Hypoglossal Nerve Stimulation for Obstructive Sleep Apnea in a Young Child With Down Syndrome

Isaac Wasserman, MD, MPH,[a] Douglas J. Chieffe, MD,[a] Kevin S. Gipson, MD, MS,[b,c,d] Brian G. Skotko, MD, MPP,[c,e] Christopher J. Hartnick, MD[a]

abstract

Obstructive sleep apnea (OSA) is common in children with Down syndrome (DS). Adenoidectomy and/or tonsillectomy are the usual first interventions employed to treat OSA in children with DS but sometimes do not achieve adequate resolution of clinical signs. Positive airway pressure treatment is often used next, but this treatment is poorly tolerated by this population. Persistent OSA can adversely affect a child's health and cognitive development. Hypoglossal nerve stimulation (HGNS), previously shown to be safe and effective in adults with OSA, has been used in children as young as 10 years old with DS and has achieved measurable neurocognitive benefits. The US Food and Drug Administration recently lowered the age for HGNS implantation to 13 years for children with DS. However, questions remain regarding treatment of refractory OSA in younger children. Here, we report the case of a 4-year-old boy with DS and treatment–refractory OSA who underwent successful HGNS implantation. The decision to proceed with HGNS implantation in such a young child involved discussions about anatomic feasibility and potential neurocognitive benefits. The device was implanted without complication and with minimal postoperative bulk. This case suggests a possible treatment option that can be discussed in the course of shared decision-making between clinicians and families of young children with DS and treatment–refractory OSA.

Obstructive sleep apnea (OSA) disproportionately affects children with Down syndrome (DS), affecting up to 80% of children with DS compared with the estimated 5% prevalence of OSA in the general pediatric population.[1] Adenoidectomy and/or tonsillectomy (AT) are broadly accepted as first-line interventions in children with clinically significant OSA, but AT resolves clinical signs of OSA in less than a third of children with DS.[2] Therefore, many of these children are started on positive airway pressure (PAP) treatment, which is often poorly tolerated given concomitant sensory processing limitations.[3] There is concern that suboptimally managed OSA in the developing child can adversely affect cognition.[4] To address this barrier to effective longitudinal OSA treatment, the hypoglossal nerve stimulator (HGNS) was developed and first implanted in a child in 2015.[5] We have previously shown that this treatment is safe and effective in children with DS as young as 10 years of age.[6] In addition, our group has demonstrated a trend in neurocognitive benefits in this treated population.[7] Building on these discoveries, the US Food and Drug Administration announced on March 21, 2023, (World DS Day) that it had reduced the regulatory threshold for HGNS implantation in children with DS to age 13. With this advance in access to care, questions persisted regarding the treatment of refractory OSA in very young children who face many years of challenge to achieving

[a]*Department of Otolaryngology, Massachusetts Eye and Ear, Boston, Massachusetts;* [b]*Department of Pediatric Pulmonary Medicine, Massachusetts General Hospital for Children, Boston, Massachusetts;* [d]*Division of Sleep Medicine, and* [c]*Department of Pediatrics, Harvard Medical School, Boston, Massachusetts; and* [e]*Down Syndrome Program, Division of Medical Genetics and Metabolism, Department of Pediatrics, Massachusetts General Hospital, Boston, Massachusetts*

Dr Hartnick conceptualized and designed the study, and collected data; Drs Gipson, Skotko, and Chieffe collected data; Dr Wasserman collected data and drafted the initial manuscript; and all authors critically reviewed and revised the manuscript, approved the final manuscript as submitted, and agree to be accountable for all aspects of the work.

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Address correspondence to Christopher J. Hartnick, MD, Department of Otolaryngology, Massachusetts Eye and Ear, 243 Charles St, Boston, MA 02114.
E-mail: christopher_hartnick@meei.harvard.edu

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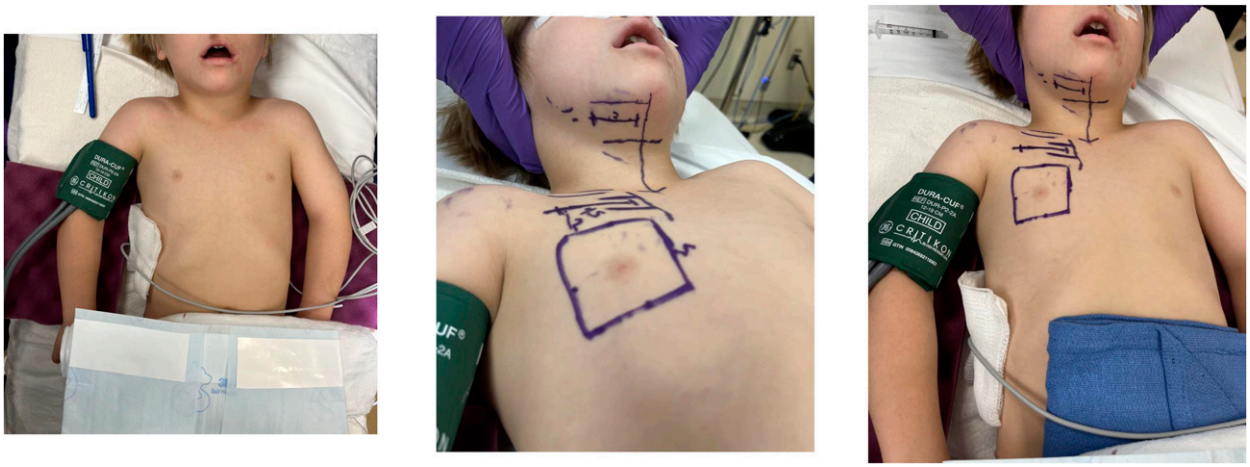

FIGURE 1
Preoperative marking of planning incisions, electrode placement, and stimulator pocket.

optimal neurocognition. In the course of discussing how best to manage very young patients with DS and OSA with our pediatric, pulmonary, sleep medicine, and neurology colleagues, our group sought to better understand the anatomic feasibility of implantation and to define any short- and long-term benefits to neurocognitive development which might be seen with early implantation. Here, we report the case of a 4-year-old boy with DS who underwent an uncomplicated placement of a HGNS for refractory OSA and persistent PAP intolerance.

PATIENT PRESENTATION

Our patient, a boy with DS, initially underwent a polysomnogram (PSG) at 1 year of age that demonstrated severe OSA (apnea–hypopnea index [AHI] 22.9 per hour; obstructive apnea and hypopnea subindex [OAHI] of 19.3 per hour; oxygen saturation nadir 79%; and 20 minutes total sleep time at or below and pulse oxygen saturation [SpO2] of 90%). He subsequently underwent an AT and supraglottoplasty without significant benefit noted on 6-month postoperative PSG (AHI 19, OAHI 12.1, nadir SpO2 81%). In response, he underwent midline tongue base reduction at age 3; however, persistent moderate-to-severe OSA (AHI 11.8 per hour; OAHI 9.2 per hour, nadir SpO2 82%) was noted at a 3-month postoperative visit. Despite significant efforts from the family and with the support of occupational therapy, the patient was persistently intolerant of PAP therapy. Drug-induced sleep endoscopy suggested that the patient would be a good candidate for HGNS, with significant tongue base collapse and without residual adenoids, palatine tonsils, or lingual tonsils.

After extensive discussion with the family regarding the risks of proceeding with an attempt at implantation in a child this young (the youngest, to our knowledge), including the possibility that the hypoglossal nerve may not accommodate the electrode, the shared decision was made to proceed with surgery, and a compassionate exemption petition was made to his third-party insurance who approved the procedure as an off-US Food and Drug Administration label procedure (Fig 1). The surgery proceeded uneventfully, and the appropriate inclusion branches of the

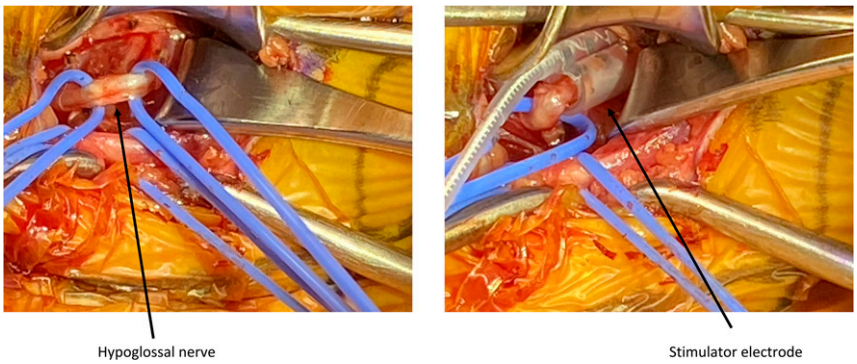

FIGURE 2
Intraoperative identification of the hypoglossal nerve and placement of the stimulator electrode.

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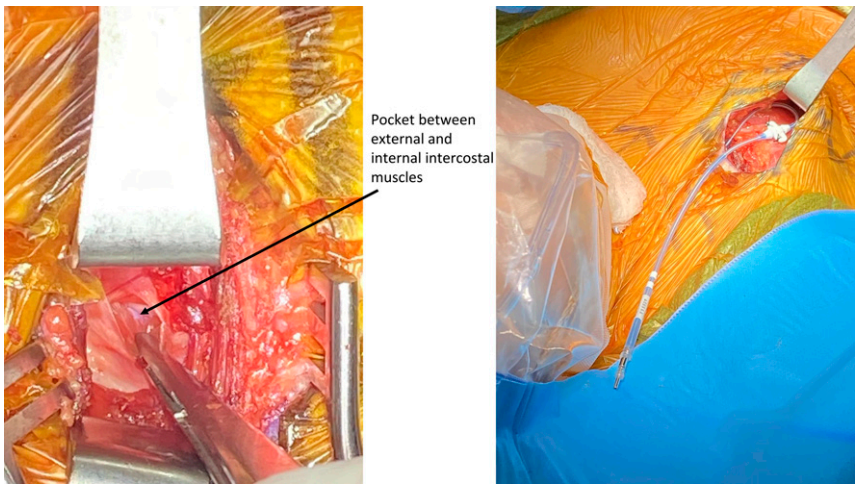

FIGURE 3
Intraoperative development of a pocket between the external and internal intercostal muscles where the sensing lead was then placed.

hypoglossal nerve were identified and accommodated by the standard implant electrode (Fig 2). The device was implanted on the anterior chest wall (Fig 3) with minimal postoperative bulk (Fig 4).

The postoperative course was uncomplicated. An occlusive dressing made of a Telfa and Tegederm was used to protect incisions from inadvertent scratching or picking. Supplies were given to the family to replace as needed for the first 10 to 14 days postoperatively. A regimen of Tylenol and Toradol was used (with the latter transitioned to Motrin on postoperative day 5). A standard week of cefazolin antibiotic prophylaxis was prescribed. The patient was discharged from the hospital on postoperative day 1 once adequate oral intake was achieved and pain was relieved with enteral medications.

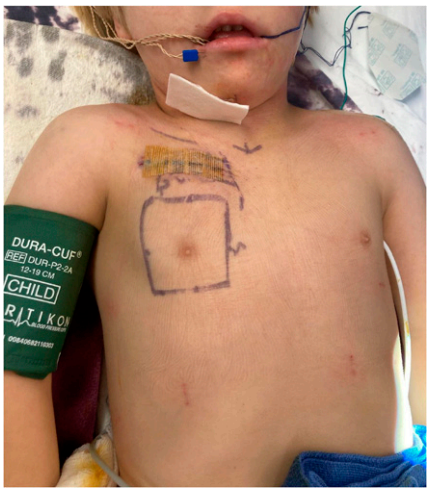

FIGURE 4
Postoperative photo demonstrating minimal bulk of stimulator device in chest wall.

HGNS titration PSG was performed ~1-month postimplantation. The patient tolerated initiation of voltage well, without overt discomfort or sleep disruption. Sleep efficiency was 87% and sleep structure was normal. At a highest voltage trialed of 0.9 V, the OAHI improved to 5.5 per hour (reflecting a 40% decrease from the previous diagnostic PSG), and his hypoxemia was resolved. Further titration will be undertaken after some acclimation at home.

DISCUSSION

Children with DS are disproportionally affected by OSA that is refractory to traditional treatment paradigms. In addition to the described cardiovascular and metabolic complications of untreated OSA, there is growing concern about the long-term neurocognitive effect of persistent OSA in children.[4,8] Given previous success in implanting the HGNS in children with OSA as young as 10, we have questioned whether the benefits of more effective treatment of OSA may start to accrue at an even younger age.

Previous surgical eligibility was limited to the American Academy of Pediatrics-defined adolescence group (at least 10 years of age and <22).[9] This case, in a 4-year-old, was the youngest performed and raised several surgical concerns. Would the hypoglossal nerve be robust enough to accommodate the normal-sized cuff of the electrode to stimulate only the "protrude" branches (leaving the "retract" branches untouched)?[10] Would the implantable pulse generator have adequate space to sit on the anterior chest wall?

While approaching the anatomic concerns, we reviewed the historical evolution (and progressive lowering of eligible age) of cochlear implantation. Initially approved in 1984 for adults, there were concerns regarding anesthetic exposure and anatomic access to the facial recess that delayed pediatric implantation until 1990,

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TABLE 1 Anatomic and Physiology Considerations in Hypoglossal Plantation	
Consideration	**Approach**
Atlanto-axial instability in children with DS	Transnasal intubation with head in neutral position Lack of head extension using gentle padding can limit exposure of the submental space.
Size of chest pocket to accommodate processor and battery	Design of pocket along anterior chest wall, deep to nipple
Electrode length and growth of patient.	Extra looped electrode left preferentially around processor in chest (as well as some in the neck) to accommodate future growth.
Protection of surgical site postoperatively	Pressure dressing taken down after 24 h, with occlusive dressing left in place for 2 wk to minimize picking at surgical site

and since then, the age has steadily lowered, from age 2 (1990) to 9 months in (2022). We had extensive discussions with the family, during which we outlined that we would abort the procedure if the hypoglossal nerve could not accommodate the electrode. In considering implantation in increasingly younger children, we routinely discuss and consider various anatomic and physiologic parameters (Table 1).

We have previously reported follow-up of adolescents implanted with the HGNS and documented sustained improvements in OSA without any device failures.[11] To accommodate the expected growth of our 4-year-old patient, we decided to leave part of the redundant lead in the neck, as well as the chest wall, to avoid undue tension on the lead as the patient grows in height. As further, long-term experience with implantation is gained (especially in younger patients), it will be important to monitor and assess for both expected and unexpected sequalae. We will track the stimulation intensity required to achieve sustainable reductions in AHI to ensure stable stimulation thresholds. Additionally, as the battery life maximum is encountered (traditionally thought of as around 11 years), attention to the surgical replacement of the battery in this young cohort will be important.

The potential to improve long-term neurocognition through improved management of OSA in a young child was a major driver of the outcome of shared decision-making with the family. In 2004, Bass et al in their review chronicled the myriad untoward impacts of "chronic or acute hypoxia on development, behavior, and academic achievement" in children with sleep-disordered breathing.[8] Breslin et al limited their study in 2014 to children aged 7 to 12 years with DS, finding that those with OSA had significantly lower verbal IQ scores, as well as poorer performance on measures of cognitive flexibility.[4] Previous work has shown the improvement to baseline in neurocognitive measures in otherwise healthy children aged 5 to 9 years old with OSA who underwent AT.[12] Of note, the Childhood AT Trial that randomized treatment of children with OSA to AT versus expectant management found no significant differences in attention or executive function (although beneficial secondary outcomes were seen as mentioned above).[13]

Longitudinal follow-up with attention to the effect of HGNS on long-term neurocognitive function and polysomnographic measures, as well as long-term surveillance of the device while the patient continues to grow, are ongoing. This case represents a possible option to be discussed in the course of shared decision-making with families with young children with DS with treatment–refractory OSA.

ABBREVIATIONS

AHI: apnea–hypopnea index
AT: adenotonsillectomy
DS: Down syndrome
HGNS: hypoglossal nerve stimulator
OAHI: obstructive apnea and hypopnea subindex
OSA: obstructive sleep apnea
PAP: positive airway pressure
PSG: polysomnogram
SpO2: pulse oxygen saturation

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