHIAN TUBE EVALUATION

	Testing techniques	Intact T.M.	Non-intact T.M.
Testing air transport	Tympanometry	Yes	No
	Sonotubometry	Yes	Yes
	Air pressure equaliz.	Yes	Yes
Testing clearance	Scintigraphy	Yes	Yes
Testing protective function	Impedance measure	Yes	No
	Air pressure measure	No	Yes

In the ear with an intact tympanic membrane the assessment of a non-patulous tube is easily done with impedance measurements. If an impedance change occurs synchronously with breathing the tube is patulous. Fig. 6 illustrates the impedance changes with breathing resulting from a patulous tube. Obviously in the patient with a perforated drum and a patulous tube a pressure change directly reflecting respiration may be recorded in the external acoustic meatus.

REFERENCES

ANDREASSON, L., and HARRIS, S. (1979) Middle ear mechanics and Eustachian tube function in tympanoplasty. *Acta Otolaryngologica*, Stockholm, Sweden. Supplement **360,** 141–147.

BLATNIK, D. S., MILLEN, S. J., and TOOHILL, R. J. (1977) Ventilating tubes in tympanoplasty. *Laryngoscope*, **87,** 1847–1852.

BLUESTONE, C. D., CANTEKIN, E. I., BEERY, Q. C., and STOOL, S. E. (1979) Function of the Eustachian tube related to surgical management of acquired aural cholesteatoma in children. *Laryngoscope*, **88,** 1155–1164.

BLUESTONE, C. D., CANTEKIN, E. I., and DOUGLAS, G. S. (1979) Eustachian tube function related to the results of tympanoplasty in children. *Laryngoscope*, **89,** 450–458.

DECOLLOGNY, L. G., LAFAYE, M., VEYRE, A., BRUNHAUD, D., CALLIER, J., and MENIEL, G. (1977) Physiological exploration of the Eustachian tube using labeled compounds. Applications in the control of treatment. *Annals of Otology, Rhinology and Laryngology*, **94,** 233–243.

EKVALL, L. (1970) Eustachian tube function in tympanoplasty. *Acta Otolaryngologica*, Stockholm, Sweden. Supplement **263,** 33–42.

ELNER, Å., INGELSTEDT, S., and IVARSSON, A. (1971) Indirect determination of the middle ear pressure. *Acta Otolaryngologica*, **72,** 255–261.

FLISBERG, K., INGELSTEDT, S., and ÖRTEGREN, U. (1963) Controlled 'Ear Aspiration' of air. *Acta Otolaryngologica*, Stockholm, Sweden. Supplement **182,** 35–38.

HOLMQUIST, J. (1968) The role of the Eustachian tube in myringoplasty. *Acta Otolaryngologica*, **66,** 289–295.

HOLMQUIST, J. (1969) Eustachian tube function in patients with ear drum perforations following chronic otitis media. Results of a simplified testing procedure by deflation and aspiration methods. *Acta Otolaryngologica*, **68,** 391–401.

HOLMQUIST, J. (1969) Eustachian tube function assessed with tympanometry, a new testing procedure in ears with intact tympanic membrane. *Acta Otolaryngologica*, **68,** 501–508.

HOLMQUIST, J. (1970) Middle ear ventilation in chronic otitis media. *Archives of Otolaryngology*, **92,** 617–623.

HOLMQUIST, J. (1973) Assessment of Eustachian tube function behind an intact tympanic membrane. *O.R.L. Digest*, **35,** 21–24.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

HOLMQUIST, J. (1977) Eustachian tube evaluation. In *Proceedings of the Shambaugh 5th International Workshop*. Editors: Shambaugh and Shea. 135–138.

HOLMQUIST, J. (1977) Assessment of the draining function of the Eustachian tube. In *Proceedings of the XI World Congress in Otorhinolaryngology*.

INGELSTEDT, S., and JONSON, B. (1967) Mechanism of the gas exchange in the normal human middle ear. (Read before Nordisk Otolaryngologisk Förening, Helsinki, 1966.) *Acta Otolaryngologica*, Stockholm, Sweden. Supplement **224,** 452–561.

LIDÉN, G., PETERSON, J. L., and BJÖRKMAN, G. (1970) Tympanometry. *Archives of Otolaryngology*, **92,** 248–257.

MCKINNON, D. M. (1970) Relationship of preoperative Eustachian tube function to tympanoplasty. *Acta Otolaryngologica*, **69,** 100–107.

MILLER, G. F., JR., and BILODEAU, R. (1963) Preoperative evaluation of Eustachian tube function in tympanoplasty. *South Medical Journal*, **60,** 868.

MILLER, G. W. (1965) Eustachian tubal function in normal and diseased ears. *Archives of Otolaryngology*, **81,** 41–48.

MÜNKER, G. (1972) Funktionsanalyse der Tuba Eustachii. *Medizinische Habilitationsschrift*, Freiburg.

NIWA, H. (1972) The study on the measurement of the Eustachian tubal function. *Japanese Journal of Otolaryngology*, **75,** 10–11.

PERLMAN, H. B. (1939) The Eustachian tube. Abnormal patency and normal physiologic state. *Archives of Otolaryngology*, **30,** 212–238.

RIU, R., FLOTTES, L., BOACHE, J., and LEDEN, R. (1966) La physiologie de la trompe d'Eustache. Librairie Arnette, Paris.

SHARP, M. (1970) The manometric investigation of tubal function. *Journal of Laryngology and Otology*, **84,** 545–551.

TOS, M. (1978) Die operative Therapie der chronischen Otitis und des Mettelohrcholesteatoms mit Erhaltung der hinteren Gehörgangswand ('Intact wall technique'). *HNO*, **26,** 217–223.

VIRTANEN, H. (1978) Eustachian tube sound conduction. *Acta Otolaryngologica*, **86,** 93–103.

Reprint requests to:

Jörgen Holmquist, M.D.,
Department of Otolaryngology,
Sahlgren's Hospital,
S–413 45 Göteborg,
Sweden.

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press

https://doi.org/10.1017/S0022215100088411 Published online by Cambridge University Press