Syndrome of the month

Pendred syndrome

William Reardon, Richard C Trembath

Almost uniquely among syndromic forms of deafness, Pendred syndrome has been the subject of wide ranging epidemiological study indicating that it may account for up to 7.5% of all cases of childhood deafness. Remarkably the condition has been substantially overlooked in recent years. However, the recent mapping of the Pendred locus to chromosome 7q31 and the reporting of locus homogeneity have brought the syndrome back into focus as a distinct clinical entity.23 (J Med Genet 1996;33:1037–1040)

Key words: Pendred syndrome; deafness; thyroid dysfunction.

The natural history of the syndrome first described by Vaughan Pendred (fig 1) in 1896 has not followed a streamlined course, largely owing to the variable clinical presentation and the absence of a specific diagnostic test. Pendred reported an Irish family, resident in the north of England, in which two adult females were deaf and had large goitres, the first evidence of which was dated from the age of 13. Over 30 years later and without reference to Pendred’s report, Brain7 presented details of four families with two or more children affected. Phenotypic variability and, occasionally, difficulty in classifying families/patients as having Pendred syndrome or otherwise are central themes emerging both from Brain’s report and Fraser’s later study of 207 families, comprising 334 cases of Pendred syndrome. Fraser’s study established Pendred syndrome as an important and relatively common cause of inherited deafness, estimating a prevalence of 75 cases per million population.

The exact proportion of genetic deafness attributable to Pendred syndrome is uncertain. Fraser’s estimate of 7.5% of all childhood deafness considerably exceeding more recent estimates. The 7.5% estimate was derived from an adult deaf population, the argument being that the lower figures, varying from 4.3% to 6.4% obtained in large scale studies of paediatric deaf populations, masked those cases of Pendred syndrome in whom the goitre was not detectable in childhood. That this high prevalence figure has not been corroborated in later studies may, at least in part, reflect difficulties in ascertainment, there being no single definitive diagnostic test for the condition.

That deafness and thyroid dysfunction are aetiologically related is beyond dispute. Trotter summarised the situation in 1960, distinguishing clearly between deafness in relation to endemic cretinism/goitre and sporadic goitre with deafness (Pendred syndrome). He drew attention to the several reports identifying unusually high rates of deafness in geographically distinct areas noted to be regions of endemic goitre. Frequently the deafness and goitre were observed in the same people and a likely causative link was further substantiated by the observation in Switzerland of a positive correlation between the falling incidence of deafness over time and the extent of salt iodisation.

Fraser’s criteria for the diagnosis were congenital deafness, goitre, and a positive perchlorate discharge test. Latterly some authors have advocated that a Mondini malformation of the cochlea be included as an essential prerequisite to the diagnosis8 and have recognised a degree of plasticity in the matter of goitre.

Figure 1 Dr Vaughan Pendred (1869–1945), after whom the syndrome is named.
larger study, was that most cases are euthyroid. Many cases do come to surgery for tracheal compression, this hazard being more common among females. Most cases undergoing subtotal thyroidectomy suffer recurrence of the goitre. While goitre was essential to the diagnosis in early reports, identification of the thyroidal defect before the development of goitre is now facilitated by the perchlorate discharge test.

The perchlorate discharge test
In a normally functioning thyroid gland inorganic iodide, having been trapped, is immediately organified by binding to thyroglobulin. Iodination of thyroglobulin requires the generation of $\text{H}_2\text{O}_2$ and the oxidation of iodide and tyrosyl residues by the enzyme thyroid peroxidase. The subsequent coupling of iodytrosyls into iodothyronines $T_3$ and $T_4$ within the matrix of thyroglobulin is also governed by thyroid peroxidase. Perocholate and thiocyanate unmask defects of organification by provoking the discharge of inorganic iodide from the gland. As a result, administration of potassium perchlorate in the presence of an organification defect, having primed the thyroid with radiiodide results in a dramatic fall in the counting rate from sequestered radiiodide over the thyroid, as observed by Morgans and Trotter in 1958. In the case of complete block of organification, thyroidal radioactivity declines in parallel with the plasma radiiodide. A discharge in response to perchlorate of 10% or greater is considered normal (fig 3). Similar levels of iodide discharge may also be recorded in autoimmune thyroid disease and toxic patients treated with radioactive iodine. Hence the perchlorate discharge data must always be considered in the context of clinical and other investigative data.

Radiological studies in Pendred syndrome
The first radiological report appears to be that of Illum et al, who observed Mondini abnormalities in eight of 13 cases examined by temporal bone tomography. CT demonstration of the Mondini abnormality (fig 4) was reported by Johnsen et al in a cohort of cases already known to have the malformation from tomograms. The Mondini malformation is neither a consistent nor specific observation in Pendred syndrome, being well recognised in other forms of deafness, both genetic and non-genetic.

The inherited basis of Pendred syndrome
Brain considered a single recessive trait of pleiotropic effect, segregating in a mendelian manner affecting "several children of normal parents in the absence of a family history of the complaint . . . manifested by both males and females equally" as the likely basis of Pendred syndrome. Fraser concurred, the evidence for autosomal recessive inheritance in his study (the largest on record) being supported not...
Pendred syndrome

While accepting that most cases are likely to be autosomal recessive in nature, does he cite a single example of "pseudodominance". It seems clear that Pendred syndrome does comply with the criteria for autosomal recessive inheritance in most families.

Molecular genetic studies in Pendred syndrome

Subsequent to the exclusion of TPO and thyroglobulin loci,19 Pendred syndrome has recently been mapped to chromosome 7q31. Sheffield et al20 studied two inbred Middle Eastern kindreds and, applying the autozygosy mapping strategy, defined a 9 cM critical interval of homozygosy. In a panel of 12 unrelated British and Israeli sibships, Coyle et al2 independently mapped the Pendred locus to a 5 cM region flanked by the markers D7S501 and D7S523. Neither study showed any evidence for locus heterogeneity. We have recently exploited these findings in a diagnostic capacity in a sibship, offspring of first cousin parents, presenting with deafness. Thyroid function tests were normal and neuroradiology of the cochlea was normal. However, in view of the clinical expression of slight enlargement of the thyroid in one of the sibs, we sought evidence for homozygosy at the Pendred locus (fig 5), rather than proceeding directly to perchlorate discharge testing. Homozogosity was confirmed and a perchlorate discharge of 60% was subsequently recorded in this child.

Interestingly, Pendred syndrome maps to the region containing the recently reported non-syndromic autosomal recessive deafness locus DFNB4. This latter report was based upon a single inbred Druze kindred in Israel20 in which the disorder was localised by the autozygosy approach. In the context of the apparent co-localisation of Pendred syndrome and DFNB4, it is worth noting that the Druze family was not investigated for Pendred syndrome. Whether DFNB4 represents Pendred syndrome, an adjacent deafness locus, or an allelic form remains to be resolved. The identification of non-syndromic autosomal recessive loci for deafness is complicated by significant locus heterogeneity, nine such loci having been mapped to date. In contrast, the locus homogeneity found in Pendred syndrome and the availability of multiple independent families should facilitate a positional cloning approach to gene identification.

Towards the molecular basis of Pendred syndrome

The linkage interval for Pendred syndrome does not contain any recognised candidate genes. Foremost among the prerequisites of any such candidate are the reconciling of both thyroid and cochlear involvement. Both organs are of ectodermal derivation. Moreover, thyroid hormone receptor genes are widely expressed during auditory neurogenesis21 and homozogous deletion for the thyroid hormone beta receptor is known to result in sensorineural deafness.22,23 Little is known of the role or contribution of iodide to normal inner ear development and function. The pathway of iodide organisation required in the production of thyroid hormones occurs within the follicular cells of the thyroid gland. This process requires
the generation of H₂O₂ in conjunction with the enzyme thyroid peroxidase. In the total iodide organification defect (TIOD), an independent autosomal recessive condition characterised by congenital hypothyroidism alone, and a greater than 90% iodide discharge following perchlorate administration, a range of mutations in the coding sequence of the thyroid peroxidase gene have been established.²⁴⁻²⁸ For two distinct reasons the molecular basis of Pendred syndrome is likely to represent an organification defect. Firstly, the perchlorate induced discharge of iodide in TIOD shows a causal relationship between defective organification and perchlorate sensitivity. Secondly, Sheffield et al.,¹ by in vitro analysis of thyroid tissue from affected patients, have shown a post iodide uptake defect and an organification defect with proportionate reduction in T₁ secretion. Neither of these observations exclude a defect in the intracytoplasmic domains of the iodide transporter.

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