

Measurements of selected parameters of the guinea pig temporal bone

Jarosław Wysocki^{1, 2}, Mansoor Sharifi²

¹Institute of Physiology and Pathology of Hearing, Warsaw, Poland

²Department of Anatomy, Centre for Biostructure, Medical University of Warsaw, Poland

[Received 4 July 2005; Accepted 22 July 2005]

On the basis of dissections of 32 temporal bones of the guinea pig, measurements were taken of selected size parameters of the temporal bone. The measurements performed included external and internal size parameters of the bone. Among these were the following: the length, width and height of the external and internal auditory meatus, the length of the incudomalleal complex, the height of the attic, the full length and height of the tympanic cavity and the parameters characterising the localisation of the external orifice of the facial nerve.

The semicircular canals are relatively large, the lateral canal being the largest and the posterior the smallest. The length of the spiral canal of the cochlea does not exceed 16 mm. It is worth noting that both the vertical and horizontal dimensions of the scala vestibuli and scala tympani only exceed 1 mm in the basal turn, decreasing significantly in the further turns to as little as decimal parts of a millimetre. This should be taken into account during all tests which require the introduction of examining instruments into the cochlear scala.

Key words: temporal bone, anatomy, measurements, guinea pig

INTRODUCTION

The guinea pig is frequently the animal of choice for pre-clinical experiments. The ear of the guinea pig constitutes a good experimental subject because of the considerable size of the tympanic bulla, whose opening provides wide access to the tympanic cavity and the opportunity to observe the movements of the ossicles or to reach the inner ear [5, 10]. Although considerable experience has been gained through experimental research, knowledge of the topographical and descriptive anatomy of the guinea pig temporal bone still does not extend beyond the cursory descriptions found in atlases or manuals on the anatomy of laboratory species [2, 7, 9]. Few

works have been devoted exclusively to the anatomy of the guinea pig ear [1, 3, 5, 6, 11]. No data on the anatomy of the guinea pig temporal bone can be found in traditional academic textbooks on the anatomy of domestic animals [4, 8]. Especially striking is the lack of measurement data that is useful in a variety of experiments. My previous anatomical description of the guinea pig temporal bone was performed without measurement data [13]. This study attempts to fill that gap. Detailed measurements of the size parameters of the guinea pig temporal bone were made with the purpose of providing researchers with the necessary data, especially as far as the spiral canal of the cochlea is concerned.

Address for correspondence: Jarosław Wysocki, MD, PhD, Department of Anatomy, Medical University of Warsaw, ul. Chałubińskiego 5, 02–004 Warszawa, Poland, tel/fax: +48 22 629 52 83, e-mail: jwysocki@ib.amwaw.edu.pl

Supported by funds from the Institute of Physiology and Pathology of Hearing, Warsaw, Poland.

MATERIAL AND METHODS

Study was made of 32 temporal bones (16 left and 16 right) obtained from 16 adult guinea pigs (8 male and 8 female). The animals were previously used for experimentation carried out at the Drug Institute, Warsaw, Poland and were routinely sacrificed after the experiments, so in the present study there was no need for special permission from the Committee for Bioethics. The material was preserved in 10% formaldehyde solution and prepared under an operating microscope. After the superior semicircular canal and the cochlear aqueduct had been found and opened, both structures were cannulated. Liquid latex (latex milk) was introduced through the superior semicircular canal. After filling the cochlear scala, this flowed out through the cochlear aqueduct. The method of injecting the cochlear scala was that described in my previous research [12]. Next the bones were dissected, which enabled measurements to be taken. All the measurements were performed using an ocular with a gauge calibrated at every 0.05 mm. The principle and method of measurement are presented schematically in Figures 1 and 2. Thus a given cast of the structures of the bony labyrinth was examined separately and measured, also using the gauge. The heights of the scala vestibuli and scala tympani were measured. The height was defined as a maximal measurement perpendicular to the spiral lamina. The horizontal measurement, the scala width, is defined as the maximal measurement parallel to

the spiral lamina. The measurement results were systematically drawn up, provisionally counting the description statistics (the average, standard deviation and the range and coefficient of diversity). The differences between the counted averages were analysed using standard parametric tests (Student's *t*-test and the test of differences for co-dependent pairs). Correlations were tested by using Pearson's test. The results have been shown in the form of consecutive figures and tables. Comparison of these with the data available in the literature enabled us to reach certain conclusions.

RESULTS

The guinea pig temporal bone is composed of 3 parts: petrous, tympanic and squamous. The squamous part is relatively small. However the petrous and the tympanic parts are quite considerable in size. Measurements of the selected parameters characterising the temporal bone are presented in Table 1. The greatest air space of the guinea pig temporal bone is the tympanic bulla (Fig. 3). Above the tympanic bulla there is an additional air cell, the so-called "dorsal tympanic bulla" and several additional small compartments (Fig. 3). These two air spaces are almost totally separated, excluding one small orifice, which is almost filled by a penetrating incudomalleolar complex, the body of the incus and the head of the malleus being already in the dorsal bulla. The dorsal bulla, which can be termed, by analogy with the

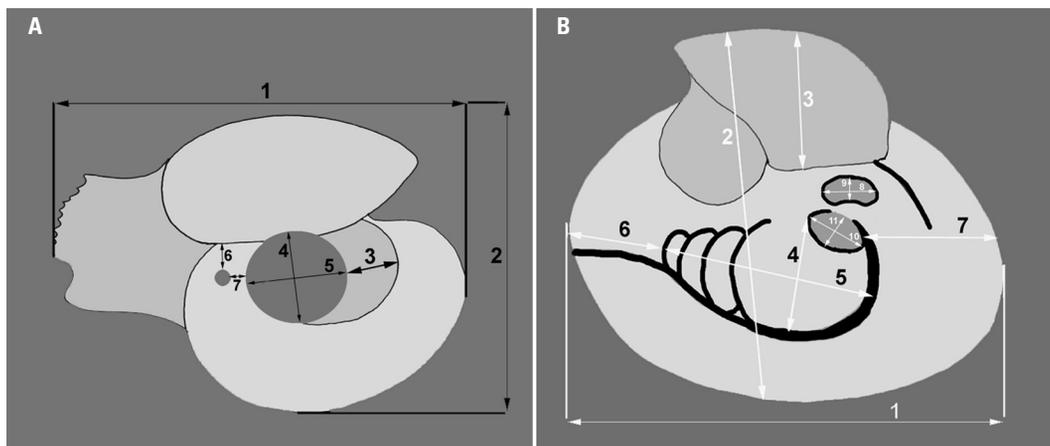


Figure 1. Scheme of measurements of selected parameters of the guinea pig temporal bone. **A.** Parameters of the whole temporal bone in lateral view; 1 — length of the temporal bone, 2 — height of the temporal bone, 3 — length of the external auditory meatus, 4 — height of the external auditory meatus, 5 — width of the external auditory meatus, 6 — distance between stylomastoid foramen and the superior limitation of the auditory bulla, 7 — distance between the stylomastoid foramen and the posterior wall of the external auditory meatus; **B.** Parameters of the interior of the middle ear spaces; 1 — length of the ventral tympanic bulla, 2 — height of the tympanic cavity, 3 — height of the dorsal bulla, 4 — diameter of the basal turn of the cochlea, 5 — height of the bony cochlea, 6 — distance between the apex of the cochlea and the anterior wall of the ventral tympanic bulla, 7 — distance between the posterior aspect of the round window and the posterior wall of the ventral tympanic bulla, 8 — width of the oval window, 9 — height of the oval window, 10 — width of the round window, 11 — height of the round window.

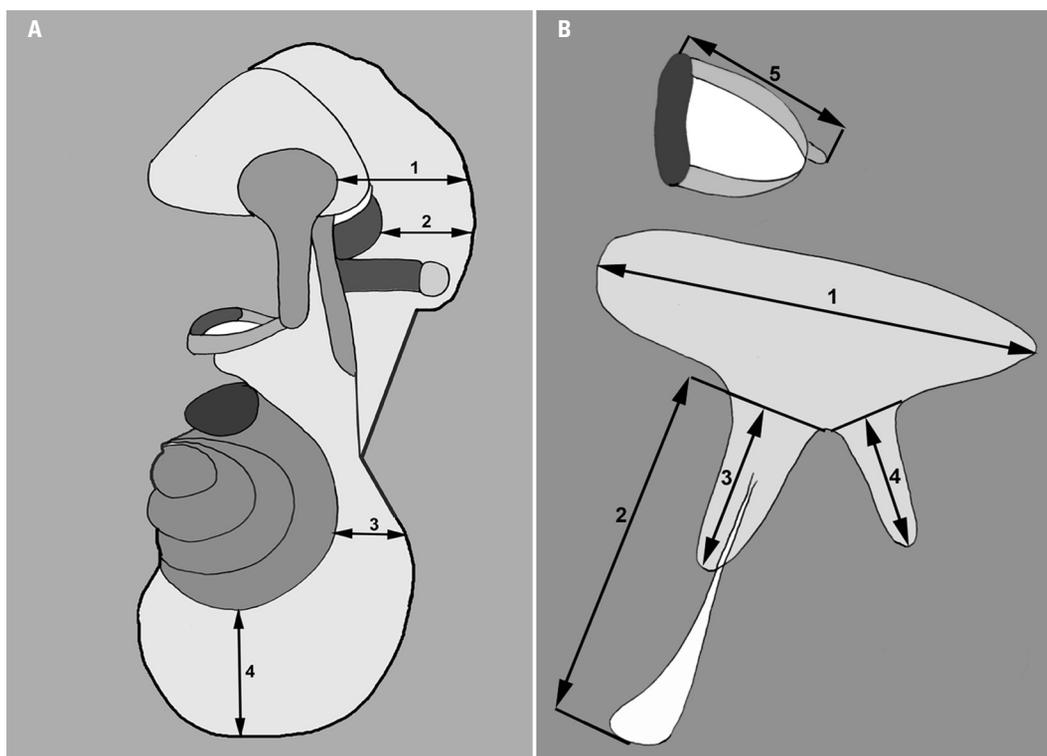


Figure 2. Scheme of measurements of selected parameters of the guinea pig temporal bone. **A.** Parameters of the interior of the tympanic cavity from its anterior-posterior view; 1 — distance between the head of the malleus and the lateral wall of the dorsal bulla, 2 — distance between the lateral semicircular canal and the lateral wall of the dorsal bulla, 3 — distance between the cochlear bone and the lateral wall of the ventral bulla, 4 — distance between the cochlear bone and the inferior wall of the ventral bulla; **B.** Parameters characterising the auditory ossicles; 1 — length of the malleo-incudal complex, 2 — full length of the malleus handle, 3 — length of the bony malleus handle, 4 — length of the long process of the incus, 5 — height of the stapes.

Table 1. Results of measurements of selected size parameters of the guinea pig temporal bone. All values are in millimetres. Arithmetical means are in bold, values of standard deviations in parentheses and ranges given below

Structure	Parameter	Value
Whole bone	Full length of bone	14.57 (0.56); 13.45–15.6
	Full height of bone	10.67 (0.40); 10.05–11.65
	Length of petrous part	11.39 (1.0); 9.85–14.1
External auditory meatus	Length	5.77 (0.45); 4.45–7.45
	Width	3.04 (0.39); 2.15–4.3
	Height	2.58 (0.32); 2.2–3.45
Localisation of external orifice of facial canal	Distance between external orifice of facial canal and posterior wall of external auditory meatus	1.37 (0.26); 1.15–2.35
	Distance between external orifice of facial canal and upper limitation of ventral tympanic bulla	2.17 (0.34); 1.45–3.1
Internal auditory meatus	Length	4.0 (0.57); 3.05–5.15
	Height	2.81 (0.23); 2.0–3.25
	Width	2.24 (0.25); 1.95–2.85

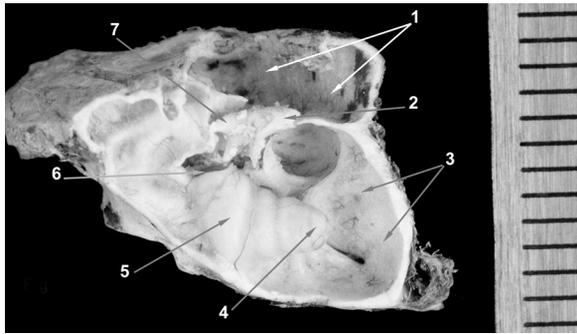


Figure 3. Air spaces of the guinea pig temporal bone. Right temporal bone, lateral view; 1 — dorsal tympanic bulla, 2 — head of the malleus, 3 — ventral tympanic bulla, 4 — cochlear apex, 5 — promontory, 6 — round window niche, 7 — incus.

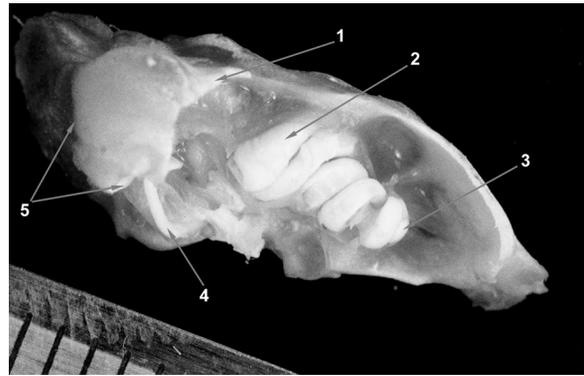


Figure 4. Rubber mould of the guinea pig cochlea within its bony cavity; 1 — anterior semicircular canal, 2 — basal cochlear turn, 3 — apical cochlear turn, 4 — posterior semicircular canal, 5 — lateral semicircular canal.

human anatomy, an epitympanic recess or an attic, is not uniform but consists of one or, more frequently, several air chambers separated by incomplete bony walls.

The ventral bulla of the middle ear is enclosed by thin walls, creating the proper tympanic cavity. Measurements of selected size parameters of the tympanic cavity of the guinea pig temporal bone are presented in Table 2. The bony cochlea protrudes into the medial part of the tympanic bulla, creating the central point of the medial wall of the tympanic cavity. The bony layer covering the spiral canal of cochlea is very thin. The spiral lamina is fixed to the centrally situated spindle and with the spiral canal forms from $3\frac{1}{4}$ up to $3\frac{3}{4}$ of a turn. The rubber mould of the perilymphatic spaces of cochlea is presented

in Figure 4. The length of the spiral canal of the cochlea measured from 12 to 16 mm, an average of 14.3 mm. The dimensions of the *scala vestibuli* and *scala tympani* are shown in Figure 5. The analysis of the casts enables us to conclude that superior to the basal turn both the vertical and horizontal dimensions of both perilymphatic spaces decrease drastically, falling below 1 mm. The vestibule forms the entrance to the cochlea caudally and the semicircular canals rostrally. The lateral semicircular canal is situated in the horizontal plane, although the anterior and posterior ones are in the vertical plane. Measurements of selected size parameters of the inner ear structures of the guinea pig temporal bone are displayed in Table 3.

Table 2. Results of the measurements of selected size parameters of the tympanic cavity of the guinea pig temporal bone. All values are in millimetres. Arithmetical means are in bold, values of standard deviations in parentheses and ranges given below

Structure	Parameter	Value	
Auditory ossicles	Malleus	Length of bony malleus handle	1.0 (0.12); 0.85–1.25
		Full length of malleus handle	2.14 (0.3); 1.4–2.65
	Incus	The length of the long process	0.89 (0.13); 0.7–1.25
		Stapes	The branch length
	Malleus and incus	Full length of malleoincudal complex	3.43 (0.21); 3.15–3.9
		Distance between malleus handle and long process of incus	1.1 (0.1); 1.05–1.25
Tympanic cavity	Height of attic	2.6 (0.41); 2.15–4.1	
	Full height of tympanic cavity	9.4 (0.67); 7.6–11.0	
	Full length of tympanic cavity	9.9 (0.95); 8.65–12.5	
	Distance of malleoincudal complex from lateral attic wall	2.34 (0.68); 1.35–3.35	
	Distance of lateral semicircular canal from lateral attic wall	1.4 (0.29); 0.65–1.75	

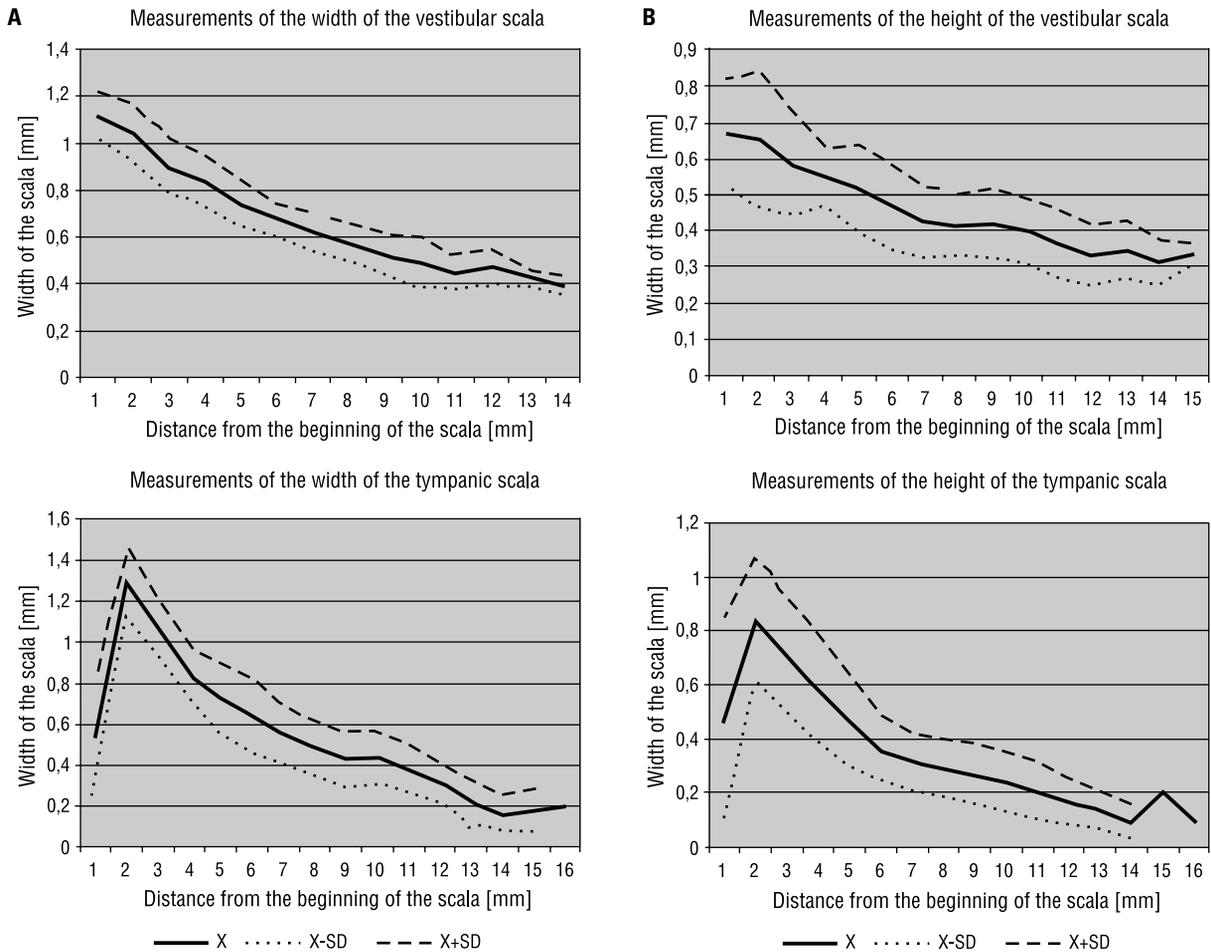


Figure 5. Measurements of the vestibular and tympanic scalae of the guinea pig temporal bone. The width (**A**) and height (**B**) of the scalae are displayed as a function of a distance from the beginning of the scalae.

DISCUSSION

We have not found any data on guinea pig temporal bone measurements and only slight information about the guinea pig cochlea. The morphology of the guinea pig cochlea observed in the present research contradicts the data of Counter et al. [3], who used MRI images and showed the presence of 4 or more turns of the cochlear scalae. This accords with the thesis that there are about $3\frac{1}{2}$ turns [5, 6] (in our observations $3\frac{1}{4}$ to $3\frac{3}{4}$ turns). The *scala tympani* in the guinea pig, despite forming over 3 turns, is characterised by a relatively small length. Both scalae dimensions, the vertical and the horizontal, behave similarly to those of humans and other animal species [12]. One difference is the dominance of the *scala tympani* from the very beginning; its dimensions already dominate those of the *scala vestibuli* in its basal turn. The dimensions of the *scala vestibuli* and *scala tympani* are indirectly consistent with Counter's et al. data [3]. The print of the cross-section of the spiral canal of the cochlea in the work

cited indicates, after analysis (according to our interpretation of the side ruler appended by the author), that the results obtained by us are consistent with his: the vertical measurement of the *scala vestibuli* is approx. 0.5 mm, that of the *scala tympani* approx. 1 mm and the horizontal measurements are approx. 1 and 1.25 mm, respectively. Counter et al. [3], however, did not total the whole length of the scala, which is essential when planning experiments involving the introduction of an electrode into the interior of the cochlea. The scala media occupy a relatively small space, not exceeding an estimated 5% of the surface of the scalae cross-section. Analysis of MRI images suggests that the long axis of the cochlea runs almost in the sagittal line, deviating from it laterally merely by a dozen or so degrees. The cochlear axis is, then, significantly less aslant than in humans. This is confirmed by our own observations [12].

One needs to confirm the observation made by Asarch et al. [1] that the lateral semicircular canal

Table 3. Results of measurements of selected parameters characterising the magnitude of internal ear of the guinea pig. All values are in millimetres. Arithmetical means are in bold, values of standard deviations in parentheses and ranges given below

Structure		Parameter	Value
Semicircular canals	Superior	Vertical diameter	3.35 (0.83); 2.05–4.25
		Horizontal diameter	2.86 (0.57); 2.15–3.75
	Posterior	Vertical diameter	2.35 (0.26); 2.05–2.75
		Horizontal diameter	2.34 (0.28); 1.75–2.55
	Lateral	Vertical diameter	3.76 (0.39); 3.25–4.25
		Horizontal diameter	2.35 (0.25); 2.0–2.65
Cochlea		Diameter of the base of cochlea	4.25 (0.8); 3.05–5.35
		Height	4.43 (0.64); 3.5–5.25
		Distance from apex to anterior wall of ventral tympanic bulla	2.53 (0.24); 2.25–3.35
		Distance from round window to posterior wall of ventral tympanic bulla	3.25 (0.58); 2.45–4.4
		Distance from basal turn of cochlea to inferior wall of ventral tympanic bulla	1.25 (0.39); 0.85–2.35
		Distance from basal turn of cochlea to lateral wall of ventral tympanic bulla	1.78 (0.55); 1.15–3.35
Oval window		Length	0.62 (0.12); 0.45–0.85
		Width	0.85 (0.22); 0.55–1.1
Round window		Length	0.75 (0.17); 1.05–1.35
		Width	1.1 (0.25); 0.55–1.45

lies approx. 3 mm from the postero-inferior cochlear edge, although this size parameter was not within the scope of this work. The data characterising the size parameters of the guinea pig temporal bone arrived at in this research are for the most part innovative and have not been included in the available literature. These data, in the opinion of the authors, are essential and may be valuable for experiment planners using this model.

REFERENCES

- Asarch R, Abramson M, Litton WB (1975) Surgical anatomy of the guinea pig ear. *Ann Otol*, 84: 250–255.
- Cooper G, Schiller A (1975) *Anatomy of the guinea pig*. Cambridge, Mass., Harvard Univ. Press.
- Counter AA, Bjelke B, Klason T, Chen Z, Borg E (1999) Magnetic resonance imaging of the cochlea, spiral ganglia and eighth nerve of the guinea pig. *Neuro Report*, 10: 473–479.
- Dyce KM, Sack WO, Wensing CJG (1996) *Veterinary anatomy*. Ed 2nd. W.B. Saunders Company, Philadelphia, London, Toronto, Montreal, Sydney, Tokyo.
- Goksu N, Hazirolu R, Kemaloglu Y, Karademir N, Bayramoglu I, Akyildiz N (1992) Anatomy of the guinea pig temporal bone. *Ann Otol Rhinol Laryngol*, 101: 699–704.
- Salt AN, Henson MM, Gewalt SL, Keating AW, DeMott JE, Henson OW (1995) Detection and quantification of endolymphatic hydrops in the guinea pig cochlea by magnetic resonance microscopy. *Hear Res*, 88: 79–86.
- Popesco P, Rajtová V, Horák J (2002) *Color atlas of small laboratory animal anatomy*. Vol. 1. Rabbit and guinea pig. Saunders, London, pp. 150–175.
- Sisson S, Grossman JD (1945) *The anatomy of the domestic animals*. 3 Ed. W.B. Saunders Company, Philadelphia.
- Smallwood JE (1992) *A guided tour of veterinary anatomy*. W.B. Saunders Company. Philadelphia, London, Toronto, Montreal, Sydney, Tokyo, pp 350–358.
- Suzaki Y, Hozawa K, Takasaka T, Ohyama K, Kobayashi T, Wada H (1997) Dynamic behavior of the guinea pig middle ear. In: Tos M, Thomsen J, Balle V (eds.). *Otitis media today*. Kugler Publ., Hague, pp. 333–339.
- Wells JR., Gernon WH, Ward G, Davis K, Hays L (1986) Otological model in the guinea pig (*Cavia porcellus*). *Otolaryngol Head Neck Surg*, 95: 450–457.
- Wysocki J (2001) Dimensions of the vestibular and tympanic scalae of the cochlea in selected mammals. *Hear Res*, 161: 1–9.
- Wysocki J (2005) topographical anatomy of the guinea pig temporal bone. *Hear Res*, 199: 103–110.