Letrozole Significantly Improves Growth Potential in a Pubertal Boy With Growth Hormone Deficiency

Ping Zhou, MD; Bina Shah, MD; Kris Prasad, PhD; and Raphael David, MD


ABBREVIATIONS. AI, aromatase inhibitor; BMD, bone mineral density; GH, growth hormone; PTH, parathyroid hormone; IGF, insulin-like growth factor.

Estrogen plays a critical role for the pubertal growth spurt, skeletal maturation, and accrual and maintenance of bone mass in females as well as males.1–4 It is now evident that gene mutations of aromatase or estrogen receptor that result in impairment of estrogen production or action have similar phenotypes, including abnormally tall stature with euenuchoid proportions, a lack of pubertal growth spurt, unfused epiphyses, and osteopenia. Aromatase, encoded by the CYP19 gene located on chromosome 15q21.2 and expressed in bones, is the key enzyme for estrogen biosynthesis.2–4 It has been proposed that an aromatase inhibitor (AI) can be used to improve the final adult height in short pubertal boys. The hypothesis is that suppressing estrogen formation after the onset of puberty would delay the closure of the epiphyses, thus allowing for an extended period of growth without affecting the progression of androgenic development. Potential adverse effects of AIs, such as reduced bone mineral density (BMD), metabolic effects including a propensity for insulin resistance and dyslipidemia, and impairment of the hypothalamic-pituitary-gonadal axis, need to be considered.5 To date, a couple of studies, at least in the short term, indicate that the use of an AI is safe and promising.6–8

CASE REPORT

A white male was first seen for evaluation of short stature at 14 years 8 months old. He was healthy with no other medical problems, and his birth weight and length were reported as normal. Family history was unremarkable. His father’s height was 177.8 cm and his mother’s height was 162.5 cm. His midparental target height was 176.7 cm (calculated as the average of parents’ heights + 6.55). His initial examination revealed the following: height, 143 cm (<3rd percentile; z score = −2.94); upper/lower segment ratio, 1.0; weight, 44.5 kg (11th percentile); pubic hair, Tanner II; testicular volume, 4 to 6 mL; bilateral gynecomastia. Growth hormone (GH) deficiency was diagnosed after a standard comprehensive work-up (GH peak: 6.1 ng/mL poststimulation), and GH treatment (0.3 mg/kg per week) was initiated at 15 years. The patient responded well (Fig 1). After 14 months of GH treatment, his height increased from 144.5 to 158 cm (z score: from −2.94 to −2.04), a gain of 13.5 cm (Table 1). However, although his puberty advanced to Tanner stage IV for pubic hair and testicular volume increased to 10 mL (Tanner III), his final adult-height prediction still remained 2 SDs below his target height. Letrozole (2.5 mg/day) was added at 16 years 2 months, when his bone age advanced only 9 months (Greulich-Pyle method). His height z score improved further, from −2.04 to −1.08 (Table 1), and his adult-height prediction as estimated by the Bailey-Pineau method improved from 166.4 to 175.3 cm, corresponding to his target height. His upper/lower segment ratio was maintained at 1.0. Weight gain was noticed during the course of treatment (Fig. 1). His BMI increased from 22 (75th percentile) to 24 (83rd percentile) after GH and to 27 (92nd percentile) after the addition of letrozole. Bone turnover markers were monitored. Four months after starting letrozole, the patient started to receive calcium supplementation (1200 mg/day) and vitamin D3 (400 IU/day) because of a mildly elevated intact parathyroid hormone (PTH) level of 69.9 pg/mL (reference: 10–65 pg/mL), low-normal 25-H vitamin D3 level of 23 ng/mL (reference: 10–69 ng/mL), and mildly elevated 1,25-(OH)2 vitamin D level of 76 pg/mL (reference: 27–71 pg/mL). Alkaline phosphatase was stable in the reference range, and PTH normalized after calcium and vitamin D supplementation. Bone markers including osteocalcin and N-telopeptide were decreased during therapy with letrozole and GH (see Table 1). Aerial bone density was determined by using a Hologic DEXA scanner (Bedford, MA), and the results were expressed as age-, gender-, and ethnicity-adjusted z scores. Although there was no pretreatment BMD study, a series of studies obtained at 4, 14, and 17 months during therapy actually showed some improvement of z score from −2.50 to −1.90.

As shown in Table 1, there was an initial increase in serum insulin-like growth factor 1 (IGF1) from 124 to 824 ng/mL, undoubtedly reflecting the effects of GH therapy, which was then maintained in the high to upper-normal range (reference: 182–839 ng/mL). Basal follicle-stimulating hormone ranged from 9 to 12 mIU/mL (reference: 1.2–11.0 mIU/mL), and luteinizing hormone ranged from 5 to 7 mIU/mL (reference: 0.2–7.0 mIU/mL), both of which are in the high-normal range. Serum testosterone increased from 43 to 460 ng/dL after letrozole and then stabilized between 251 and 450 ng/dL (Tanner V; reference: 300–900 ng/dL).

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Fig 1. Growth chart.
### TABLE 1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Age</th>
<th>Patient Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 y</td>
<td>15 y</td>
<td>15 y 15 y2 m o 16 y2 m o 16 y4 m o 16 y6 m o 16 y10 m o 17 y2 m o 17 y4 m o 17 y6 m o</td>
</tr>
<tr>
<td>2 mo</td>
<td>118</td>
<td>GH (0.3 mg/kg per wk)</td>
</tr>
<tr>
<td>4 mo</td>
<td>118</td>
<td>Letrozole (2.5 mg/d)</td>
</tr>
<tr>
<td>8 mo</td>
<td>118</td>
<td>Height, cm 144.5 146.0 158.0 159.5 161.0 162.2 165.5 166.5 168.0</td>
</tr>
<tr>
<td>12 mo</td>
<td>118</td>
<td>Score of height z 1.72 1.25 1.08 1.35 2.92 2.94 2.04 1.92</td>
</tr>
<tr>
<td>14 mo</td>
<td>118</td>
<td>Tanner stage 2 2 3 3 3 4 4 5 5</td>
</tr>
<tr>
<td>17 mo</td>
<td>118</td>
<td>Bone age 13 y 14 y 14 y 14 y 14 y 14 y 14 y</td>
</tr>
<tr>
<td>17 mo</td>
<td>118</td>
<td>Predicted adult height, cm 158.0 166.4 173.0 175.3</td>
</tr>
<tr>
<td>15 y 2 mo</td>
<td>118</td>
<td>IGF1, ng/mL 124.0 607.0 824.0 740.0 664.0 700.0 527.0 792.0 804.0</td>
</tr>
<tr>
<td>15 y 4 mo</td>
<td>118</td>
<td>Follicle-stimulating hormone, mIU/mL 2.0 10.0 12.0 9.0 9.0 11.0 17.0 4.0 5.0</td>
</tr>
<tr>
<td>15 y 6 mo</td>
<td>118</td>
<td>Luteinizing hormone, mIU/mL 17.0 4.0 5.0 4.0 5.0</td>
</tr>
<tr>
<td>15 y 8 mo</td>
<td>118</td>
<td>Testosterone, ng/dL 43.0 460.0 390.0 270.0 250.0 312.0 450.0</td>
</tr>
<tr>
<td>15 y 10 mo</td>
<td>118</td>
<td>Estradiol, pg/mL 5.4 6.0 8.0 8.0 9.0 9.0 5.4 6.0 8.0</td>
</tr>
<tr>
<td>15 y 2 mo</td>
<td>118</td>
<td>Intact PTH, pg/mL 238.0</td>
</tr>
<tr>
<td>15 y 4 mo</td>
<td>118</td>
<td>Alkaline phosphatase, U/L 238.0 287.0 360.0 332.0 275.0 312.0 344.0 256.0</td>
</tr>
<tr>
<td>15 y 6 mo</td>
<td>118</td>
<td>Osteocalcin, ng/mL 134.3 115.0 23.0 29.2</td>
</tr>
<tr>
<td>15 y 8 mo</td>
<td>118</td>
<td>-Telopeptide, nM BCE/mM creatinine 682.0 398.0 421.0 370.0</td>
</tr>
<tr>
<td>15 y 10 mo</td>
<td>118</td>
<td>Z-score of height 2.50 1.70 1.90 1.70</td>
</tr>
<tr>
<td>15 y 12 mo</td>
<td>118</td>
<td>BMD, score</td>
</tr>
</tbody>
</table>

+ indicates off prescription; —, on prescription; BCE, bone collagen equivalents.


## DISCUSSION

The effect of estrogen on the dynamic processes of bone turnover is multifactorial. Its actions involve other hormones and factors such as GH, IGFs and their binding proteins, other growth and morphogenic factors, thyroid hormone, vitamin D, retinoids, PTH and PTH-related peptide, cytokines, and their receptors. Although it is clear now that estrogen plays a major role in the pubertal growth spurt, skeletal maturation, and the accrual and maintenance of bone mass in both females and males, there is also evidence supporting a direct role for androgen on bone mass accrual. Manipulating hormone levels by AIs to decrease estrogen and increase androgen levels is an attractive option for extending the period of growth of short boys in puberty.

Our case documents a favorable outcome with GH and AI therapy in the enhancement of growth potential at least on a short-term basis. The adult-height prediction improved significantly while pubertal maturation proceeded unimpeded. Letrozole has been well tolerated by the patient. Potential adverse effects of AIs including decreased bone accretion and maturation and abnormalities in pubertal maturation have to be monitored carefully. Although BMD in our patient was at −2.5 (z score) after initiation of letrozole, it subsequently improved, which is likely because of the beneficial effect of GH and probably also the increase in endogenous testosterone. Biochemical markers of puberty including serum testosterone, gonadotropins, and changes in the estradiol-to-testosterone ratio showed the expected effects of relative estrogen suppression, and the hormone levels eventually remained in the normal range for the pubertal stage.

After 17 months’ treatment of GH and letrozole, the lipid profile was normal. The only adverse finding was an indication of insulin resistance, with an elevated fasting insulin level. The cause of this insulin resistance (whether due to the patient’s excess weight or the treatment) is impossible to determine in this single case. Overall, the degree of the aromatase inhibition significantly improved height prediction without a negative impact on either the gonadotropin-testicular axis or bone health.

Recent studies by Dunkel and co-workers in Finland showed results generally consistent with our observations. The authors compared the effect of letrozole plus testosterone to testosterone alone in
treatment boys with delayed puberty. After 18 months of
treatment, their letrozole group increased the av-
average predicted final adult height by 5.1 cm. In our
own patient treated with comparable doses of letro-
zole in addition to GH, the predicted final height
increased by 8.9 cm. It is encouraging to note that in
the patients of Dunkel and co-workers, no detrimen-
tal effects on BMD were found.7

Gonadotropin-releasing hormone analog (GnRHa)
therapy has been used for the treatment of short
stature in pubertal boys and girls.14 Detrimental ef-
fects of GnRHa on body composition, muscle
strength, and protein, lipid, and calcium metabolism,
in addition to inhibiting virilization in males, have
been the subject of several publications.15–17 These
effects make the use of these analogs unsuitable in
the long term if the sole purpose of treatment is to
increase final height. The conclusion from a recent
study by Yanovski et al stated that “treatment with
an LHRH [luteinizing hormone-releasing hormone]
agonist for 3.5 years increases adult height by 0.6 SD
in adolescents with very short stature but substan-
tially decreases bone mineral density. Such treatment
cannot be routinely recommended to augment height
in adolescents with normally timed puberty.”18(p908)
Thus, the use of a potent selective aromatase blocker
offers the advantage of continued virilization and
maintenance of pubertal body composition5,7 in boys
while potentially delaying skeletal maturation. We
therefore believe that the use of an AI with or with-
out GH is a better option for enhancing the growth
potential of short pubertal boys. Although our case
and the Finnish studies showed a short-term benefit
using an AI, long-term controlled studies are neces-
ary to establish its safety and efficacy.

REFERENCES
1. Grumbach M, Auchus RJ. Estrogen: consequences and implications
of human mutations in synthesis and action. J Clin Endocrinol Metab.
1999;84:4677–4694
2. Meinhardt U, Mullis PE. The aromatase cytochrome P-450 and its
clinical impact. Horm Res. 2002;57:145–152
331:1056–1061
deficiency in male and female siblings caused by a novel mutation and
the physiological role of estrogens. J Clin Endocrinol Metab. 1995;80:
3689–3698
5. Mauras N, O’Brien KO, Oerter Klein K, Hayes V. Estrogen suppression
in males: metabolic effects. J Clin Endocrinol Metab. 2000;85:2370–2377
A specific aromatase inhibitor and potential increase in adult height in
boys with delayed puberty: a randomised controlled trial. Lancet. 2001;
357:1743–1748
7. Wickman S, Kajantie E, Dunkel L. Effects of suppression of estrogen
action by the p450 aromatase inhibitor letrozole on bone mineral den-
sity and bone turnover in pubertal boys. J Clin Endocrinol Metab. 2003;
88:3785–3793
8. Wickman S, Saukkonen T, Dunkel L. The role of sex steroids in the
regulation of insulin sensitivity and serum lipid concentrations during
male puberty: a prospective study with a P450-aromatase inhibitor. Eur
9. Bayley N, Pinneau SR. Tables for predicting adult height from skeletal
1952;40:423–441
10. Stevens DA, Williams GR. Hormone regulation of chondrocyte differ-
entiation and endochondral bone formation. Mol Cell Endocrinol. 1999;
151:195–204
11. Orwell ES. Androgens as anabolic agents for bone. Trends Endocrinol
Metab. 1996;7:77–84
12. Wiren K, Keenan E, Zhang X, Ramsey B, Orwell E. Homologous an-
drogen receptor up-regulation in osteoblastic cells may be associated
with enhanced functional androgen responsiveness. Endocrinology.
1999;140:3114–3124
13. Vanderschueren D. Androgens and their role in skeletal homeostasis.
Horm Res. 1996;46:95–98
14. Lanes R, Giczler P. Final height after combined growth hormone and
gonadotropin-releasing hormone analogue therapy in short healthy
children entering into normally timed puberty. Clin Endocrinol (Oxf).
1998;49:197–202
15. Palmert MR, Mansfield MJ, Crowley WF Jr, Crigler JF Jr, Crawford JD,
Boepple PA. Is obesity an outcome of gonadotropin-releasing hormone
agonist administration? Analysis of growth and body composition in
110 patients with central precocious puberty. J Clin Endocrinol Metab.
1999;84:4480–4488
16. Heger S, Partsch CJ, Sippell WG. Long-term outcome after depot gona-
dotropin-releasing hormone agonist treatment of central precocious
puberty: final height, body proportions, body composition, bone min-
eral density, and reproductive function. J Clin Endocrinol Metab. 1999;
84:4383–4390
17. Boot AM, De Muinck Keizer-Schrama S, Pols HA, Krenning EP, Drop
SL. Bone mineral density and body composition before and during
treatment with gonadotropin-releasing hormone agonist in children
with central precocious and early puberty. J Clin Endocrinol Metab.
1998;83:370–373
ing hormone-releasing hormone agonist in adolescents with short stature.
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