Somatic \textit{GPR101} Duplication Causing X-Linked Acrogigantism (XLAG)—Diagnosis and Management

Celia Rodd, Maude Millette, Donato Iacovazzo, Craig E. Stiles, Sayka Barry, Jane Evanson, Steffen Albrecht, Richard Caswell, Benjamin Bunce, Sian Jose, Jacqueline Trouillas, Federico Roncaroli, Julian Sampson, Sian Ellard, and Mártaw Korbonits

Pediatrics and Child Health (C.R.), University of Manitoba, Winnipeg MB R3E 0Z2, Canada; Department of Pediatrics (M.M.), Centre mère-enfant Soleil, Centre Hospitalier de l’Université de Quebec, QC G1V 4G2, Canada; Endocrinology (D.I., C.E.S., S.B., J.E., M.K.), Barts and the London School of Medicine, Queen Mary University of London, London EC1M 6BQ, United Kingdom; Department of Pathology (S.A.), McGill University, Montreal QC H4A 2J1, Canada; Molecular Genetics (R.C., B.B., S.E.), University of Exeter, Exeter EX4 4SB, United Kingdom; Institute of Medical Genetics (S.J., J.S.), School of Medicine, Cardiff University, Cardiff CF10 3XQ, United Kingdom; Centre de Pathologie Est (J.T.), Hospices Civils de Lyon, University of Lyon, 69622 Lyon, France; and Neuropathology (F.R.), University of Manchester, Manchester M13 9PL, United Kingdom

\textbf{Context:} Recent reports have proposed that sporadic or familial germline Xq26.3 microduplications involving the \textit{GPR101} gene are associated with early-onset X-linked acrogigantism (XLAG) with a female preponderance.

\textbf{Case Description:} A 4-year-old boy presented with rapid growth over the previous 2 years. He complained of sporadic headaches and had coarse facial features. His height Z-score was $+4.89$, and weight Z-score was $+5.57$. Laboratory testing revealed elevated serum prolactin (185 $\mu$g/L; normal, $<18$ $\mu$g/L), IGF-1 (745 $\mu$g/L; normal, 64–369 $\mu$g/L), and fasting GH $>35.0$ $\mu$g/L. Magnetic resonance imaging demonstrated a homogenous bulky pituitary gland (18 $\times$ 15 $\times$ 13 mm) without obvious adenoma. A pituitary biopsy showed hyperplastic pituitary tissue with enlarged cords of GH and prolactin cells. Germline \textit{PRKAR1A, MEN1, AIP, DICER1, CDKN1B}, and somatic GNAS mutations were negative. Medical management was challenging until institution of continuous sc infusion of short-acting octreotide combined with sc pegvisomant and oral cabergoline. The patient remains well controlled with minimal side effects 7 years after presentation. His phenotype suggested XLAG, but his peripheral leukocyte-, saliva-, and buccal cell-derived DNA tested negative for microduplication in Xq26.3 or \textit{GPR101}. However, DNA isolated from the pituitary tissue and forearm skin showed duplicated dosage of \textit{GPR101}, suggesting that he is mosaic for this genetic abnormality.

\textbf{Conclusions:} Our patient is the first to be described with somatic microduplication leading to typical XLAG phenotype. This patient demonstrates that a negative test for Xq26.3 microduplication or \textit{GPR101} duplication on peripheral blood DNA does not exclude the diagnosis of XLAG because it can result from a mosaic mutation affecting the pituitary. (\textit{J Clin Endocrinol Metab} 101: 1927–1930, 2016)

\textbf{X}-linked acrogigantism (XLAG) is a recently described clinical syndrome of early-onset gigantism with typical onset in the first few months of life and more often affecting females (1–3). The disease is associated with microduplications at Xq26.3 involving the \textit{GPR101} gene, which encodes a G protein-coupled orphan receptor.
Most of the patients present with a GH and prolactin (PRL)-secreting pituitary adenoma or less commonly GH and PRL cell hyperplasia. The vast majority of the previously described patients required extensive anterior pituitary resection or radiotherapy, resulting in hypopituitarism to control exuberant hormone secretion and growth velocity, because medical management with somatostatin analogs has not been sufficient (3).

**Case Report and Methods**

A 4-year and 8-month-old Caucasian boy presented to the Montreal Children’s Hospital with rapid growth over the preceding 2 years. Born at term with a weight of 4.7 kg (>95th percentile), he had grown steadily along the 90th percentile for length up to 24 months of age and was above the median for weight and head circumference. He had undergone a tonsillectomy and adenoidectomy at the age of 3 years and 10 months. He complained of intermittent headaches over the preceding 8 months, was otherwise asymptomatic, and took no medications. His family history was unremarkable for any endocrinopathies; his mid-parental height was 174.5 cm. On examination, he appeared older than his stated age, was prepubertal, and had coarse facial features, which had developed over the previous 3 years. His height was 129.7 cm (Z = +4.89), and his weight was 35.5 kg (Z = +5.57) (WHO Growth Charts for Canada; Ref. 4) (Figure 1A).

![Figure 1. A, Growth chart before and after surgical and medical interventions. Treatment strategies are indicated as follows: arrow, diagnosis and surgery; DA, dopamine agonist (initially bromocriptine then followed by cabergoline); SSA, somatostatin analog (initially Sandostatin LAR and Somatuline Autogel, then continuous sc infusion [cSSA] administered at 120–320 µg/d dose); and PG, pegvisomant dose, 30–105 mg/wk. B, Growth velocity in centimeters per year (left y-axis, circles) and IGF-1 concentrations (right y-axis, triangles; fold above 95% upper reference limit for age). C—F, Magnetic resonance imaging of the pituitary gland, coronal (C) and sagittal (D) view before surgery, and 5 weeks (E) and 24 months (F) after surgery. G and H, Histological examination of the pituitary tissue demonstrates normal architecture of the gland with preservation of the reticulin network but markedly enlarged cell cords, suggesting diffuse hyperplasia: hematoxylin-eosin staining, ×10 (G); and Gomori’s reticulin stain, ×10 (H). I and J, The gland shows an increase in GH-positive (immunoperoxidase, ×10; I) and PRL-positive cells (immunoperoxidase, ×10; J).](image-url)
Laboratory investigations revealed elevated serum concentrations of PRL (185 μg/L; normal, <18 μg/L [8043 pmol/L; normal, <788 pmol/L]; Access II; Beckman Coulter), IGF-1 (74.5 μg/L; normal for age, 6.4–36.9 μg/L [9.78 nmol/L, 0.8–4.8]; Immulite), and a fasting GH of >35.0 μg/L (Access II; Beckman Coulter) (Figure 1B). GH suppressed only to 29.0 μg/L after standard oral glucose load (normal, <1.0). His clinical and biochemical diagnosis was pituitary gigantism with hyperprolactinemia. Magnetic resonance imaging demonstrated a homogeneous sellar mass measuring 18 × 15 × 13 mm with mild suprasellar extension without optic chiasm or cavernous sinus invasion (Figure 1C and D). Surgical debulking was performed via transfrontal craniotomy. Histological examination of the tissue confirmed the absence of adenoma and demonstrated a hyperplastic pituitary with enlarged cords of GH and PRL cells (Figure 1, G–J). Cells with ultrastructural features resembling mammosomatotrophs were also identified. Genetic analysis was negative for germline AIP, PRKAR1A, DICER1, MEN1, and CDKN1B mutations and for GNAS mutations in both leukocyte and pituitary tissue-derived DNA. Plasma GHRH (Inter Science Institute) levels were normal on two separate samples. His bone age was 5 years.

Postoperatively, his hormone levels remained elevated; the hyperplastic tissue re-expanded rapidly in the fossa (Figure 1, E and F), and his growth continued at an accelerated pace (Figure 1, A and B). His management was challenging. Dopamine agonists proved unsuccessful in suppressing GH hypersecretion; bromocriptine was initiated for the first 3 months but was later replaced with cabergoline (0.25–0.5 mg/wk) to control PRL levels. Long-acting somatostatin analog therapy induced a slight suppression of the tissue confirmed the absence of adenoma and found duplications allowing a definitive diagnosis of Xq26.3 microduplications or GPR101 duplication. One of the four different genomic DNA samples we tested from various tissues also showed GPR101 duplication, suggesting that he is mosaic for this mutation.

Ethics approval was granted from the Montreal Children’s Hospital Research Ethics Board. Informed consent was obtained for all genetic analyses from the parents of this boy and for publication of this case report.

**Discussion**

XLAG often manifests in the first year of life and is more prevalent in girls. Unlike our case, all previously reported patients have had either sporadic or familial germline Xq26.3 microduplications allowing a definitive diagnosis on leukocyte-derived DNA. Because our case presented with a typical phenotype, we tested the pituitary tissue sample, and this showed GPR101 microduplication. One of the four different genomic DNA samples we tested from various tissues also showed GPR101 duplication, suggest-

**Figure 2.** GPR101 copy number as measured with copy number variation droplet digital PCR (assay id Hs01818174_cn, Life Technologies), showing two copies of GPR101 for normal female control, one copy for normal male control, one copy for the patient’s blood-derived DNA, and two copies for the patient’s pituitary tissue-derived DNA. Vertical bars show 95% Poisson confidence limits.
ing that this patient has somatic mosaicism as a result of a postzygotic mutation. No cases of somatic mosaicism have been described previously in patients with XLAG syndrome.

Treatment of XLAG is challenging. Previously described cases treated with surgery followed by medical treatment and/or radiotherapy have often developed hypopituitarism and central diabetes insipidus (1–3, 6). Management of our patient with cabergoline, continuous SC infusion of short-acting somatostatin analog, and pegvisomant proved successful in controlling growth without hypopituitarism or other significant side effects.

Conclusion

This is the first report on a patient with documented somatic GPR101 duplication leading to XLAG. The case is instructive because it: 1) demonstrates that a negative genetic test for Xq26.3 microduplication or GPR101 duplication on peripheral blood DNA does not exclude the diagnosis of XLAG because it can result from a somatic mutation affecting the pituitary and possibly other tissues as a result of somatic mosaicism; and 2) proposes an effective combination and route of medical treatment for this condition that can be acceptable for young children.

Acknowledgments

We are grateful to Prof Kalman Kovacs, Toronto, Canada, for advice on the pathology findings, and to Prof Michael Besser, London, UK, for management of the case. Address all correspondence and requests for reprints to: Prof. Márta Korbonits, Department of Endocrinology, Barts and the London School of Medicine and Dentistry, Charterhouse Square, London EC1M 6BQ, United Kingdom. E-mail: m.korbonits@qmul.ac.uk.

Grant support from the National Institutes of Health Research (NIHR), Wales Gene Park, and Pfizer Ltd is gratefully acknowledged. C.E.S. is supported by a Wellcome Clinical Training Fellowship. S.E. is a Wellcome Trust Senior Investigator.

C.R., M.M., and M.K. cared for the patient. S.A., J.T., and F.R. made the histological diagnosis. All other authors were involved in the genetic testing; all authors contributed to the writing of the manuscript.

Disclosure Summary: M.K. is a member of the Scientific Advisory Board of Pfizer. None of the other authors report any conflict of interest.

References

1. Trivellin G, Daly AF, Faucz FR, et al. Gigantism and acromegaly due to Xq26 microduplications and GPR101 mutation. N Engl J Med. 2014;371:2363–2374.
2. Beckers A, Lodish MB, Trivellin G, et al. X-linked acrogigantism syndrome: clinical profile and therapeutic responses. Endocr Relat Cancer. 2015;22:353–367.
3. Rostomyan L, Daly AF, Petrossians P, et al. Clinical and genetic characterization of pituitary gigantism: an international collaborative study in 208 patients. Endocr Relat Cancer. 2015;22:745–757.
4. Canadian Paediatric Society. WHO Growth Charts. Promoting optimal monitoring of child growth in Canada: using the WHO growth charts. http://www.cps.ca/tools-outils/who-growth-charts. Accessed December 27, 2015.
5. Näntö-Salonen K, Koskinen P, Sonninen P, Toppari J. Suppression of GH secretion in pituitary gigantism by continuous subcutaneous octreotide infusion in a pubertal boy. Acta Paediatr. 1999;88:29–33.
6. Naves LA, Daly AF, Dias LA, et al. Aggressive tumor growth and clinical evolution in a patient with X-linked acro-gigantism syndrome. Endocrine. 2016;51:236–244.