

## AUDIOLOGY

# Right-to-left shunt and idiopathic sudden sensorineural hearing loss

## *Shunt destro-sinistro e ipoacusia neurosensoriale improvvisa idiopatica*

L. CAPUANO<sup>1</sup>, M. CAVALIERE<sup>1</sup>, D. LOPARDO<sup>2</sup>, G. PARENTE<sup>1</sup>, A. DAMIANO<sup>2</sup>, R. PERONE<sup>2</sup>, A. MARINO<sup>1</sup>, P. BOTTIGLIERI<sup>3</sup>, M. IEMMA<sup>1</sup><sup>1</sup> Department of Otorhinolaryngology; <sup>2</sup> Department of Diving Medicine and Hyperbaric Therapy; <sup>3</sup> Department of Intensive Cardiac Therapy, University Hospital "San Giovanni di Dio e Ruggi d'Aragona", Salerno, Italy

## SUMMARY

In the present retrospective cohort study, we investigated the association between idiopathic sudden sensorineural hearing loss (ISSNHL) and right-to-left shunt (RLS). For this study, we recruited 40 patients with ISSNHL treated in our department between January 2015 and January 2016. Inclusion criteria were:  $\geq 18$  years old, unilateral sensorineural hearing loss diagnosed within 2 weeks after onset, unknown cause, no previous surgery in the respective ear and no fluctuation in hearing loss. All patients underwent a pure-tone audiogram and a trans-cranial Doppler ultrasonography (TCD) with contrast saline (c-TCD) and received hyperbaric oxygen (HBO) and concomitant steroid therapy. C-TCD examination detected the RLS in 20 patients (50%). ISSNHL patients with RLS were younger than those without RLS ( $p = 0.007$ ). Vertigo was present mainly in the RLS group, while hypercholesterolaemia, arterial hypertension and hyperglycaemia were mainly seen in the "no RLS" group. The proportion of complete recovery was highest in the "No RLS" Group (40%), although it was not statistically significant. In conclusion, RLS is frequent in ISSNHL, particularly in young patients without comorbidities and with associated dizziness, who should routinely undergo TCD to exclude the presence of RLS. Unfortunately, TCD can only detect the RLS, and not the location of the shunt. This would be possible through transesophageal echocardiography (TEE) or intracardiac echocardiography (ICE), which are much more invasive than TCD, and require further study.

KEY WORDS: Sudden sensorineural hearing loss • Right-to-left shunt • Hyperbaric oxygen therapy

## RIASSUNTO

*Nel presente studio retrospettivo di coorte, abbiamo esaminato l'associazione tra ipoacusia neurosensoriale improvvisa idiopatica (ISSNHL) e lo shunt destro-sinistro (RLS). Lo studio è stato condotto su 40 pazienti con ISSNHL trattati presso il nostro dipartimento tra gennaio 2015 e gennaio 2016. I criteri di inclusione sono stati: età  $\geq 18$  anni, ipoacusia neurosensoriale monolaterale diagnosticata entro 2 settimane dopo la sua comparsa, causa sconosciuta, anamnesi negativa per pregressi interventi chirurgici all'orecchio corrispondente, assenza di fluttuazioni dell'ipoacusia. Tutti i pazienti sono stati sottoposti ad audiometria tonale e ad esame ultrasonografico Doppler trans-cranico (TCD) con contrasto salino (c-TCD) e sono stati trattati con ossigenoterapia iperbarica (HBO) e concomitante terapia steroidea. L'esame C-TCD ha rilevato uno shunt destro-sinistro (RLS) in 20 pazienti (50%). I pazienti affetti da ISSNHL con RLS erano più giovani rispetto a quelli senza RLS ( $p = 0,007$ ). La presenza di vertigini è stata osservata soprattutto nel gruppo con RLS, mentre l'ipercolesterolemia, l'ipertensione arteriosa e l'iperglicemia sono stati osservati soprattutto nel gruppo senza RLS. La percentuale di completa guarigione è stata più alta nel gruppo senza (40%), sebbene non statisticamente significativa. In conclusione, il riscontro di RLS è frequente nell'ISSNHL, particolarmente in giovani pazienti senza comorbidità e con associato disequilibrio, i quali dovrebbero essere regolarmente sottoposti ad esame ultrasonografico Doppler trans-cranico per escludere la presenza di RLS. Purtroppo, il TCD può solo rilevare l'RLS, non la posizione dello shunt. Ciò sarebbe possibile attraverso l'ecocardiografia transesofagea (TEE) o l'ecocardiografia intracardiaca (ICE), che sono molto più invasive del TCD, e richiede ulteriori studi.*

PAROLE CHIAVE: Ipoacusia neurosensoriale improvvisa • Shunt destro-sinistro • Ossigenoterapia iperbarica

## Introduction

Idiopathic sudden sensorineural hearing loss (ISSNHL) is a clinical emergency characterised by a 30 dB hearing loss over three contiguous frequencies occurring within 3 days<sup>1</sup>. Its aetio-pathogenesis is not well known. Researchers have suggested viral infection, vascular compromise, intracochlear membrane rupture and immune inner ear

disease<sup>2</sup>. Right-to-left shunt (RLS) is one of the most important causes of ischaemic stroke in patients without vascular risk factors or other causes of embolism<sup>3</sup>.

This study investigated the association between ISSNHL and the presence of RLS and derives from the observation of some authors who report a very high incidence of RLS (73-83%) in divers with "inner ear decompression sickness" vs 25-30% in control subjects<sup>4,5</sup>.

## Materials and methods

Study subjects included patients with ISSNHL treated in our department between January 2015 and January 2016. In this retrospective study, we evaluated the incidence of RLS and its influence on hearing loss severity and recovery. The ethics committee of our institution approved the present study.

### Patients

Subjects met the following inclusion criteria:  $\geq 18$  years old, unilateral sensorineural hearing loss diagnosed within 2 weeks after onset; unknown cause of hearing loss (based on complete history review, clinical evaluation, blood tests, imaging exams - MRI, CT); no previous surgery in the respective ear; no fluctuation in hearing loss. We obtained all pure-tone audiograms at the time of initial presentation (day 0) and on days 30, 60, 90, and 180 after the initiation of treatment. We recorded hearing thresholds at 250; 500; 1,000; 2,000; 4,000 and 8,000 Hz.

### Treatment

All patients received hyperbaric oxygen (HBO) and concomitant steroid therapy, i.e. the treatment which in the experience of us and others<sup>6-8</sup> has given the best results. The steroid protocol included intravenous methylprednisolone at decreasing doses of 40 mg for 7 days, and 20 mg for other 3 days. HBO therapy was practiced daily from Monday through Friday for 16 sessions at 2.5 ATA with 90 min per session.

### Evaluation criteria

All patients underwent a pure-tone audiogram from 250 Hz to 8 KHz. The audiometric tests conformed to the specification in ISO 8253 (Acoustic Audiometric test methods; basic pure tone and bone conduction audiometry, International Organization for Standardization, Geneva, Switzerland). We evaluated the pure-tone average (PTA) for each audiogram by calculating the mean of thresholds at 500; 1,000; 2,000 and 4,000 Hz. Hearing recovery was classified into three grades<sup>3</sup>, as follows: I Good: hearing returned within 15 dB of the unaffected contralateral ear; II Fair: hearing level improved by more than 10 dB, but did not return to within 15 dB of the unaffected ear; III Poor: no change in hearing level, improved  $\leq 10$  dB or even deteriorated after treatment.

All patients also underwent a trans-cranial Doppler ultrasonography (TCD) with contrast saline (c-TCD), performed by a specialist cardiologist to detect RLS. The middle cerebral artery (MCA) was identified from the temporal window at a depth of 50-55 mm using a

2-MHz hand-held transducer (Pioneer TC 8080; Nicolet Vascular, Madison, Wisc, USA) continuously monitoring the flow signals. For the c-TCD study, we used a mixed saline (9 ml) and air (1 ml) solution, agitated between two 10-ml syringes connected via a 3-way stopcock. An indwelling catheter placed in the anterior cubital vein injected bubble-containing saline under 2 conditions: I no Valsalva manoeuvre; II Valsalva manoeuvre for 10 s, starting 5 s after the start of bubble containing saline introduction. We diagnosed RLS if one micro-bubble was noted in 1 vessel within 40 s after injection. The size of the shunt was classified as minor (from 1 to 10 micro-bubbles), moderate (more than 10 micro-bubbles, but without the drop-down effect) or severe (more than 10 micro-bubbles and with the drop-down effect).

Statistical analysis was conducted using the Pearson chi-squared test followed by Fisher's exact test as a post hoc test. We considered differences at  $p < 0.05$  as significant.

## Results

Our study included 40 patients (40 diseased ears) treated at our clinic (Table I).

C-TCD examination allowed us to detect RLS in 20 patients (50%). ISSNHL patients with RLS were younger than those without RLS and the right ear was mainly interested ( $p = 0.007$  and  $0.009$  respectively).

Vertigo at onset was seen in 80% of patients with RLS and in 20% without RLS ( $p = 0.07$ ).

Hypercholesterolaemia ( $> 240$  mg/dL), arterial hypertension and hyperglycaemia were seen mainly in the "no RLS" group ( $p = 0.004$ ,  $0.07$  and  $0.2$  respectively).

Mean gain in the "RLS" group was numerically worse than the "No RLS" group, although it was not statistically significant (Table II). We did not observe any relation between RLS severity and pre- or post-treatment PTA (Table III).

## Discussion

This study, the first in the literature, examines the characteristics of patients with RLS and ISSNHL and the impact of the RLS on auditory recovery. ISSNHL, described by De Kleyn in 1944, is a hearing loss of at least 30 dB in three sequential frequencies in the standard pure-tone audiogram occurring within 3 days<sup>4</sup>. Incidence of ISSNHL is between 5 and 30 cases per 100,000 per year. A specific cause is generally found in about 10% of patients<sup>9</sup>. To explain mechanisms of sudden deafness, two common theories have been proposed: an inflammatory reaction and a circulatory disturbance.

**Table I.** Baseline characteristics of the study population.

	RLS	No RLS	P values
No. of patients	20	20	
Age (mean $\pm$ SD)	33 $\pm$ 8.23	45.20 $\pm$ 7.05	0.007
Gender (M/F)	12/8	8/12	0.579
Side (right/left)	16/4	0/20	0.009
Pre-treatment PTA (dB)	74 $\pm$ 10.84	74 $\pm$ 28.81	1
Vertigo (%)	80	20	0.07
Comorbidities (%)			
arterial hypertension	20	80	0.07
hyperglycaemia	20	60	0.24
hypercholesterolemia	0	80	0.004
dysthyroidism	0	0	1

**Table II.** Response to therapy.

	RLS	No RLS	P values
Pre-treatment PTA (dB)	74 $\pm$ 10.84	74 $\pm$ 28.81	1
Post-treatment PTA (dB)	51 $\pm$ 20.12	43 $\pm$ 27.52	0.55
good recovery	20%	40%	0.54
fair recovery	40%	40%	1
poor recovery	40%	20%	0.54

**Table III.** RLS severity and hearing loss.

	RLS minor	RLS severe	P values
Pre-treatment PTA (dB)	73.33 $\pm$ 2.89	75 $\pm$ 21.21	0.89
Post-treatment PTA (dB)	48.33 $\pm$ 27.54	55 $\pm$ 7.07	0.77

The higher prevalence of RLS in our patients (50%) compared with 25-30% in the control population suggests that sudden deafness may be attributable to a paradoxical embolism, i.e. emboli from venous circulation as a result of RLS<sup>3,10</sup>.

Numerous studies have confirmed that patients with RLS have a risk of thrombo-embolic event that is four times higher than those without RLS and have an increased risk (3.4% annually) of recurrent stroke or transient ischaemic attack<sup>11,12</sup>.

The paradoxical embolism might provoke transient occlusion of the internal auditory artery (labyrinthine artery) that supplies blood to both the cochlea and the vestibule. If thrombosis occludes the internal auditory artery, vertigo and hearing loss may occur<sup>4</sup>. In our series, in fact, 16 of 20 sudden deafness patients with RLS (80%) had vertigo at the onset of sudden deafness.

ISSNHL patients with RLS were younger than those without RLS in our series, in accordance with previous authors who reported that the incidence of RLS gradually declines with increasing age<sup>3,13</sup>.

However, we did not find relationship between the degree of deafness and RLS severity, the presence of RLS or hearing recovery. Other authors<sup>14</sup> have shown that cardiovascular risk factors do not have any significant influence on threshold recovery in ISSNHL, although they are involved in its pathogenesis.

## Conclusions

RLS is frequent in ISSNHL, particularly in young patients without comorbidities and with associated dizziness. However, in our initial study we did not find any significant association of hearing recovery in the RLS group. Furthermore, the TCD can only detect the RLS, not the location of the shunt. This would be possible through trans-oesophageal echocardiography (TEE) or intracardiac echocardiography (ICE), which are much more invasive than TCD.

Therefore, based on our current data, we cannot routinely recommend TCD to exclude the presence of RLS, but only in young patients without comorbidities.

Further studies on a larger group are necessary to confirm these results, to detect the location of the shunt and evaluate whether patients with RLS are more susceptible to sudden deafness recurrence as for stroke<sup>15</sup>.

## Conflict of interest statement

None declared.

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**Address for correspondence:** Matteo Cavaliere, via Madonna di Fatima 53, 84084 Fisciano (SA), Italy. E-mail: matorl@inwind.it