Audiological evaluation in a heterogeneous sample of subjects with Down syndrome.

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Abstract

Objective: Hearing loss in Down syndrome (DS) is well-documented in literature but there is no agreement on the true incidence, ranging from 38 to 78%. The main purpose of this study was to collect into a database the otological disorders and to perform an audiological assessment in a group of DS patients of different age, in order to appreciate their actual incidence.

Study design: otological and audiological data from 143 DS patients (age range 1-59 year) were prospectively collected.

Setting: The sample was divided into 8 age-groups. The general and specific anamnesis of all 143 subjects was taken; all underwent otological examination, measurement of the caliber of the EAC, tympanometry and pure tone air and bone conduction threshold assessment or infantile audiometry.

Results: 44% of subjects complained audiologic pathologies, which occurred in pre-school age in 87.7% of the cases, and in 56.4% within the first year; most patients presented normal hearing or mild hearing loss: only group 1 (from 6 to 35 months) and 8 (over 55) suffered from moderate hearing loss. Children up to 5 years old presented a high incidence of otitis media with effusion (OME) (more than 85% in the age group between 6 and 35 months old) and associated conductive hearing loss. OME after the age of 6 was infrequent.

Conclusion: Hearing problems in pediatric DS subjects are extremely frequent and affect negatively learning and language development; for this reason, periodic audiological evaluation is crucial in order to act promptly. On the other side, almost all adults do not present hearing impairments such as to affect communication, even though an early presbyacusis is quite frequent.

Keywords: Down Syndrome, hearing loss, ear, audiological evaluation, otological disorders, OME, EAC, tympanogram, audiogram.

Introduction

Down Syndrome (DS) is a genetic disorder caused by a non-dysjunctional mutation which results in chromosome 21 trisomy. It occurs in approximately one in 600 to 800 live births and remains one of the most frequent causes of mental retardation in industrialized countries and the most common genetic abnormality seen in otolaryngologic practices (Blaser 2006, Park 2012).

Common ENT manifestations of DS include external ear canal stenosis, Eustachian tube dysfunction, chronic middle ear effusion, chronic middle ear infections, cholesteatoma, orofacial and upper airway abnormalities, laryngomalacia, sleep apnea and recurrent upper airway infections, such as rhinitis and sinusitis (affecting 40-50% of DS children) (Bacciu 2005, Kanamori 2000, Manaligold 1998, Strome 1981, Desai 1997, Jacobs 1996).

Over the past years, a number of comprehensive studies concerning the auditory threshold in DS population have been conducted. Most of the studies depict a higher incidence of deafness in comparison to the normal population: a high prevalence of hearing loss in individuals affected by 65 years in DS

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is well-documented in literature, but there is no agreement on the true incidence of hearing loss in DS, ranging from 38 to 78% (Bacciu 2005, Ino 1999, Shott 2001, Brooks 1972, Balkany 1979, Cunningham 1981, Dahle 1986, Kattan 2000, McPherson 2007, Clark 1981).

Moreover, previous studies mainly concerned pediatric patients, and limited investigation has been done on the audiological status of a heterogeneous group of subject with DS.

Materials and Methods

Otological and audiological data from 143 patients affected by DS, and members of the "Vivi Down" Association, were collected; all subjects registered at the "Vivi Down" association undergo periodic general health examinations that include audiological evaluation with audiometry: the data of this study were collected during these evaluations. The study was approved by the Ethical Committee of the Foundation IRCCS "Ca' Granda" Ospedale Maggiore Policlinico (n.1550, 18-06-2009).

The general and specific anamnesis of all subjects was taken, and they all underwent otological examination, measurement of the calibre of the external auditory canal (EAC), tympanometry and pure tone air and bone conduction threshold assessment or infantile audiometry, depending on the patient's age and mental retardation.

In order to collect the participants' anamnesis, clinical data and otological evaluation as well as to make them more easily comparable, a specific multiple choice form was designed and used.

Demographic data including age, gender, degree of intellectual impairment, history of recurrent infection of the upper airways and of previous ear disease, hearing loss and use of hearing aids were recorded.

Otoscopy was performed to detect occluding ear wax and investigate the status of the outer ear canal and the tympanic membrane (TM). The status of the TM was categorized as: normal, myringosclerosis, middle ear effusion, acute middle ear otitis and perforated TM. Subjects with impacted cerumen, external or middle acute otitis were invited to be retested after resolution of the problems through drug therapy and removal of ear wax. The EAC diameter was measured with auricular perfectly introducible in the cartilaginous portion of the EAC (Park 2012). In order to confirm these data with repeat measurement with another technique: we used the silicone paste for hearing aids prints and reset the EAC diameters, but we did not find significant difference.

To overcome the varying levels of developmental skills of DS that might have affected their ability to participate in age-appropriate audiometric tests, an expert audiologist did an informal assessment of mental levels prior and during audiometric testing to choose the most appropriate method for the examination.

Conventional pure tone audiometry was performed, and air conduction thresholds were obtained for octave frequencies 0.25-8 KHz and, for most subjects, at 3 and 6 KHz. Bone conduction thresholds were obtained for the octave frequencies 0.25-4 KHz. Pure tone thresholds were defined as the minimum hearing level at which the subject responded at least three times on ascending trials. The infantile audiometry, instead, consisted of obtaining conditioning threshold for frequencies between 0.25 and 4 KHz.

All collaborative subjects were tested in a sound-insulated test chamber with Amplaid A321 Twin Channel audiometer using TDI-1 49 earphones. All young children and non-collaborative were tested in a sound-insulated chamber with conditioning audiometry with Amplaid A315 audiometer. When indicated, narrow-band noise was used for pure-tone air and bone conduction audiometry.

The degree of hearing loss was calculated according to the mean value of thresholds at 500, 1000 and 2000 Hz and categorized in: normal (< 25 dB), mild (from 26 to 40 dB), moderate (from 41 to 60 dB), severe (from 61 to 90 dB) and profound (> 91 dB) (Clark 1981).

Hearing loss was categorized as conductive, sensorineural and mixed hearing loss: conductive hearing loss was confirmed with the presence of an air-bone (AB) gap greater than 10 dB on auditory test or on click and tone burst evoked ABR (Auditory Brainstem Response)-threshold data for pediatric and non-collaborative patients (under 36 months).

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Moreover, all patients were subjected to speech audiometry with an infantile list of bisyllabic words elaborated by Bocca Pellegrini through Amplaid 321 Twin Channel to evaluate speech detection (Bocca 1950). Standard tympanometry with 220 Hz probe tones was performed with Amplaid 720 to evaluate the tympanogram and to define the stapedial reflex's threshold with contra-lateral stimulation.

Regarding the evaluation of benefits of the hearing aid (HA), patients with HA were also submitted to tone audiometry with WARBLE stimulus and to speech audiometry with the list of bysillabic word by Bocca Pellegrini.

Results

Of the 143 subjects recruited to the study, 60 were females. The age varied from 1 to 59 years old. The chromosome map analysis revealed that 134 patients were affected by free chromosome 21 trisomy (93.7%), 3 by translocation trisomy (2.1%) and 6 by mosaic (4.2%). One hundred forty subjects were caucasian (97.9 %), 1 was Hispanic (0.7%), 1 black race (0.7 %) and 1 mestizo (0.7%). Not all patients recruited were subjected to all evaluations, as expected by the protocol of the study, due to the individual variability of mental retardation, collaboration and reliability. The percentage data will therefore be used instead of the absolute values.

Recurrent upper airway infections were reported by 24.6% of patients, 64.7% of them were under 15 years old.

Familiarity (amongst first degree relatives) for deafness was present in 12.7% of the subjects; 2.3% of the patients had past or current occupational noise exposure.

Audiological pathologies were reported in 44%, occurring in pre-school age in 87.7% of the cases, and in 56.4% within the first year. Only 3% of the subjects had hearing aid, with a quantitative profit satisfactory in 66.7% of the cases and optimal in the rest.

The sample studied was not homogeneous and it was affected by the age-related susceptibility to effusive episodes and hearing loss. In order to obtain a better interpretation of the results, the sample was therefore divided into age-groups (table 1) according to the Erikson states of Psychosocial Development (Erikson 1963).

An age-related stratification of the EAC dimensions was also carried out, due to its high variability according to the age, because of facial growth. The results are reported in table 2.

The otoscopic objectivity results have been separated according to age and ear side, as reported in table 3.

Table 1 Sample groups subdivided according to the Erikson states of Psychosocial Development

Group	Age	Number of people in the group
1	Infancy (0-23 months)	5
2	Early childhood (24-47 months)	5
3	Pre-school age (48-59 months)	6
4	School age (5-12 years)	25
5	Adolescence (13-19 years)	28

6	Early adulthood (20-39 years)	31
7	Adulthood (40-64 years)	43
8	Maturity (over 65 years)	0

Table 2. Average of the EAC dimensions according to ear side and age group.

Group	**Dimension of EAC**	**Normal value**
1	2.57±0.35	>4
2	2.89±0.65	3.2 to 7.1
3	3.59±0.84	
4	4.06±0.66	
5-6-7-8	4.35±1.13	5.99- 7.79

Table 3. Otoscopic objectivity, classified according to age and ear side.

Group	**Normal (%)**		**Myringosclerosis (%)**		**OME (%)**		**Perforated TM (%)**	
	R	L	R	L	R	L	R	L
1	0	28.6	7.15	7.15	85.7	57.1	0	0
2	0	66.716.6	16.6	11.1	66.7	11.1	0	0
3	14.8	81.5	33.3	9.25	18.5	0	0	0
4	41.2	83.3	26.5	8.35	0	0	5.9	0
5	41.2	89.5	29.4	5.25	0	0	0	0
6	50.0	70.0	25.0	15.0	0	0	0	0
7	44.4	66.7	27.8	16.7	0	0	0	0
8	29.6	72.7	27.2	11.4	14.7	3.8	0.8	0

OME= Otitis wuth Effusion; TM =Tympanic Membrane; R= Right; L=Left

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Patients underwent either a conventional pure tone audiometric test (PTA), in silent cabin, or a conditioned-orienting-response audiometric examination (in free field with peep show or with headphones and play audiometry), coherent to the age and collaboration. In group 1 only a conditioned peep show in free field was carried out; whereas a child (10%) among those aged from 3 to 5 years old managed to perform the audiometric exam with headphones and play audiometry. The mean of the tone thresholds for each frequency, obtained with the exam in free field, was subsequently calculated. Similarly, also the mean of the air and bone conducted thresholds was calculated, for each frequency, with conventional tone audiometry and play audiometry depicts the results according to age group and ear side. The patients' classification according to the PTA mean values (based on the mean values at 500, 1000, 2000 and 4000 Hz), left and right when not in free field, are illustrated in the tables 4a and 4b. Most patients presented normal hearing or mild hearing loss. Only group 1 and 8 suffered from moderate hearing loss. Two patients had a unilateral left deafness. In table 5 the percentages of the three tympanogram types, are portrayed.

Speech detection thresholds, speech reception thresholds and speech recognition thresholds, according to age, gained with a disyllabic speech audiometry test where compared with the results obtained using the verbal tasks and motor responses test (VTMR). The results are portrayed in table 6.

Patients with sensorineural or mixed hearing loss from middle to deep and with speech discrimination <60% at intensity of a 60 dBnHL and would therefore benefit from the use of hearing aids were 23% but only 18.8% of these (4.2% of the entire sample) used hearing aids; in these cases, the quantitative and qualitative performance of hearing aids was satisfactory.

Table 4a P.T.A. (right ear).

Group	**250**	**500**	**1000**	**2000**	**4000**	**8000**
1	45 ± 10.5	44.73 ± 9.33	41.55 ± 7.87	39.8 ± 8.38	40.08 ± 8.38	-
2	32.37 ± 7.4	30.92 ± 7.24	26.98 ± 12.92	22.24 ± 10.51	23.16±12.02	-
3	28.49 ± 12.32	26.67 ± 10.46	24.3 ± 11.28	24.53 ± 15.32	27.38±16.14	33.75±18.47
4	35 ± 14.4	33.7 ± 14.72	31.95 ± 15.74	30.39 ± 17.11	35.95±17.03	61.67±26.57
5	34.77 ± 14.83	32.5 ± 13.54	30.65 ± 12.78	30.65 ± 12.23	40.34±14.49	60±17.86
6	35 ± 7.63	33.33 ± 7.9	31.11 ± 5.58	30.56 ± 8.13	36.11±14.03	60±24.15
7	50 ± 22.98	45 ± 10.84	48 ± 19.51	50 ± 22.98	55±16.05	96.67±2.89
Air Conduction						

Group	250	500	1000	2000	4000	8000
1	10± 2.59	10 ± 3.27	10± 4.11	10 ± 5.97	10± 3.19	-
2	11.07 ± 2.33	11.21 ± 2.33	11.52 ± 3.6	13.31 ± 6.99	13.11 ± 7.23	-
3	13.05 ± 3.78	14.38 ± 6.8	15.3 ± 10.63	17.19 ± 11.69	19.69 ± 11.9	-
4	18.52 ± 9.11	18.75 ± 11.62	21.56 ± 17.29	21.88 ± 18.88	27.81 ± 18.35	-
5	19.37 ± 17.89	20.36 ± 16.66	21.25 ± 16.59	24.64 ± 15.51	33.93 ± 18.63	-
6	16.99 ± 7.91	18.33 ± 5.16	20.83 ± 7.36	21.67 ± 11.69	30.83 ± 19.34	-
7	25.67 ± 20.21	28.33 ± 14.43	33.33 ± 23.09	45 ± 25.98	56.67 ± 16.07	-
Bone Conduction						

Table 4b P.T.A. (left ear).

Group	250	500	1000	2000	4000	8000
1	45 ± 10.5	45 ± 9.33	41.55 ± 7.87	40.07 ± 8.38	39.8 ± 8.38	-
2	31.19 ± 8.15	29.6 ± 7.95	25.79 ± 13.49	21.58 ± 10.33	21.84 ± 10.44	-
3	31.67 ± 18.02	30 ± 18.1	26.11 ± 17.51	25.56 ± 17.76	26.95 ± 18.96	38.75 ± 21.34
4	33.04 ± 11.12	30.87 ± 11.45	29.58 ± 14	26.7 ± 12.29	33.78 ± 13.57	58.75 ± 25.33
5	31.9 ± 11.29	29.92 ± 9.87	28.98 ± 10.5	29.59 ± 10.36	37.92 ± 11.76	62.17 ± 18.33
6	38.75 ± 7.01	37.5 ± 8.65	33.75 ± 5.59	31.88 ± 10.06	36.25 ± 11.53	66.67 ± 12.58
7	50 ± 17.78	51 ± 14.31	54 ± 14.31	53 ± 12.59	55 ± 16.05	100
Air Conduction						

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Group	250	500	1000	2000	4000	8000
1	10.2 ± 2.12	10± 2.71	10±3.91	10± 5.12	10± 3.37	-
2	10.9 ± 2.49	11.21 ± 2.33	11.52 ± 3.6	13.25 ± 7.82	13.11 ± 7.23	-
3	11.98 ± 3.66	12.14 ± 3.78	11.79 ± 3.17	13.93 ± 5.61	16.07 ± 8.36	-
4	16.05 ± 3.87	18.44 ± 8.11	20.31 ± 14.43	19.06 ± 13.32	26.25 ± 15.11	-
5	15.52 ± 8.18	16.25 ± 7.89	17.50 ± 9.18	22.68 ± 11.43	30.00 ± 15.34	-
6	19.37 ± 17.98	20.00 ± 7.91	20.00 ± 7.91	21.00 ± 11.40	28.00 ± 16.81	-
7	25.67 ± 20.21	31.67 ± 20.21	35.00 ± 25.98	43.33 ± 23.09	53.33 ± 18.93	-
Bone Conduction						

Table 5 Percentage of tympanograms classified for type

Age	A		B		C	
	Right	Left	Right	Left	Right	Left
1	0	0	100	85.7	0	14.3
2	0	0	88.9	77.7	11.1	22.3
3	15.4	23.1	58.3	58.3	41.7	41.7
5	25	33.3	25	33.3	50	33.3
6	47.1	55.6	23.5	11.1	29.4	33.3
7	35	45	20	20	45	35
8	62.5	62.5	15.6	12.5	21.9	25.0

Table 6 Comparison between the mean speech detection thresholds. Speech reception thresholds and speech recognition thresholds, according to age, gained with a bisyllabic speech audiometry test and a speech test using verbal tasks and motor responses (VTMR).

Group	P.T.A. 0.5, 1, 2 KHz *(dB)* bisyllabic		Speech Detection Threshold *(dB)*		Speech Reception *(dB)*		Speech Recognition Threshold *(dB)*	
			VTRM	bisyllabic	VTRM	bisyllabic	bisyllabic	VTRM
1	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
2	20.97 ± 8.12	20.42 ± 6.67	20.42 (±6.67)	32.92 ± 8.73	34.06 ± 8.48	53.75 ± 14.10	45 ± 13.6	20.97 ± 8.12
3	19.92 ± 3.32*	23.64 ± 9.24	23.64 ± 9.24	34.55 ± 11.28	35.00 ± 10.72	50.00 ± 13.60	45.45 ± 9.07	19.92 ± 3.32*
4	29.63 ± 11.93	23.33 ± 8.66	23.33 ± 8.66	34.44 ± 10.14	30 ± 11.47	51.11 ± 16.16	38.89 ± 11.67	29.63 ± 11.93
5	27.87 ± 9.40	30.00 ± 9.52	30.00 ± 9.52	41.18 ± 8.93	37.50 ± 7.91	56.76 ± 11.45	46.47 ± 6.32	27.87 ± 9.40
6	31.67 ± 0.00	30.00 ± 0.00	30.00 ± 0.00	35.00 ± 0.00	35.00 ± 0.00	40.00 ± 0.00	40.00 ± 0.00	31.67 ± 0.00
7	45.83 ± 0.01	62.50 ± 10.61	62.50 ± 10.61	77.50 ± 10.61	65.00 ± 7.07	97.50 ± 10.61	77.50 ± 10.61	45.83 ± 0.01
Total	29.32 ± 11.93	31.64 ± 11.80	31.64 ± 11.80	42.6 ± 12.85	39.42 ± 11.10	58.18 ± 16.46	48.88 ± 12.45	29.31 ± 9.96

Discussion

This study comprises of a large population of patients affected by DS, heterogeneous for age and social integration, as opposed to other studies, which are mostly focused on institutionalized subjects or children (Epstein 1991, Brown 1989, Dahle 1986, McPherson 2007, Hildmann 2002, Maatta 2006, Lott 2010, Mitchell 2003,). Children up to 5 years old, in accordance to other authors, present a high incidence of serous otitis media (more than 85% in the age group between 6 and 35 months old) and associated conductive hearing loss (Dahle 1986, McPherson 2007, Hildmann 2000, Maatta 2006, Mitchell 2003). A Norwegian study presents an incidence of 38% in 8 year-old children (Austeng 2013). According to our sample however, OME after the age of 6 is infrequent. According to Shibahara and Sando, the increased incidence of OME is secondary to an anomalous cartilaginous portion of the Eustachian tube (Shibahara 1989).

The immitance audiometry test resulted mostly influenced by the age of the patient. It is known that children are more susceptible to otitis media with effusion due to the tubaric and immune system immaturity, where 100% of group 1 and nearly 90% of group 2 present a type B tympanogram. On the other side, over 55-year-old patients tended to have a type C tympanogram (80%). However, these results might be overestimated due to the use of traditional probe tone (220 Hz). According to a Lewis et al. in children with DS use of a 1000Hz probe tone is more reliable (Lewis 2011).

A study measuring the EAC of 194 children not affected by DS, of mean age 5 years

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old, evidenced a diameter varying from 4.8 ± 0.5mm and 9.3 ± 0.9mm (Noh 2012). EAC measurements in our sample, of similar age, evidence a narrower canal. Other studies present an incidence of 40-50% of stenotic canal in subjects affected by DS (Cole 1990, Ito 2015, Bairati 1971, Shott 2001, Venail 2004, Rodman 2012).

In accordance to previous studies, where conductive hearing loss is present in 53-88%, 50% of our sample suffered from conductive hearing loss, while a mixed or sensorineural hearing loss varies from 4 to 55% (Balkany 1979, Kattan 2000). Our data evidence a normal hearing in almost all subjects between 6 and 14 years old, whereas from age 3 to 54 years old present a mean hearing threshold at 500, 1000, 2000 and 4000Hz between 10 and 40dB; moreover, they confirm a majority of conductive hearing loss over other types of hearing loss, and from the third decade (after 25 years old), a deflection on acute frequencies (4kHz and 8kHz) similar to presbyacusis. Conductive hearing loss can be a result of the high incidence of OME, although recent studies stress the presence of other middle ear malformations, not responsive to therapy, such as incudostapedial and incudomalleolar articulation anomalies (Ogando 2013, Fausch 2015). Several histopathological studies and radiologic studies have evidenced multiple inner ear anomalies in DS. Some inner ear anomalies, frequently found in DS, in particular lateral semicircular canal malformations and semicircular canal dehiscence, may also result in conductive hearing loss (Minor 2003, Chien 2011). On the other hand, Bilgin et al., affirm a Mondini anomaly in 25% of DS patients (Bilgin 1996). The anomaly mostly associated to SNHL is inner auditory canal stenosis (IAC), observed in 24,5% of DS ears, and up to 57.1% of DS with SNHL (Intrapiromkul 2012). Krmpotic-Nemanic observed early osteoid deposition in the fundus of the IAC adjacent to the spiral tract in this population, causing a compression of the peripheral fibers of the cochlear nerve (Krmpotic-Nemanic 1970).

In literature there are no specific studies of speech audiometry on subjects affected by DS; our results with the VTMR (verbal tasks and motor responses) test are similar to those published by Di Berardino et al. (Di Berardino 2012). In comparison to traditional speech audiometry, the use of VTMR allowed better scores at speech reception and speech recognition thresholds, at lower intensities due to an increase in clues available to the listener, generating a simpler test for subjects with cognitive impairments. Our results confirm hearing aids' utility in patients suffering from hearing loss: all subjects profit greatly from hearing aids' use.

The sample examined presents several maxillo-facial malformations, characteristic of DS: more than 80% of the patients present relative macroglossia, palate alterations (ogival palate) are present in 57.4%, nasal respiratory stenosis in nearly 38% and nasal fossae pathologic secretion in 38.3% of the cases, mostly in paediatric subjects (more than 75%), similarly to previous studies (Ramia 2014, Shott 2006, Shott 2006 bis).

This study aimed to perform an audiological screening, to provide an actual representation of the auditory picture of subjects affected by DS, irrespective of the global health state, the social integration, rehabilitation or age. In order to acquire a better interpretation of the data, it was fundamental to divide the sample according to the age.

Hearing problems in paediatric DS subjects are extremely frequent and, as reported in literature, affect negatively learning and language development, which may lead to important repercussions on cognitive abilities; a periodic audiological evaluation is therefore crucial in order to act promptly, both on a medical-surgical level and rehabilitation.

On the other hand, almost all adults do not present hearing impairments to a grade which can affect communication, even though an early presbyacusis is quite frequent. These results are caused by an improvement in cognitive capacities and of therapeutic approaches and rehabilitation, which have reduced the incidence of permanent hearing damage caused by Eustachian tube dysfunction and recurrent serous otitis media. Patients over 50, although few in our sample, present hearing loss, which is difficult to quantify due to a combined important cognitive decay, associated to the early senile deteriorating processes, typical of the trisomy 21.

The use of hearing aids rehabilitation in subject affected by DS proved to be significantly lower to real needs. In cases where rehabilitation has been carried out we found satisfactory results. This data deserves further study to assess the cognitive effects of early rehabilitation: the relationship between hearing loss and cognitive decline and between hearing loss and dementia are well known.

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