Significance of internal auditory canal diverticula in ears with otosclerosis

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Abstract

Background: Diverticula in the internal auditory canal (IAC) have been reported in ears with otosclerosis. Objective: We evaluated hearing levels and vascular activity in ears with otosclerosis with and without IAC diverticula and clarify the significance of IAC diverticula. Materials and Methods: Sixty-one ears from 54 patients who underwent stapes surgery for otosclerosis (fenestral (48 ears) and retrofenestral (13 ears) groups) were included in the present study. Preoperative hearing levels on pure tone audiometry (PTA) and intraoperative measurements of blood flow were compared between the groups. Results: A total of 24 of 61 ears (39.3%) showed IAC diverticula, significantly higher than the frequency in ears without otosclerosis (3.7%). No significant differences in air- and bone-conduction thresholds on PTA were evident between ears with and without IAC diverticula in each group. Ears without IAC diverticula tended to show higher blood flow in the area anterior to the oval window than ears with IAC diverticula, but the difference was not significant. Conclusions: The incidence of the IAC diverticula in otosclerosis was significantly higher than in cases without otosclerosis. The existence of IAC diverticula was not evidently related to the severity of the disease from the perspective of hearing level and vascular activity.

Key words: internal auditory canal diverticulum, otosclerosis, hearing level, blood flow, laser-Doppler flowmetry

1. Introduction

Otosclerosis is a progressive osteodystrophy disease of the otic capsule and is characterized by bony resorption, vascular proliferation, and sclerotic new bone formation [1]. Otosclerosis is categorized into two types: fenestral type, which shows overgrowth of hypoattenuating bone in the region of the fissula ante fenestram; and retrofenestral type, which shows a hypoattenuating halo around the cochlea. The retrofenestral type usually occurs with fenestral involvement, and these manifestations are considered to be on a continuum rather than two separate entities [2].

The existence of an internal auditory canal (IAC) diverticulum, which is detected as a small focal outpouching arising from the anterolateral wall of the IAC on computed tomography (CT), has been reported in ears with otosclerosis. Such diverticula are considered cavitary lesions of otosclerosis [3,4]. The pathophysiology of the IAC diverticula is not clear, and the prevalence may be related to the severity of otosclerosis [5]. A recent study reported that the lesions were associated with sensorineural hearing loss (SNHL), regardless of the concomitant existence of otosclerosis [6].

Vascularity appears to be a factor in the pathology of otosclerosis, and active and inactive otospongiotic or otosclerotic lesions in ears with otosclerosis can be histologically classified by different types of vascularity [7]. A pathologic feature of otosclerosis is new vessel formation, which is most pronounced when the disease is active [7,8]. Active otosclerosis could accompany increased vascularity, and intraoperative measurement of blood flow using laser Doppler flowmetry has been reported to yield useful information about the progress of vascular activity in ears with otosclerosis [9].

This study aimed to compare hearing levels and vascular activity in ears with otosclerosis with and without IAC diverticula and to clarify the association between the existence of IAC diverticula and the severity of the disease.

2. Patients and methods

Sixty-one ears from 54 patients (21 males, 33 females; age range, 31-72 years) who underwent stapes surgery for otosclerosis in our hospital were included in the present study. All patients underwent preoperative pure-tone audiometry (PTA) and CT using sequential 0.5-mm-thick slices. The surgical findings confirmed the final diagnosis of otosclerosis in all ears.

2.1. Hearing levels on PTA

Air-conduction (AC) and bone-conduction (BC) thresholds were determined at 0.5, 1, 2, and 4 kHz on PTA (AA-78; Rion, Tokyo, Japan), and mean hearing threshold at these frequencies was calculated in each ear.

2.2. Evaluation on CT

Based on CT (Asteion and Aquilion; Toshiba, Tokyo, Japan) imaging findings, ears were preoperatively classified into the following two types of otosclerosis: i) subjects with hypoattenuating lesions limited to areas anterior to the oval window (OW) (fenestral group); and ii) subjects with hypoattenuating lesions that extended over the labyrinth capsules (retrofenestral group) [9]. IAC diverticulum was defined as an obvious notch and low attenuation in the anterior IAC margin. Foci varied in size from a small focal notch to a larger diverticulum, and a diverticulum was considered

present when the depth was larger than 0.5 mm. Example images from ears with and without an IAC diverticulum are shown in Figure 1.

As a control, investigation of IAC diverticula was also applied on ears without otosclerosis, which had neither hypoattenuating lesions suggesting otosclerosis nor anomaly of the inner ear on CT. The group comprised 81 patients (27 males, 54 females; age range, 9-81 years), and all underwent ear surgeries for the following disease: acquired profound sensorineural hearing loss, 44 cases; ossicular anomalies, 18 cases; perilymphatic fistula, 7 cases; external auditory canal disease, 5 cases; facial palsy, 4 cases; and traumatic interruption of ossicular chain, 3 cases.

2.3 Measurement of blood flow

Measurements of blood flow were performed with a laser Doppler flowmeter (LDF, model ALF 21, Advance, Tokyo, Japan), as described elsewhere [9]. Briefly, the tip of the probe was attached manually to two portions: the anterior portion of the OW directed to the fissula ante fenestram (defined as the blood flow in the AOW); or the promontory (PT) located 1.5 mm inferior to the OW (defined as the blood flow in the PT). After the blood flow had stabilized, 5-s mean values were obtained. No additional procedures, such as removal of the mucosa in the region, were performed during measurement.

Statistical analyses were conducted using the independent-samples *t*-test and Mann-Whitney U test with SPSS 25.0. Values of $P < 0.05$ were considered significant. Written, informed consent was obtained preoperatively from each patient, and the study protocol was approved by the institutional review board at Nagoya University Hospital.

3. Results

Based on CT images, 48 ears were enrolled in the fenestral group and 13 ears were enrolled in the retrofenestral group. A total of 24 of 61 ears (39.3%) had IAC diverticula, which included 17 ears (35.4%) in the fenestral group and 7 ears (53.8%) in the retrofenestral group. Fifteen of 19 (78.9%) patients had bilateral IAC diverticula, including 9 of 13 patients (69.2%) and 6 of 6 patients (100%) in the fenestral and retrofenestral groups, respectively, although only five patients underwent surgery of both ears. As for the control group, 6 ears (4 cases) of the 162 ears (81cases) had IAC diverticula (3.7%), and their diagnosis was profound sensorineural hearing loss in 3 ears (2 cases), facial palsy in 2 ears (1 case), and traumatic interruption of the ossicular chain in 1 ear (1 case). The incidence of IAC diverticula in otosclerosis was significantly higher in both the fenestral and retrofenestral group than in the control group.

Table 1 shows the average AC and BC thresholds at four frequencies and the mean hearing threshold on PTA in the fenestral group. There was no significant difference in each hearing threshold between ears with and without IAC diverticula in the group. Table 2 shows the average AC and BC thresholds at four frequencies and the mean hearing threshold on PTA in the retrofenestral group. No significant difference in each hearing threshold was evident between ears with or without IAC diverticula in each group.

Figure 2 shows the values of blood flow in the AOW and PT in the fenestral group. Some ears without an IAC diverticulum showed relatively higher blood flow values in the AOW than those with a diverticulum, but the average arbitrary units (AU: mL/min/100 g) in ears without and with IAC diverticula were 5.4 and 3.8, respectively, showing no significant difference ($p=0.48$). Meanwhile, values of blood

flow in the PT were similar between groups: average AUs in ears without and with IAC diverticula were 4.2 and 4.7, respectively.

Figure 3 shows the values of blood flow in the AOW and PT in the retrofenestral group. Some ears without an IAC diverticulum showed relatively higher blood flow values in the AOW than those with a diverticulum, but averages in ears without and with IAC diverticula were 7.3 and 2.6 AU, respectively, showing no significant difference ($p=0.095$). Average values of blood flow in the PT of ears without and with IAC diverticula were 11.7 and 10.3 AU, respectively, and values were similar between groups.

4. Discussion

Etiological factors of otosclerosis have yet to be elucidated, but include autoimmunity, genetics, inflammation, viruses, and hormonal influences [10]. The most common site of the lesion is the fissula ante fenestram, followed by the round window niche, apical and medial cochlear walls, and anterior wall of the IAC [11,12].

The presence of IAC diverticula has been reported in limited cases, and the pathophysiology remains unclear. An IAC diverticulum might reflect a cavitary lesion of otosclerosis and represent a variant of cochlear otosclerosis [3,4], which could involve a much more extensive cavitation phenomenon in the otic capsule of patients with this disease [3]. Another reported assumption is that IAC diverticula are related to SNHL in a different pattern than the classic CT presentation of otosclerosis [6], although these lesions occasionally present in otosclerosis. In the present study, the incidence of an IAC diverticulum in ears with otosclerosis was 39.3%, significantly higher than in the control group. This finding might suggest a relationship between otosclerosis and the presence of IAC diverticula to some extent.

The retrofenestral type of otosclerosis could cause conductive hearing loss, mixed hearing loss, or SNHL [13], in which direct injury to the cochlea and spiral ligament due to the lytic process or release of proteolytic enzymes might cause SNHL [14]. The present study showed no significant differences in AC and BC thresholds between ears with and without IAC diverticula, both in the fenestral and retrofenestral group. This finding does not support IAC diverticulum as a cause of SNHL in ears with otosclerosis.

The early phase of otosclerosis is characterized by the presence of spongy irregular vascular foci of demineralized bone with osteoplastic bone resorption. These foci then become less vascular and tend to calcify, forming dense bone. Active resorption and bone deposition are often present in the same focus of otosclerosis [15,16]. The vascular activity may reflect the lesion process, which could be evaluated by intraoperative laser Doppler flowmetry [9]. The present study showed no significant differences in values of blood flow in the AOW and PT between ears with and without IAC diverticula in both the fenestral and retrofenestral group. Some ears without an IAC diverticulum in both groups showed relatively higher values of blood flow in the AOW, where the most common site of the lesion is the fissula ante fenestram. At this point, ears with IAC diverticula may not have a more active vascular process than those without IAC diverticula, though interpretation of this finding is difficult.

Several limitations to the present study must be considered, including the small sample size and the methods of evaluation. Other aspects besides hearing thresholds or blood flow should be considered to evaluate otosclerosis activity concerning the significance of IAC diverticula in ears with the disease. We are planning future studies to further clarify this issue.

5. **Conclusions**

IAC diverticulum was significantly more frequent in otosclerosis in both the fenestral and retrofenestral group than in the control group, although the rate tended to be higher in the retrofenestral group. The existence of IAC diverticula did not appear related to the severity of disease assessed using hearing levels and vascular activity.

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Figure legends

Figure 1: Example images from ears with (A) and without (B) an internal auditory canal (IAC) diverticulum. An IAC diverticulum can be detected as an obvious notch in the anterior wall of the IAC (A, arrow).

Figure 2: Values of blood flow in (A) areas anterior to the oval window and (B) the promontory of ears with and without an internal auditory canal diverticulum in the fenestral group. (A.U., arbitrary units)

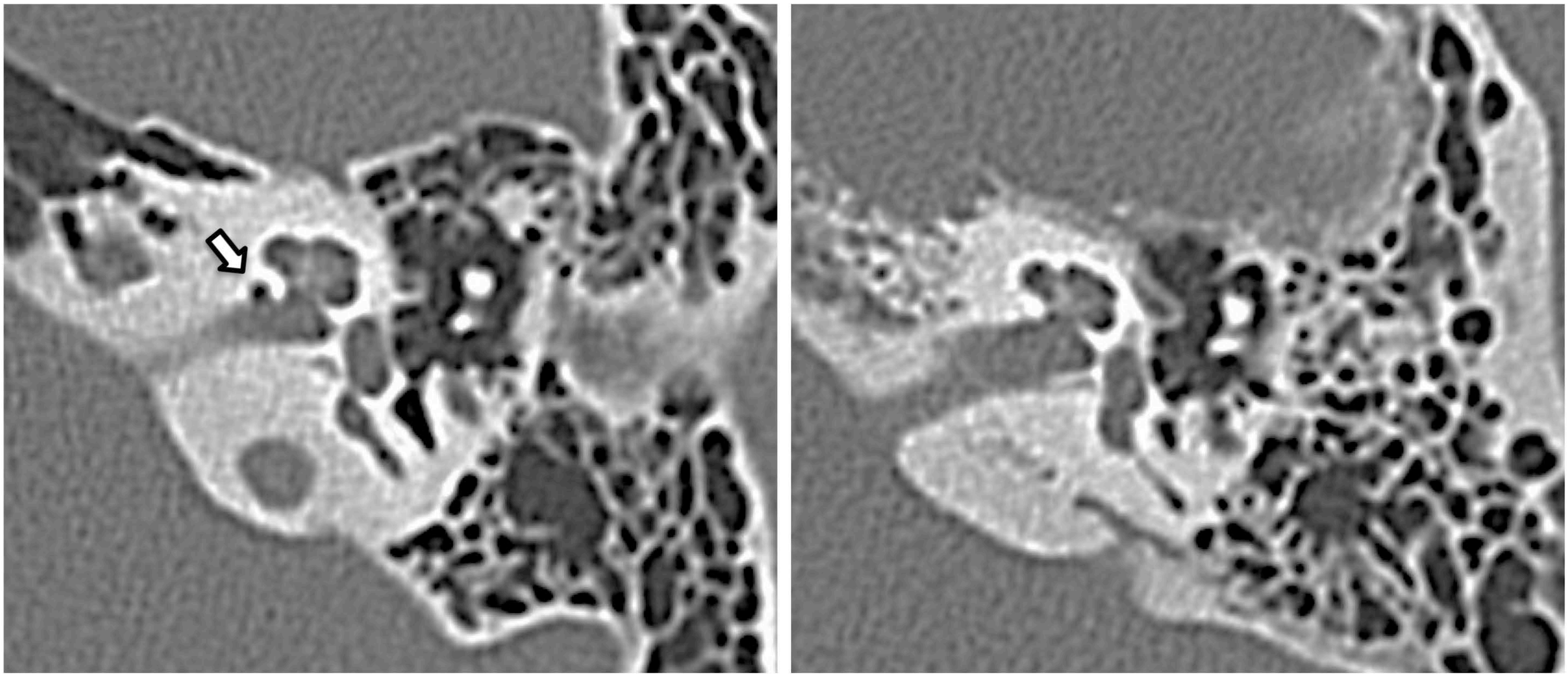
Figure 3: Values of blood flow in (A) areas anterior to the oval window and (B) the promontory of ears with and without an internal auditory canal diverticulum in the retrofenestral group. (A.U., arbitrary units)

Table I: Average air- and bone-conduction thresholds (AC and BC) at four frequencies and mean hearing thresholds in ears with and without an internal auditory canal diverticulum in the fenestral group

		500 Hz	1000 Hz	2000 Hz	4000 Hz	Mean
With diverticulum	**AC**	65.0	62.1	55.8	48.7	57.9
	BC	18.1	29.2	38.2	24.8	27.6
Without diverticulum	**AC**	66.4	60.6	55.0	46.2	57.1
	BC	15.6	26.2	32.9	24.1	24.7

Table II: Average air- and bone-conduction thresholds (AC and BC) at four frequencies and mean hearing thresholds in ears with and without an internal auditory canal diverticulum in the retrofenestral group

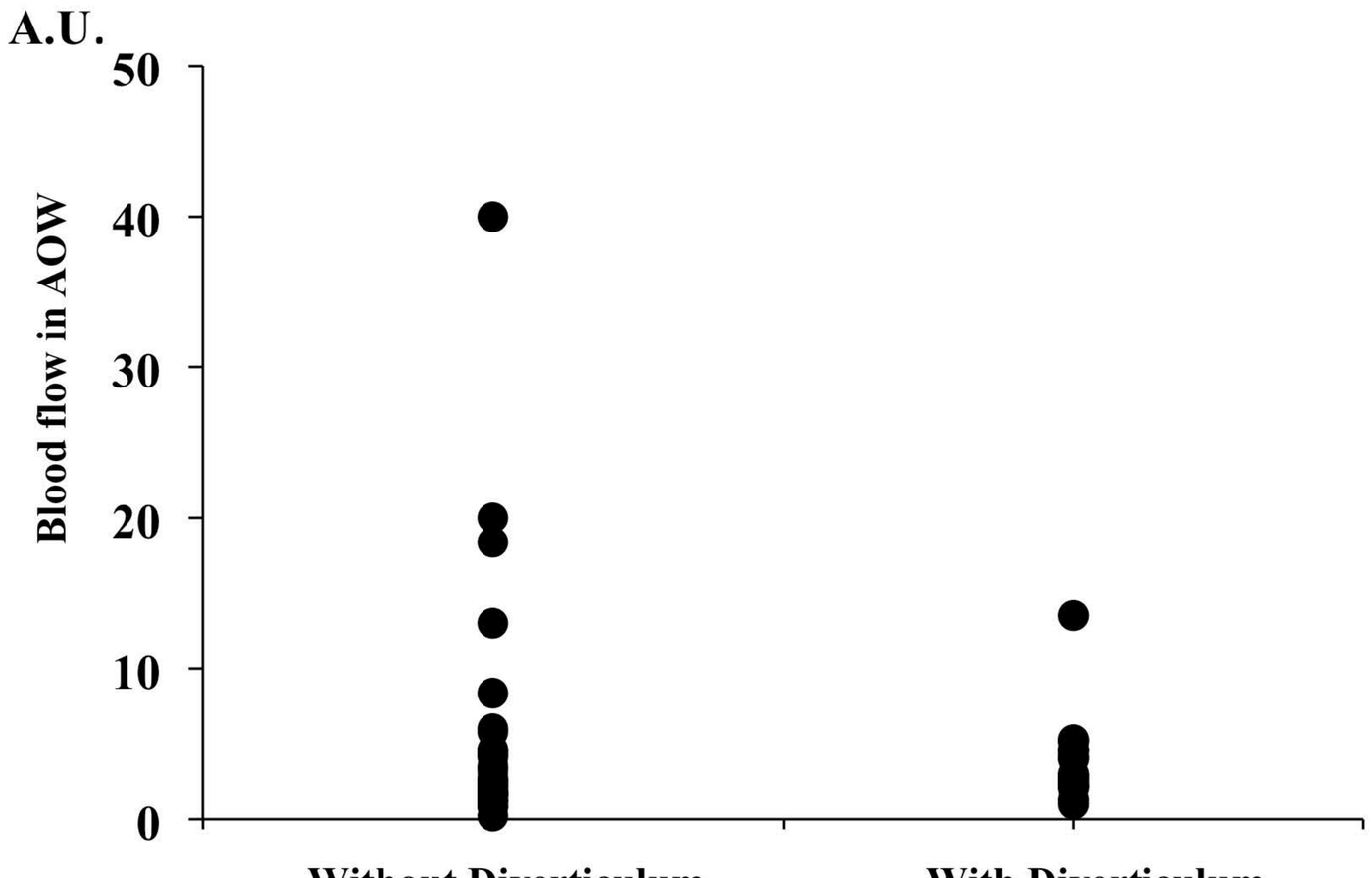
		500 Hz	1000 Hz	2000 Hz	4000 Hz	Mean
With diverticulum	**AC**	62.5	60.0	55.0	55.0	58.1
	BC	28.3	29.2	40.0	34.2	32.9
Without diverticulum	**AC**	67.9	70.0	71.4	74.3	70.9
	BC	28.6	32.9	50.7	43.6	38.9



A) B)

Figure 1

A)


A.U.
Blood flow in AOW
50
40
30
20
10
0
Without Diverticulum
With Diverticulum

B)

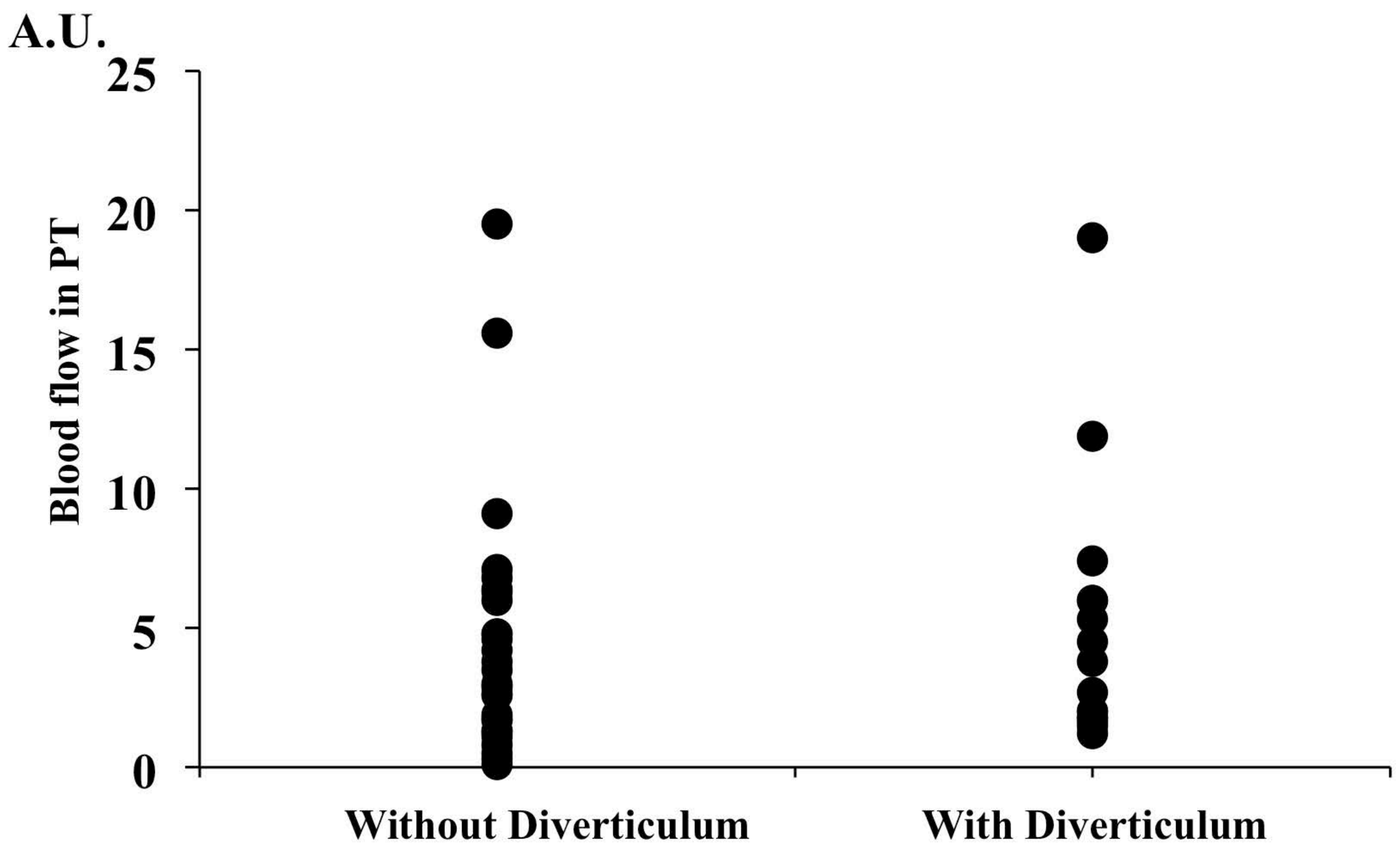
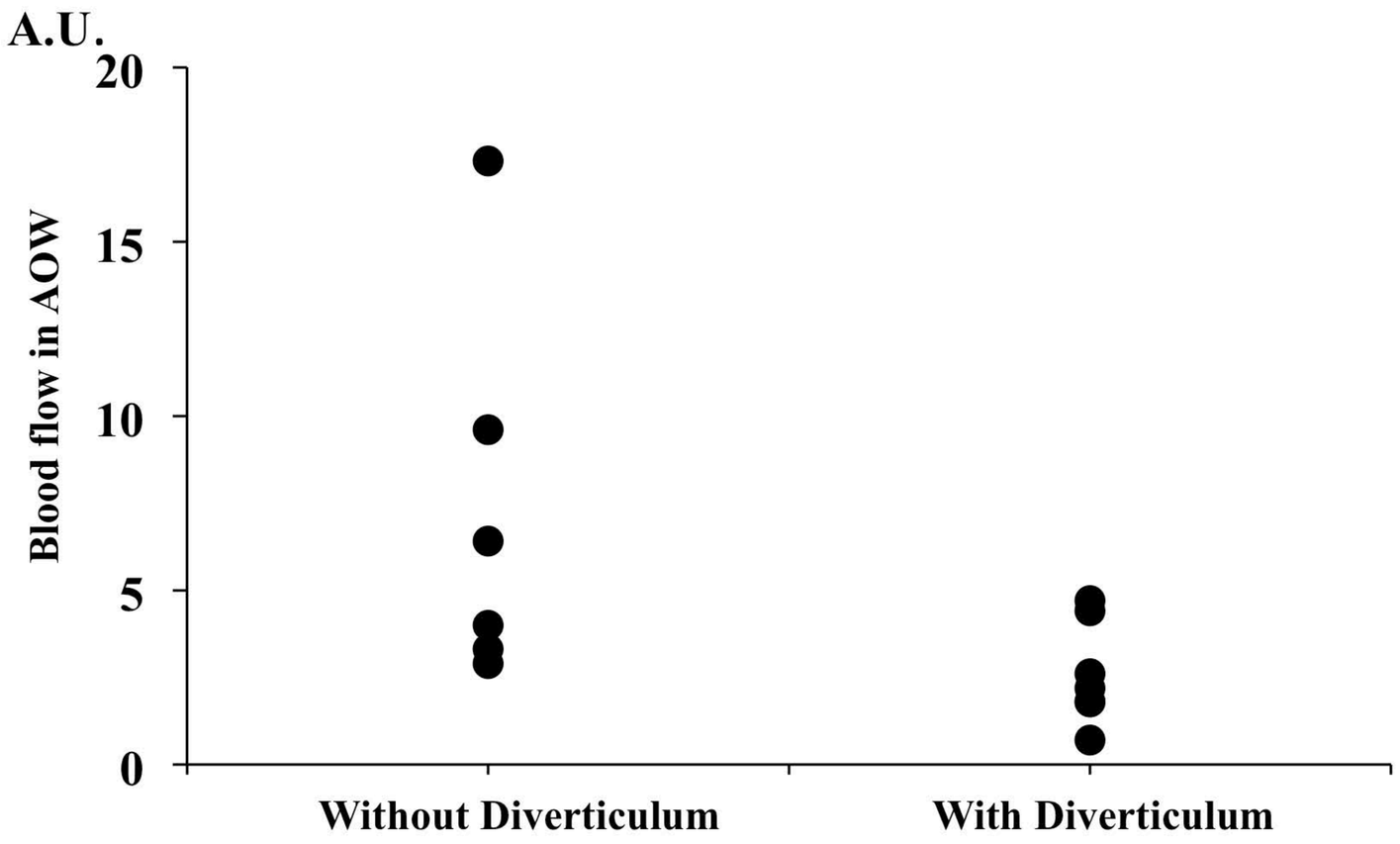

A.U.
Blood flow in PT
25
20
15
10
5
0
Without Diverticulum
With Diverticulum

Figure 2

A)


A.U.
20
15
10
5
0
Blood flow in AOW
Without Diverticulum
With Diverticulum

B)

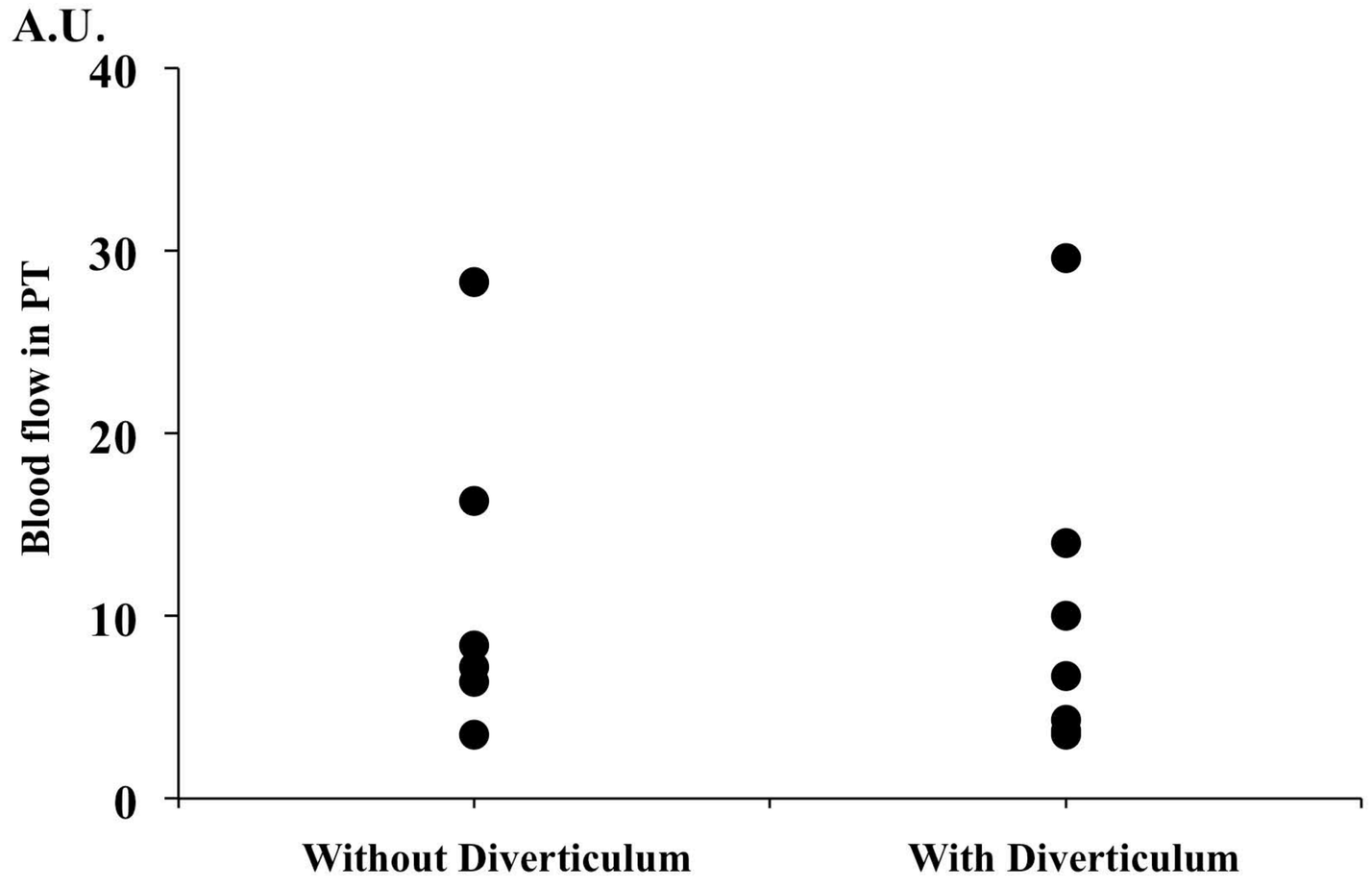

A.U.
40
30
20
10
0
Blood flow in PT
Without Diverticulum
With Diverticulum

Figure 3