JOURNAL OF JPOSNA®

Volume 4, Number 2, May 2022

Quality, Safety and Value (QSVI)

Supervised Deep Breathing Exercises Improve Functional Aerobic Capacity in Patients with Severe Spinal Deformity

Karina A. Zapata, PT, DPT, PhD; Kayla M. Clem, PT, DPT; Rupha H. Stevens, BA, RRT-NPS; Charu Sharma, MHA, MS, CLSSBB, CPHQ; Amy L. McIntosh, MD

Scottish Rite for Children, Dallas, TX

Correspondence: Amy L. McIntosh, MD, Scottish Rite for Children, 2222 Welborn St., Dallas, TX 75219.
E-mail: amy.mcintosh@tsrh.org

Received: January 21, 2022; Accepted: March 14, 2022; Published: May 1, 2022

DOI: 10.55275/JPOSNA-2022-0029

Abstract:

Background: Our institution has traditionally treated children with severe spine deformity using halo gravity traction (HGT) to improve curve magnitude and increase flexibility.

Local Problem: Assessing the non-radiographic benefits of HGT such as pulmonary function is difficult. Pulmonary function is commonly reflected by pulmonary function testing (PFT) which is dependent on MAXIMAL patient effort. A six-minute walk test (6MWT) reflects functional exercise capacity.

Specific Aims: This quality initiative (QI) was performed to evaluate the addition of supervised deep breathing exercises (DBE) utilizing an incentive spirometer (IS) to supervised physical therapy exercise in patients with severe spinal deformity that require HGT.

Methodology: A QI core team was established with the aim of improving the pulmonary function aspect of our HGT program. The team consisted of one orthopaedic surgeon, one quality improvement program manager, two physical therapists (PTs), and one respiratory therapist (RT). The QI core team met every 4 to 6 weeks to discuss patients and processes.

Intervention: RTs supervised HGT patients performing DBE four times per day and asked families to independently perform DBE four additional times per day. PTs performed the six-minute walk tests (6MWT). A pulse oximeter was used to monitor oxygen saturation levels. RTs performed the PFTs. The 6MWT and PFTs were performed prior to halo application and every 2 weeks while in HGT treatment.

Results: The intervention HGT patients who received supervised DBE (n=14) demonstrated significantly improved 6MWT scores from 1440±546 feet pre-halo to 1663±398 feet pre-surgery (p=0.02). A historic cohort of HGT patients who did not receive supervised DBE (n=10) demonstrated no significant changes in 6MWT scores at 1493±391 feet pre-halo and 1477±406 feet pre-surgery. Averaged forced vital capacity worsened 4±10% and average forced expire volume in one second worsened 1±8%.

Conclusions: Children in HGT undergoing supervised DBE and physical therapy demonstrate improved functional aerobic capacity according to the 6MWT despite no improvement in pulmonary function tests.

Introduction

Our institution has a long history of treating children with severe spine deformity using halo gravity traction to improve curve magnitude and increase flexibility.[1] Children with severe scoliosis and/or kyphosis placed in halo traction improve their curve magnitude from 20% to 50% throughout their 4- to 8-week course of halo traction treatment.[2] We use halo gravity traction for many diagnoses, age ranges, and types of scoliosis. A halo, which is a metal ring around the head, is applied under general anesthesia. Multiple pins attach the ring to the child's skull. Traction is applied with ropes, pulleys, and weights or springs that are anchored to the child's wheelchair, walker, or bed. Our institution's traction goal is at least 50% of the child's body weight.[1]

We are attempting to assess non-radiographic benefits of halo gravity traction such as pulmonary function.[3] Pulmonary function is commonly reflected by pulmonary function test (PFT) and six-minute walk test (6MWT) results. PFT reflects respiratory function and 6MWT reflects functional exercise capacity. Children who require halo gravity traction, at this institution, typically have forced expired volume in one second (FEV_1) less than 85% and forced vital capacity (FVC) less than 50%. A FVC <50% is clinically important since it indicates significant restrictive disease and risk of respiratory failure in adulthood.[4,5]

We identified a need for improved pulmonary function for our patients in halo gravity traction. Orthopaedic surgeons agree that physical therapy and respiratory therapy should be prescribed for children in halo gravity traction, especially those with pre-existing respiratory conditions.[2] Supervised physical therapy is routinely performed as part of our institutional halo traction guidelines throughout the inpatient treatment course to promote pulmonary function, cervical strength, and functional mobility.[1] Daily respiratory therapy is another way to improve pulmonary function,[6-8] but supervised deep breathing exercises (DBE) were not part of our institution's halo gravity traction regimen. Historically, incentive spirometry, a type of DBE, was performed immediately after halo application but not on a supervised basis throughout the entire halo gravity traction treatment course. The purpose of this quality improvement (QI) initiative is to implement the practice of supervised DBE in addition to supervised physical therapy to improve pulmonary function according to PFT and 6MWT results in children who require halo traction.

Methods

Setting and Context

A multidisciplinary team was established at this tertiary-care pediatric hospital in May 2019 with the aim of improving the pulmonary function aspect of our halo gravity traction program. The team consisted of one orthopaedic surgeon, one QI program manager, two physical therapists (PTs), and one respiratory therapist. The QI core team met every 4 to 6 weeks to discuss children and processes. This project was undertaken as

a QI initiative at this institution; therefore, it was not formally supervised by the IRB per their policies.

Measurement

Walking children who required halo gravity traction who could follow commands were included if they had a diagnosis of scoliosis or kypho-scoliosis (n=24). Children were excluded if they had pre-existing pulmonary disease (diaphragmatic hernias), neuromuscular disease with intercostal muscle weakness (congenital muscular dystrophy, spinal muscular atrophy), skeletal dysplasias with limited chest wall growth potential (chondrodysplasia punctate, diastrophic dysplasia), Jeune syndrome, congenital scoliosis with nine or less ribs per side and/or more than three fused ribs.

Physical therapists performed the 6MWT. Physical therapists instructed children to walk as far as they could walk for 6 minutes. Children walked back and forth from one cone to another cone spaced 100 feet apart. A pulse oximeter was used to monitor oxygen saturation levels (Figure 1).

Respiratory therapists (RTs) performed the PFT which provided the FVC and FEV_1 results. PFT results are based on American Thoracic Society standards. RTs instructed children to take an enormous deep breath in until they feel like their lungs would burst with air, blast the air out hard, then push and squeeze out every last bit of air. Children completed three efforts that are acceptable according to the Morgan Scientific Spirometry Training ComPAS Software & Pneumotrac Spirometer. In children who received supervised DBE, 6MWT and PFT were performed pre-halo and every 2 weeks until surgery. In children who did not receive supervised DBE, we were only able to find 10 previous children with 6MWT results pre-halo and pre-surgery and 10 PFTs pre-halo.

Figure 1. *Six-Minute Walk Test (6MWT).*

Children's performance from PFT and 6MWT results prior to implementation of supervised DBE were compared to children's performance after implementation of supervised DBE. Implementation of supervised DBE included that children performed PFTs and 6MWTs immediately before halo gravity traction placement and every 2 weeks until spine surgery. RTs supervised children performing DBE four times per day (about 5 minutes per session) and asked families to independently perform DBE four additional times per day. The incentive spirometry DBE were performed in upright sitting or standing. Children were instructed to breathe in as deep as possible while keeping an eye on the floater and holding their breath as long as they could. They were instructed to make sure the floater remained within the clouds and tree as they breathed in and held their breath (Figure 2).

They breathed out slowly and repeated the process for 10 breaths. Children were asked to cough after every five breaths unless they needed to cough before then. Most children improved their numbers over time, viewing the incentive spirometry as a game and trying to beat their most recent number every time. The highest number is 2500 cubic centimeters (cc), which only a few achieved. Most children could not pass 1750 cc. Children continued to receive supervised physical therapy several times per week. Outside of physical therapy, children were instructed to walk laps around the nursing unit

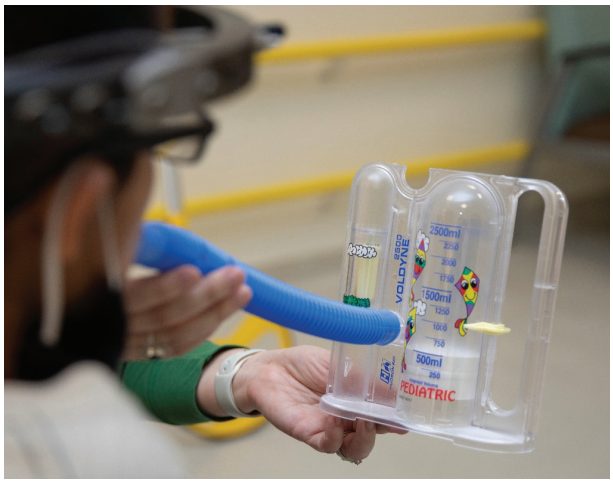

Figure 2. *Incentive spirometry.*

and perform a daily home exercise program of cervical exercises.

To improve compliance with the use of supervised DBE, we modified our "halo traction order set" for children requiring halo gravity traction. The physical therapy department order specified that children getting supervised physical therapy also needed 6MWT every 2 weeks. The respiratory therapy department order added verbiage for supervised DBE and PFT every 2 weeks. Updated orders are now routed electronically to the physical and respiratory therapy departments any time a patient requiring halo traction is admitted to our hospital.

Statistical Analysis

This QI project is the implementation of supervised DBE in children with severe spinal deformity who require halo gravity traction. Pre-implementation data was measured by a retrospective review of prospectively collected data at a single institution. Means and standard deviations were used to describe continuous variables. Paired t-tests were used to compare 6MWT and PFT results pre-halo and pre-surgery. Significant differences were based on a P-value of .05. Statistical analyses were performed using SAS/STAT (version 9.4).

Results

All 24 children were noted to be a minimum of 6 years of age, with younger children demonstrating difficulty giving maximal effort with PFT and/or 6MWT. Children prior to supervised DBE implementation (n=10) were 12.7±4.5 years old and averaged 6.0 weeks in halo traction. 6MWT scores averaged 1493±391 feet pre-halo and 1477±406 feet pre-surgery, demonstrating no significant changes (P=0.91). No changes were found overall compared to a reference population according to age and gender. PFT scores were more than half of the expected age- and gender-matched values, with FVC averaging 54±26% of age-matched values pre-halo and FEV_1 averaging 54±25% of age-matched values pre-halo.

Children who received supervised DBE (n=14) were 12.7±3.7 years old and averaged 6.5 weeks in halo traction. 6MWT scores averaged 1440±546 feet pre-halo and 1663±398 feet pre-surgery, demonstrating a significant improvement (P=0.02). In fact, all children showed positive changes in their 6MWT scores compared to a reference population according to age and gender. PFT scores pre-halo were almost half of the expected age- and gender-matched values. Average FVC worsened 4±10% (48±19% pre-halo, 44±19% pre-surgery), and average FEV_1 worsened 1±8% (42±20% pre-halo, 41±17% pre-surgery).

Discussion

Children in halo traction at this institution benefit from supervised DBE in conjunction with supervised physical therapy. Supervised DBE will be added to our institution's halo gravity traction program. This data also highlights the importance of obtaining both PFTs and 6MWT in the early onset scoliosis patient population to assess functional aerobic capacity since the 6MWT scores of children improved despite no improvement in PFTs. We are now considering the 6MWT as a preferred indicator of aerobic function. We may not be able to improve how big a child's pulmonary "box" is according to a PFT, but we may be able to improve how a child uses that "box," which a 6MWT captures. DBE give children a way to access the area of the lungs that can still function. Also, the 6MWT may be more desirable than a PFT. When performing a 6MWT, children have the entire 6-minute duration to walk as far as possible,

which negates minor effort-dependent variations. When performing a PFT, children have difficulty giving maximal effort in blowing out all of their air until they are "empty."

We also noticed that the standing height measurements used for normative PFT results in this project may be inaccurate due to children's severe spine deformity. Measuring height using ulnar length (from the ulnar styloid to the olecranon tip) instead of standing height was supposed to be adopted as the standard of care at this institution but hadn't been formalized. Therefore, we followed up on the processes for measuring ulnar length to ensure that all children in halo traction were getting ulnar length measurements. In the future, we will ascertain whether using the ulnar length calculator to determine height provides changes in PFT scores.

While reporting 6MWT scores, we also identified a need for improved 6MWT normative comparisons. The 6MWT norms need updating and a broader range of ages so that the 6MWT performance can be graphed over time as children age. We currently use norms with the widest possible age range, from ages 3 to 18 years.[9] However, these norms were published in 2007, were developed in Austria, and are published in age bands every 3 to 4 years. An article with norms from children in the U.S. ages 7 to 11 years found significantly lower norms.[10]

Orthopaedic surgeons agree that physical therapy and respiratory therapy should be prescribed for children in halo gravity traction, especially those with pre-existing respiratory conditions.[2] The pulmonary function of children with scoliosis is an area that deserves more attention. Even children with mild to moderate curves have reduced pulmonary parameters and exercise compared to sex- and age- matched controls.[11] A 12-week exercise-based program including breathing exercises (rotational breathing) in children with mild to moderate idiopathic scoliosis found improved PFT and 6MWT scores but still lower scores compared to controls.[11]

Studies mention that children in halo gravity traction undergo daily physical therapy and respiratory treatments, but they do not specify what type of treatments have been used. We are trying to further challenge children's aerobic function with a high-interval intensity training physical therapy program in children with severe idiopathic scoliosis and high functional status. A previous study implemented a pre-operative aerobic exercise rehabilitation program in participants with severe AIS curves, finding improved 6MWT scores compared to a control group pre-surgery and 1-year post-surgery.[12] Another study by the same lead author found improved respiratory muscle strength (maximum inspiratory and expiratory pressures) after a rehabilitation program in participants with severe AIS curves. The rehabilitation programs consisted of a 40-minute workout on a treadmill or stationary bike at 60-85% of maximum heart rate with a 10-minute warm-up and 10-minute cool down.[12,13] Different researchers discuss improvements in the 6MWT from growth-friendly surgery in congenital scoliosis at 5-year follow-up.[14] We are interested in evaluating whether children continue to demonstrate improved 6MWT results 2 years after surgery.

We are currently working on additional ways to promote physical and respiratory function for this patient population at this institution. Although RTs performed incentive spirometry for the DBE in children in halo gravity traction, we are exploring other ways to perform DBE that may further enhance pulmonary function. We are discussing promoting singing through our therapeutic recreation department and volunteer activities at the hospital, as singing choirs have improved pulmonary function for other conditions. Also, children can dedicate time toward exhalation through fun, motivating activities such as breathing on a mirror, blowing through a straw into water, blowing bubbles, blowing a pinwheel, and playing the harmonica. Children can practice moving different items while exhaling, such as blowing cotton balls with a straw, blowing tissue paper away, blowing on water toys, and moving a scrunched paper towel away. To increase repetitions while facilitating exhalation, children can use different breathing sounds such as "ssss," "whhh," and "shhh."[15] Finally, yoga for children can focus on continuous, deep breathing, in through the

nose and out like blowing out candles. Both physical and respiratory therapy techniques adapted for children may further improve pulmonary function at this institution.

Conclusion

Children with severe spinal deformity who require halo gravity traction undergoing supervised DBE and physical therapy demonstrate improved functional aerobic capacity according to the 6MWT despite no improvement in PFTs. This data also highlights the importance of obtaining both PFTs and 6MWTs in children with severe scoliosis to assess functional aerobic capacity. We are now considering the 6MWT as a preferred indicator of aerobic function in this population.

Acknowledgements

The authors would like to acknowledge Melanie Rodriguez and the Respiratory Therapy Department for assisting with supervised DBE and PFTs and Stephanie Conti for assisting with 6MWT administration.

Disclaimer

No funding was received by the authors. The authors have no conflicts of interest to disclose.

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