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Surgical Management of a Persistent Stapedial Artery: A Review

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Objective: To evaluate the outcome and per- and postoperative complications of the surgical management of patients with a persistent stapedial artery (PSA).
Methods: A systemic literature search for reports on patients treated for pulsatile tinnitus and/or conductive hearing loss caused by a PSA was conducted of the PubMed and Embase databases using the terms ''stapedial'' and ''artery.'' Inclusion criteria were adequate description of the intervention and pre- and postoperative signs and symptoms. In addition, one case of a PSA, treated at VU University Medical Center Amsterdam, The Netherlands, was included in this series.
Intervention: Middle ear surgery consisting of stapedotomy or stapedectomy, and/or transection of the PSA.
Main Outcome Measures: Pre- and postoperative hearing levels, pre- and postoperative pulsatile tinnitus, and per- and postoperative complications.
Results: Seventeen patients and 18 operated ears were evaluated (16 patients described in 14 articles and our case). Twelve out of 14 ears in which a stapedotomy or stapedectomy was initiated experienced improvement in hearing. In four cases pulsatile tinnitus was described pre- and postoperatively. In all four, pulsatile tinnitus subsided after transection of the PSA. Peroperative bleeding from the PSA was described in four patients, which could be controlled during the procedure. No significant postoperative sequelae were reported.
Conclusions: In case of a PSA, improvement of conductive hearing loss is best achieved by stapes surgery, while pulsatile tinnitus is effectively treated with transection of the PSA. To date no long-term postoperative complications have been reported. **Key Words:** Conductive hearing loss—Pulsatile tinnitus—Stapedectomy—Stapedial artery—Stapedotomy—Stapes ankylosis.

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The stapedial artery connects the internal carotid artery with the external carotid artery in early embryonic development. The stapedial artery plays an important role in the cranial vasculature of the human embryo, but degenerates in the 10th week of fetal life (1). In rare cases, this artery persists as a persistent stapedial artery (PSA). The prevalence of this anomaly is estimated to be 0.02 to 0.48% (2,3). When a stapedial artery persists, it can cause conductive hearing loss by limiting the movement of the stapes, thereby mimicking otosclerosis. It can also produce pulsatile tinnitus (3,4). Four subtypes of PSA have been described (5). They all have in common that the PSA runs over the promontory and courses through the obturator foramen of the stapes to enter the facial canal through a dehiscence in its wall just posterior from the cochleariform process. The PSA then courses anteriorly in the facial canal and after exiting the canal just before the geniculate ganglion, it travels anteriorly and cranially into the extradural space of the middle cranial fossa (1,4,5). If the stapedial artery persists into postnatal life, it supplies the middle meningeal artery. The foramen spinosum, which normally contains the middle meningeal artery, is absent or underdeveloped (5,6).

Middle ear surgery in case of a PSA has been controversial because of the possible per- and postoperative complications. Transecting a PSA could lead to profuse bleeding peroperatively and, in theory, cause infarction of the facial nerve or parts of the temporal lobe of the brain or the brainstem, leading to postoperative

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complications such as facial paralysis, hemiplegia or central auditory, and vestibular impairment (1,5).

In this study, we review the literature and our own experience with the surgical management of a PSA, the outcome on hearing levels and pulsatile tinnitus, and the per- and postoperative complications.

MATERIALS AND METHODS

A systemic search of the English literature was performed for articles published up to September 1st, 2016. The databases PubMed and Embase were searched with the keywords ''stapedial'' and ''artery.'' Articles were included if a PSA was identified with certainty during the procedure and if treatment of this anomaly and its symptoms, i.e., conductive hearing loss and/or pulsatile tinnitus, was attempted. Reports that did not specify the surgical technique or outcome of the procedure were excluded. Patients were analyzed for hearing loss (pre- and postoperatively), pulsatile tinnitus (pre- and postoperatively), the existence of footplate ankylosis, and per- and postoperative complications. Hearing levels were determined by pure tone audiometry (PTA) and calculated by averaging both air and bone conduction thresholds at 500, 1,000, and 2,000 Hz (the Fletcher Index). One patient with a PSA treated at the VU University Medical Center Amsterdam, The Netherlands was added to the analysis. A detailed description of patient characteristics, clinical presentation, and the additional case, can be found as supplemental digital content, http://links.lww.com/MAO/A529.

RESULTS

Results of Literature Review

The search of the PubMed and Embase databases yielded 154 and 184 articles, respectively. After applying the in- and exclusion criteria, 14 articles were eligible for evaluation (3–16). A total of 17 patients, including our patient, and 18 operated ears were eligible for evaluation.

Surgical Procedure

Three main surgical strategies for the management of a PSA were identified: 1) stapes surgery (either stapedotomy, stapedectomy, or malleostapedotomy) without transection of the PSA (reported in eight patients and nine ears); 2) transection of the PSA without stapes surgery (reported in four patients, four ears), and 3) stapes surgery combined with transection of the PSA (reported in five patients, five ears) (Table 1).

During the procedure, ankylosis of the footplate additional to the presence of a PSA was found in 12 of 13 (92%) evaluated ears (Table 1). One patient had a mobile footplate and in five patients the mobility of the footplate was not described.

Per- and Postoperative Complications

Two stapedotomies were aborted because of a mobilized footplate during removal of the stapes superstructure (3). One profuse bleeding and three minor peroperative bleedings from a PSA were reported. In three cases the bleeding occurred after deliberate transection of the PSA. In all four patients the bleeding could be controlled, either by applying pressure on the vessel, bipolar coagulation, or applying Tabotamp (Johnson & Johnson, Chicago, IL). The peroperative bleedings did not prevent completion of the stapedotomy procedure (3,10,11). No other peroperative complications were reported. The reported postoperative complications were limited: in one patient a postoperative febrile episode was observed. In this patient, a mycotic aneurysm was also resected from the middle ear during the procedure (8). Postoperative facial palsy or other neurological complications were not reported, although the absence of postoperative complications was only explicitly addressed in 7 of 18 cases (Table 1).

Postoperative Outcome

Stapes surgery was initiated in 14 of 18 evaluated ears. Two (2/14) procedures were aborted due to a mobile footplate (Table 1) (3). In 12 of 14 (86%) patients, hearing was subjectively improved postoperatively. One patient (7%) reported unaltered hearing after the stapedotomy was aborted, and in one patient postoperative hearing was not specified. Audiometry results were reported in 8 of 14 patients who underwent stapes surgery. In all eight patients, hearing thresholds improved, from an average preoperative Fletcher Index of 53 (range, 33–70 dB) to 21 dB postoperatively (range, −5 to 47 dB). Bone conduction thresholds remained stable in all eight patients (preoperative average 13 dB, postoperative average 12 dB).

In 4 of 18 ears the PSA was transected but the stapes was left intact, resulting in unaltered hearing in one patient and a small subjective deterioration of hearing in another (4,7). Hearing was not evaluated in the remaining two patients.

In 4 of 6 patients with reported preoperative pulsatile tinnitus, postoperative pulsatile tinnitus was evaluated. In all four patients, the PSA was transected and all reported alleviation of pulsatile tinnitus after surgery (4,6,7).

DISCUSSION

Middle ear surgery in patients with a PSA presents the surgeon with a dilemma. On the one hand manipulation of the PSA could cause a profuse bleeding and theoretically cause facial paralysis, hemiplegia, or central auditory, and vestibular impairment (1,5). On the other hand, if the PSA and stapes are left in situ the symptoms will most likely remain.

At present, a limited number of reports exist on the surgical management of the PSA, its safety and the outcome with regard to hearing loss and pulsatile tinnitus. The results from our analysis should be interpreted with some caution, as the limited number of published reports might reflect a publication bias towards the more successful and uncomplicated interventions. Nevertheless, the best available evidence to date shows that middle ear surgery is feasible in the majority of PSA patients without major complications. Our review uncovered only two stapes procedures that have been aborted. The reason was stapes

TABLE 1. *Review of the literature*

Year	Author	Handling of PSA	Handling of Stapes	Procedure Aborted	Footplate Ankylosis	Postoperative Hearing Loss (Air-Conduction Threshold Pre- and Postoperatively, dB)	Preoperative Pulsatile Tinnitus	Postoperative Pulsatile Tinnitus	Peroperative Complication	Postoperative Complication
1963	Baron	PSA intact	Stapedectomy	No	Unknown	improved (33 to −5 dB)	Unknown	Unknown	Unknown	Unknown
1964	House	PSA intact	Stapedectomy	No	Unknown	Improved	No	Unknown	Unknown	Unknown
1964	House	PSA intact	Stapedectomy	No	Unknown	Improved	No	Unknown	Unknown	Unknown
1992	Pahor	PSA intact	Stapedectomy	No	Yes	Improved (38–17 dB)	No	Unknown	No	No
1993	Govaerts	PSA intact	Stapedotomy	No	Yes	Improved (65–22 dB)	Unknown	Unknown	Profuse bleeding	No
1993	Govaerts	PSA intact	Stapedotomy	Yes	Yes	Unaltered (70 dB)	Unknown	Unknown	Floating footplate	Unknown
1993	Govaerts	PSA intact	Stapedotomy	Yes	Yes	Improved (65–45 dB)	Unknown	Unknown	Floating footplate	Unknown
1994	Pirodda	PSA intact	Stapedotomy	No	Yes	Improved (75–44 dB)	Yes	Unknown	Unknown	Unknown
2014	Sugimoto	PSA intact	Malleostapedotomy	No	Yes	Improved (68–25 dB)	Unknown	No	No	No
1984	Schweitzer	PSA sectioned, technique unknown	Stapedectomy	No	Yes	Improved (47–8 dB)	No	Unknown	No	Unknown
1988	Yamamoto	Cut	Stapedectomy	No	Yes	Improved (47–25 dB)	No	Unknown	Minor bleeding	Unknown
2008	Karosi	Cut	Stapedectomy	No	Yes	Unknown	No	Unknown	Minor bleeding	Unknown
2013	Hitier	Laser coagulation	Stapedotomy	No	Yes	Improved	Unknown	Unknown	Unknown	Unknown
	Goderie	Cauterization	Stapedotomy	No	Yes	Improved (55–25 dB)	Yes	No	Minor bleeding	No
1980	Fisch	Clips	Stapes intact	No	Unknown	Unknown	Yes	Unknown	Unknown	No
1995	Murphy	Cauterization	Stapes intact	No	No	Unaltered (15–12 dB)	Yes	No	No	No
2000	Silbergleit	Cauterization	Stapes intact	No	Yes	Impaired	Yes	No	Unknown	No
2002	Araújo	Clips	Stapes intact	No	Unknown	Unknown	Yes	Decreased	Unknown	Unknown

PSA indicates persistent stapedial artery.

footplate mobilization in both cases, not peroperative bleeding (3). The reported bleedings from a PSA could all be controlled peroperatively. No neurological sequelae have been described following transection of a PSA and/or stapes surgery in presence of a PSA.

Three main strategies have been described for the surgical management of a PSA: stapes surgery without transection of the PSA, transection of the PSA without stapes surgery, and stapes surgery combined with transection of the PSA. This review shows that performing stapedotomy/stapedectomy with and without transection of the PSA is an effective way to treat a conductive hearing loss caused by a PSA. Both strategies resulted in improved hearing in all evaluated patients. However, the effect of only a stapedotomy on pulsatile tinnitus is unknown. Transection of the PSA seems to be effective in treating pulsatile tinnitus, alleviating this symptom in all evaluated cases. Transecting a PSA without performing stapes surgery seems not effective in resolving hearing loss, as no hearing improvement was achieved after this procedure in the evaluated cases.

Remarkably, footplate ankylosis seems to be a frequent occurrence in the reported PSA cases (12 of 13 patients, 92%), although the prevalence of this finding might be due to selection bias because patients with conductive hearing loss may be more likely to undergo middle ear surgery (Table 1). Currently, the mechanism linking a PSA with footplate ankylosis is unknown. In a PSA case reported by Karosi et al. (11), histology of the removed stapes revealed active otospongiosis of the anterior part of the footplate, which may explain ankylosis in PSA cases.

CONCLUSION

According to the reported cases, middle ear surgery is safe in patients with a PSA. No postoperative complications have been reported. Transection of a PSA can cause profuse peroperative bleeding, however, this can be controlled and does not lead to postoperative neurological sequelae. In patients with a PSA, transection of the PSA alone seems to be an effective way to treat pulsatile tinnitus, but not hearing loss. Stapes surgery seems to be an effective treatment for conductive hearing loss, but its effect on tinnitus is unknown. In PSA patients suffering from both pulsatile tinnitus and hearing loss, the combination of PSA transection and stapes surgery seems appropriate.

REFERENCES

1. Hogg ID, Stephens CB, Arnold GE. Theoretical anomalies of the stapedial artery. *Ann Otol Rhinol Laryngol* 1972;81: 860–70.
2. Moreano EH, Paparella MM, Zelterman D, et al. Prevalence of facial canal dehiscence and of persistent stapedial artery in the human middle ear: A report of 1000 temporal bones. *Laryngoscope* 1994;104:309–20.
3. Govaerts PJ, Marquet TF, Cremers WR, et al. Persistent stapedial artery: does it prevent successful surgery? *Ann Otol Rhinol Laryngol* 1993;102:724–8.
4. Silbergleit R, Quint DJ, Mehta BA, et al. The persistent stapedial artery. *AJNR Am J Neuroradiol* 2000;21:572–7.
5. Hitier M, Zhang M, Labrousse M, et al. Persistent stapedial arteries in human: from phylogeny to surgical consequences. *Surg Radiol Anat* 2013;35:883–91.
6. Sugimoto H, Ito M, Hatano M, et al. Persistent stapedial artery with stapes ankylosis. *Auris Nasus Larynx* 2014;41:582–5.
7. Murphy MP, Seidman MD, Baugh RF. Can a persistent stapedial artery be safely and effectively removed? A case report with therapeutic implications. *Int Tinnitus J* 1995;1: 147–52.
8. Fisch UP, Oldring DJ, Senning A. Surgical therapy of internal carotid artery lesions of the skull base and temporal bone. *Otolaryngol Head Neck Surg* 1980;88:548–54.
9. Araújo MF, Oliveira CA, Sesana WE. Radiology quiz case 1—Diagnosis: Persistent stapedial artery, left ear. *Arch Otolaryngol Head Neck Surg* 2002;128:456–8.
10. Yamamoto E, Hirono Y. Persistent stapedial artery associated with otosclerosis. *ORL J Otorhinolaryngol Relat Spec* 1988;50: 382–4.
11. Karosi T, Szabo LZ, Petko M, et al. Otosclerotic stapes with three crura and persisting stapedial artery. *Otol Neurotol* 2008;29: 1043–4.
12. Baron SH. Persistent stapedial artery, necrosis of the incus, and other problems which have influenced the choice of technique in stapes replacement surgery in otosclerosis. *Laryngoscope* 1963;73: 769–82.
13. House HP, Patterson ME. Persistent stapedial artery: report of two cases. *Trans Am Acad Ophthalmol Otolaryngol* 1964;68: 644–6.
14. Pahor AL, Hussain SSM. Persistent stapedial artery. *J Laryngol Otol* 1992;106:254–7.
15. Pirodda A, Sorrenti G, Marliani AF, et al. Arterial anomalies of the middle-ear associated with stapes ankylosis. *J Laryngol Otol* 1994;108:237–9.
16. Schweitzer VG, Lilly DJ. Otosclerosis in a black child: diagnostic acoustic impedance studies. *Int J Pediatr Otorhinolaryngol* 1984;8:79–90.