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ORIGINAL ARTICLE

25 Years of Dysphagia Rehabilitation: What Have We Done, What are We Doing, and Where are We Going?

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Abstract As deglutologists, we strive to use the best evidence available in the treatment of swallowing disorders. Evidence-based medicine is a bottom-up approach that thoughtfully combines the best external evidence with individual clinical expertise and the patients' choice reflective of their clinical state and preferences for their specific care plan. Evidence-based medicine is not restricted to randomized clinical trials and meta-analyses; rather, evidence-based medicine includes our ability to discriminate the best external evidence with which to answer clinical questions and then skillfully and appropriately being able to apply this evidence in the care and treatment of our patients (Sackett et al. in BMJ 312:71–72, 1996). Translation of efficient and effective dysphagia rehabilitative clinical practice implies the need to use treatment that has proven therapeutic value, yields measurable physiologic results and most importantly allows appreciable qualitative outcomes for the patient.

Keywords Deglutition · Deglutitive Disorders · Dysphagia · Rehabilitation · Swallowing disorders

Rehabilitative Approaches

Management of deglutitive disorders includes compensatory strategies such as alterations to diet consistency and postural changes of head turn and chin tuck during swallowing. These compensatory management approaches alter or improve the physiologic swallow function only as the strategy is being employed. Frequently, compensatory strategies are used in combination with rehabilitative approaches, thereby allowing patients with dysphagia to take food by mouth. Compensatory strategies do not alter the physiologic dysfunction permanently.

In contrast, rehabilitative approaches alter the physiology of the swallow permanently. Rehabilitation of deglutitive disorders can employ skill training or muscle strength training. Skill training and muscle strength training focus on permanently altering abnormal physiologic function of swallowing.

Strength training exercises for striated muscles alter the effects of muscle weakness or sarcopenia that accompanies normal aging. Sarcopenia is preventable and reversible. Muscle weakness may also be a result of decreased physical activity accelerated by disuse and acute or chronic illness [2–5]. Resistance training can increase muscle strength, coordination, and hypertrophy. Principles of exercise physiology have been foundational in the research and design of rehabilitative strength treatment regimens for deglutitive disorders. Successful strength training programs for rehabilitation of deglutitive disorders are based on exercise principles of overload, progression, intensity, adaptation, reversibility, specificity, and recovery [6].

Rehabilitation approaches using skill training emphasizes learning or re-learning a sequence of movements. The skill re-learning or rehabilitation of the skill occurs as the patient attempts a challenging action or movement and practices that movement repeatedly. The skill training rehabilitative approach has been successful when it has been accompanied by visual feedback such as sEMG biofeedback [7, 8].

Rehabilitative Treatment

Both strength and skill rehabilitative treatment techniques alter the physiology of a specific aspect of the disordered deglutitive process [9]. A particular rehabilitative treatment

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is chosen after evaluation and analysis of the patient's deglutitive dysfunction using an instrumental technique such as endoscopy or fluoroscopy.

Rehabilitative treatments include exercise and maneuvers and are indirect, without food or directly utilizing food or liquid in the treatment regimen. Rehabilitative treatment requires the patient to have the adequate cognitive ability to appreciate the purpose, derive benefit treatment, and be able to complete the chosen treatment program [9].

Maneuvers

The Mendelsohn Maneuver and the effortful swallow are rehabilitative maneuvers. These maneuvers demand increased muscular effort by the patient and have been shown to alter timing, bolus flow, and therefore the duration of physiologic swallow events. Effectiveness of a maneuver in altering the deglutitive physiologic function varies and therefore should always be performed during the instrumental evaluation.

The Mendelsohn Maneuver requires the patient to identify the time during the swallow when there is maximal laryngeal elevation and then be able to hold the elevation for several seconds as the bolus is completely swallowed [9]. The effectiveness of this maneuver on normal swallow function has been studied in normal healthy adults [10, 11], in patients with neurologic disease [12–14], and those with head and neck cancer [15]. The Mendelsohn Maneuver increases the extent and duration of anterior and superior laryngeal excursion [12–14] and the extent and duration of deglutitive upper esophageal sphincter (UES) opening diameter [9, 10–13]. Prolonged duration of tongue base-to-posterior pharyngeal wall contact, improved bolus clearance, and elimination of aspiration have also been reported as beneficial outcomes [11–15]. The Mendelsohn Maneuver could be considered a strengthening and skill training or re-learning rehabilitative treatment for dysphagia as it has been used to improve deglutitive function in patients post stroke during an intense two-week program utilizing sEMG to enhance the quantitative physiologic deglutitive and qualitative patient outcomes [14]. This maneuver and the effortful swallow have been found to increase tongue-to-palate contact when studied in healthy volunteers [16].

The effortful swallow requires the patient to consciously increase muscular effort. The effortful swallow decreases post-deglutitive pharyngeal residue by improving reduced tongue base retraction and pharyngeal constriction. The effectiveness of this maneuver has been studied in normal individuals [16–20] and in patients with neurologic dysfunction [20]. The effortful swallow results in greater duration and exertion of oral and pharyngeal pressure during the swallow [18–23], reduced depth of laryngeal penetration and increased base of tongue retraction during the pharyngeal swallow [19–22], duration of maximum anterior hyoid excursion, laryngeal vestibule closure, and extent of superior hyoid excursion [23]. Nekl and colleagues noted increased esophageal contractile pressure amplitude and improved esophageal clearance as a result of the effortful swallow [24]. Contradictions in research findings underscore the necessity for patients to perform the specific maneuver during the instrumental evaluation to determine its effectiveness for each patient.

Lingual Strengthening

Benefits derived from regimens of lingual resistance exercises have been studied in dysphagic patients with head and neck cancer [25] and stroke and in healthy young and older adults. The studies including healthy young and older adults and patients post stroke have shown that lingual resistance exercise increased tongue strength, resulting in decreased oral transit time, improved tongue pressure during swallowing, improved tongue base-to-posterior pharyngeal wall pressure [26–31], and have shown a correlation between tongue strength, oral transit time, and efficient bolus clearance [31]. Protocols showing positive patient outcomes have differed in frequency and duration of the regimen. Discrepancies in patient outcomes have been shown specifically in patients with head and neck cancer. Lazarus and colleagues conducted a RCT comparing lingual exercise plus traditional therapy versus traditional therapy alone in 23 patients with head and neck cancer measuring maximum tongue pressure, salivary flow, and quality of life. No significant change in tongue strength or quality of life was found [25]. Other studies of patients with head and neck cancer do not support positive outcomes post lingual strength training [25, 32]. The varied successful outcomes post lingual strengthening may depend on the exercise protocols used as the protocols vary in frequency of repetition, number of repetitions, and the exercise load for each patient group.

Masako Maneuver

The propulsive pressure exerted on the bolus as the tongue base-to-posterior pharyngeal wall contact occurs propels the bolus through the pharynx. If the contact is incomplete, the swallow would be inefficient resulting in post-deglutitive pharyngeal residual. The Masako Maneuver is a resistance strength training exercise that has been studied in healthy adults and patients with head and neck cancer, resulting in the improvement in tongue base-to-posterior pharyngeal wall contact during the swallow

[27, 28, 33–36]. This maneuver was designed to reduce vallecular residue by increasing pharyngeal constrictor contraction and compensating for decreased tongue base retraction. Recently, the Masako Maneuver has been shown to improve oral lingual strength [34]. The Masako Maneuver is performed without food or drink to prevent bolus loss and potential bolus aspiration during performance of the maneuver [34]. The exact protocol that is the frequency and the duration of each tongue hold for best patient outcomes has not been determined.

The Shaker Exercise

The Shaker Exercise, an isometric and isokinetic exercise performed for six weeks, is designed to strengthen suprahyoid muscles, thereby improving anterior laryngeal excursion and the traction force applied to increase the deglutitive anteroposterior UES opening diameter [37, 38]. Initial trials included healthy young and elderly subjects.

Additionally, a randomized clinical trial was conducted in a heterogeneous patient group (including stroke patients and patients with head and neck cancer) of tube-fed patients with post-deglutitive pyriform sinus residue and aspiration [38]. Results showed improved physiologic and functional outcomes including resumption of oral intake after completion of the exercise regime. The Shaker Exercise was found to improve deglutitive biomechanical measures of anterior hyolaryngeal excursion related to increased deglutitive anteroposterior UES opening diameter, decreased post-deglutitive pyriform residuals, and elimination of post-deglutitive aspiration in all patients regardless of etiology or duration of dysphagia. The Shaker Exercise is not appropriate for dysphagic patients with pre- or intra-deglutitive aspiration [38].

Expiratory Muscle Strength Training

Expiratory muscle strength training (EMST) utilizes a resistive adjustable pressure threshold device that strengthens the muscles of expiration by increasing the expiratory load during breathing exercises. The EMST protocol for optimal patient outcomes has not been standardized and varies by frequency, intensity, and duration across studies [39–48]. EMST has used for 4 weeks of exercise and been shown to improve expiratory pressure in healthy young adults and patients with Multiple Sclerosis and Parkinson's disease [39–48]. Because of the documented importance of the suprahyoid muscles in swallowing biomechanics, the use of the EMST adjustable resistance device by patients as an activator of the suprahyoid muscle group was studied [46]. The results showed that EMST significantly improved maximum expiratory pressure (MEP) and activation in the suprahyoid muscles, improved hyoid elevation [43–47], reduced aspiration [44, 47], and increased cough force [40, 41, 43]. The study found that maintenance programs were required to support positive rehabilitative gains [48]. Wheeler-Hegland and colleagues studied healthy adults during a single trial with the EMST device during three swallow tasks: normal swallow, effortful swallow, and Mendelsohn Maneuver. All three tasks were associated with greater hyoid displacement than the EMST task; however, the EMST contributes to increased and prolonged submental muscle activity similar to the effortful swallow and Mendelsohn Maneuver [45].

Transcutaneous Electrical Stimulation

The use of transcutaneous electrical stimulation (TES) for a particular physiologic deglutitive disorder or patient population has not been well defined. There is little evidence that the use of TES improves or has a positive effect on swallowing [49, 50]. Despite the lack of evidence for the use of TES or positive outcomes for dysphagic patients, a survey of clinicians in the US reported that TES was the most commonly used dysphagia adjunctive modality [51]. Perhaps, the most appropriate use of this type of neurostimulation is when combined with behavioral therapies [52]. A RCT comparing TES therapy combined with standard traditional therapy in a group of patients with head and neck cancer found no value for use of TES when comparing the pre- and post-therapy outcomes of patients [53]. A 5-year, 16-site randomized controlled trial enrolled 170 head and neck cancer patients into an active (electrical stimulation and swallow exercise) or control (sham electrical stimulation and swallowing exercise) arm of the trial. The conclusion of this study was that the addition of electrical stimulation to swallowing exercises resulted in worse swallowing outcomes than exercise-alone patient [54].

Promising Future Directions in Dysphagia Rehabilitation

Respiratory Swallow Training: Rehabilitative Skill Training

The coordinated reciprocity of breathing and swallowing is paramount for efficient, safe, and successful swallowing. Martin-Harris and colleagues studied retraining breathing and swallowing coordination using biofeedback with thirty patients with head and neck cancer and chronic dysphagia. The patients were trained to initiate swallowing during the mid-expiratory phase of quiet breathing and continue to expire after swallowing. The training used visual feedback to train the skill of coordinating breathing and swallowing. The patients experienced improvements in respiratory swallowing coordination with favorable effects in airway protection and bolus clearance [55].

Strengthening of the pharyngeal muscles by Swallow Resistance Exercise Device (sRED)—Rehabilitative Muscle Strengthening.

Shaker and colleagues have studied a way to strengthen the pharyngeal muscles via the Swallow Resistance Exercise Device or sRED. The sRED is worn on the neck and applies adjustable resistance load against the anterosuperior movement of the hyolaryngeal complex during repetitive swallowing. Repeated swallowing against the resistance from the sRED induced fatigue in the pharyngeal peristalsis and therefore may have potential to strengthen the pharyngeal contractile function [56].

Conclusions

Application of research evidence and achievement of positive patient outcomes depend on the clinician's understanding of the physiologic deglutitive disorder and the application of appropriate rehabilitative treatment for that disorder. The choice of the most appropriate rehabilitative treatment is made through critical evaluation and analysis coupled with an understanding of the available research evidence, clinical experience, and consideration of the patient's objectives and goals.

As deglutologists, we strive to utilize treatment techniques with sound theoretical and methodological research support. The body of research pertaining to treatment techniques for dysphagia includes relatively small numbers of subjects, and many studies which have not been controlled for effects of aging, disease, treatment dose on outcome, patient compliance issues, etc. The studies mentioned in this article provide primarily evidence Levels III, IV, and V. Further research is needed to establish the efficacy of rehabilitative treatment for specific deglutitive disorders and to establish treatment dosage to insure cost effectiveness and positive patient outcomes.

References

1. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Rickardson WS. Evidence based medicine: what it is and what it isn't. BMJ. 1996;13(312):71–2.
2. Booth F, Weeden S, Tsong B. Effect of aging on human skeletal muscle and motor function. Med Sci Sports Exerc. 1994;26:556–60.
3. Harris T. Muscle mass and strength: relation to function in population studies. J Nutr. 1997;127:4S–6S.
4. Lindle RS, Metter FJ, Linch NA, Fleg JL, Fozard JL, Tobin J. Age and gender comparisons of muscle strength in 654 women and men aged 20–93 years. J Appl Physiol. 1997;83:1581–7.
5. Porter MM, Vandervoort AA, Lexell J. Aging of human muscle: structure, function, and adaptability. Scand J Med Sci Sports. 1995;5:124–9.
6. McArdle WD, Katch FL, Datch VL. Essentials of Exercise Physiology. 3rd Edition ed. Philadelphia: Lippincott, Williams & Wilkins; 2005.
7. Huckabee ML, Cannito MP. Outcomes of swallowing rehabilitation in chronic brainstem dysphagia: a retrospective evaluation. Dysphagia. 1999;14:93–109.
8. Athukoralo RP, Jones RD, Oshrat S, Huckabee ML. Skill training for swallowing rehabilitation in patients with Parkinson's disease. Arch Phys Med Rehabil. 2014;95(7):1374–82.
9. Logemann JA. Evaluation and treatment of swallowing disorders. 2nd ed. Austin: Pro-Ed, Inc.; 1998.
10. Ding R, Larson CR, Logemann JA, Rademaker AW. Surface electromyographic and electroglottographic studies in normal subjects under two swallow conditions: normal and during the Mendelsohn manuever. Dysphagia. 2002;17:1–12.
11. Kahrilas PJ, Logemann JA, Krugler C, Flanagan E. Volitional augmentation of upper esophageal sphincter opening during swallowing. Am J Physiol. 1991;260:G450–6.
12. Logemann JA, Kahrilas PJ. Relearning to swallow after stroke—application of maneuvers and indirect biofeedback: a case study. Neurology. 1990;40:1136–8.
13. McCullough GH, Kamarunas E, Mann GC, Schmidley JW, Robbins JA, Crary MA. Effects of Mendelsohn maneuver on measures of swallowing duration post stroke. Top Stroke Rehabil. 2012;19:234–43.
14. McCullough GH, Kim Y. Effects of Mendelsohn maneuver on extent of hyoid movement and UES opening post-stroke. Dysphagia. 2013;28:511–9.
15. Lazarus C, Logemann JA, Gibbons P. Effects of maneuvers on swallowing function in a dysphagic oral cancer patient. Head Neck. 1993;15:419–24.
16. Fukuoka T, Ono T, Hori K, et al. Effect of the effortful swallow and the Mendelsohn maneuver on tongue pressure production against the hard palate. Dysphagia. 2013;28:539–47.
17. Bulow M, Olsson R, Ekberg O. Videomanometric analysis of supraglottic swallow, effortful swallow, and chin tuck in healthy volunteers. Dysphagia. 1999;14:67–72.
18. Hind JA, Nicosia MA, Roecker EB, Carnes ML, Robbins J. Comparison of effortful and noneffortful swallows in healthy middle-aged and older adults. Arch Phys Med Rehabil. 2001;82:1661–5.
19. Hiss SG, Huckabee ML. Timing of pharyngeal and upper esophageal sphincter pressures as a function of normal and effortful swallowing in young healthy adults. Dysphagia. 2005;20:149–56.
20. Huckabee ML, Butler SG, Barclat M, Jit S. Submental surface electromyographic measurement and pharyngeal pressures during normal and effortful swallowing. Arch Phys Med Rehabil. 2005;86:2144–8.
21. Pouderoux P, Kahrilas PJ. Deglutitive tongue force modulation by volition, volume, and viscosity in humans. Gastroenterology. 1995;108:1418–26.
22. Bulow M, Olsson R, Ekberg O. Supraglottic swallow, effortful swallow, and chin tuck did not alter hypopharyngeal intrabolus pressure in patients with pharyngeal dysfunction. Dysphagia. 2002;17:197–201.
23. Huckabee ML, Steele CM. An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal

pressure during effortful swallow. Arch Phys Med Rehabil. 2006;87:1067–72.
24. Nekl CG, Lintzenich DR, Leng X, et al. Effects of effortful swallow on esophageal function in healthy adults. Neurogastroenterol Motil. 2012;24:252–252.
25. Lazarus Cl, Husaini H, Falciglia D et al. Effects of exercise on swallowing and tongue strength in patients with oral and oropharyngeal cancer treated with primary radiotherapy with or without chemotherapy. Int J Oral Maxillofac Surg 2013.
26. Lazarus CL, Logemann JA, Huang CH, Rademaker AW. Effects of two types of tongue strengthening exercises in young normals. Folia Phoniatr. 2003;55(4):199–205.
27. Veis S, Logemann JA, Colangelo L. Effects of three techniques on maximum posterior movement of the tongue base. Dysphagia. 2000;15:142–5.
28. Lazarus C, Logemann JA, Song CW, Rademaker AW, Kahrilas PJ. Effects of voluntary maneuvers on tongue base function for swallowing. Folia Phoniatr Logop. 2002;54:171–6.
29. Lazarus CL, Logemann JA, Pauloski BR, et al. Swallowing and tongue function following treatment for oral and oropharyngeal cancer. J Speech Lang Hear Res. 2000;43(4):1011–23.
30. Robbins J, Gangnon RE, Theis SM, Kays SA, Hewitt AL, Hind JA. The effects of lingual exercise on swallowing in older adults. J Am Geriatr Soc. 2005;53:1483–9.
31. Robbins J, Kays SA, Gangnon RE, Hind JA, Hewitt AL, Gentry LR, Taylor AJ. The effects of lingual exercise in stroke patients with dysphagia. Arch Phys Med Rehabil. 2007;88(2):150–8.
32. Chan CW, Chen SH, Ko JY, Lin YH. Early radiation effects on tongue function for patients with nasopharyngeal carcinoma: a preliminary study. Dysphagia. 2008;23(2):193–8.
33. Fujiu M, Logemann JA, Pauloski BR. Increased postoperative posterior pharyngeal wall movement in patients with anterior oral cancer: preliminary findings and possible implications for treatment. Am J Speech Lang Pathol. 1995;1995(4):24–30.
34. Fujiu M, Logemann JA. Effect of a tongue holding maneuver on posterior pharyngeal wall movement during deglutition. Am J Speech Lang Pathol. 1996;1996(5):23–30.
35. Fujiu-Kurachi M, Fujiwara S, Tamine K, Kondo J, Minagi Y, Maeda Y, et al. Tongue pressure generation during tongue-hold swallows in young healthy adults measured with different tongue positions. Dysphagia. 2014;29:17–24.
36. Doeltgen SH, Witte U, Gumbley F, Huckabee ML. Evaluation of manometric measures during tongue hold swallows. Am J Speech Lang Pathol. 2009;18:65–73.
37. Easterling C, Kern M, Nitschke T, et al. Effect of a novel exercise on swallow function and biomechanics in tube fed cervical dysphagia patients: a preliminary report. Dysphagia. 1999;14:119.
38. Shaker R, Easterling C, Kern M, et al. Rehabilitation of swallowing by exercise in tube-fed patients with pharyngeal dysphagia secondary to abnormal UES opening. Gastroenterology. 2002;122:1314–21.
39. Silverman EF, Cm Sapienza, Saleem A, Carmichael C, Davenport PW, Hoffman-Ruddy B, et al. Tutorial on maximum inspiratory and expiratory mouth pressures in individuals with idiopathic Parkinson disease (IPD) and the preliminary results of an expiratory muscle strength training program. NeuroRehabilitation. 2006;21:71–9.
40. Saleem AF, Sapienza CM, Okun MS. Respiratory muscle strength training: treatment and response duration in a patient with early idiopathic Parkinson's disease. NeuroRehabiliation. 2005;20:323–33.
41. Chiara T, Martin AD, Davenport PW, Bolser DC. Expiratory muscle strength training in persons with multiple sclerosis having mild to moderate disability: effect on maximal expiratory pressure, pulmonary function and maximal voluntary cough. Arch Phys Med Rehabil. 2006;87:468–73.
42. Chiara T, Martin D, Sapienza C. Expiratory muscle strength training: speech production outcomes in patients with multiple sclerosis. NeuroRehabil Neural Repair. 2007;21:239–49.
43. Pitts T, Bolser D, Rosenbek J, Troche M, Okun MS, Sapienza C. Impact of expiratory muscle strength training on voluntary cough and swallow function in Parkinson's disease. Chest. 2009;135(5):1301–8.
44. Troche M, Okun M, Rosenbek J, Musson N, Sapienza C. Swallow outcomes following intervention with expiratory muscle strength training (EMST) in Parkinson's disease: results of a randomized clinical trial. Dysphagia. 2009;24(4):455–6.
45. Wheeler-Hegland KM, Rosenbek JC, Sapienza CM. Submental sEMG and hyoid movement during Mendelsohn maneuver, effortful swallow, and expiratory muscle strength training. J Speech Lang Hear Res. 2008;51(5):1072–87.
46. Wheeler KM, Chiara T, Sapienza CM. Surface electromyographic activity of the submental muscles during swallow and expiratory pressure threshold training tasks. Dysphagia. 2007;22:108–16.
47. Troche MS, Okun MS, Rosenbek JC, Musson N, Fernandez NH, Rodriguez R, et al. Aspiration and swallowing in Parkinson disease and rehabilitation with EMST: a randomized trial. Neurology. 2010;75:1912–9.
48. Troche MS, Rosenbek JC, Okun MS, Sapienza CM. Detraining outcomes with expiratory muscle strength training in Parkinson disease. J Rehabil Res Dev. 2014;51:305–10.
49. Ludlow CL, Humbert IA, Saxon K, et al. Effects of surface electrical stimulation both at rest and during swallowing in chronic pharyngeal dysphagia. Dysphagia. 2007;22:1–10.
50. Humbert IA, Poletto CJ, Saxon KG, et al. The effect of surface electrical stimulation on hyolaryngeal movement in normal individuals at rest and during swallowing. J Appl Physiol. 2006;101:1657–63.
51. Carnaby GD, Harenburg L. what is 'usual care' in dysphagia rehabilitation: a survey of USA dysphagia practice patterns. Dysphagia. 2013;28:567–74.
52. Tan C, Liu Y, Li W, Liu J, Chen L. Transcutaneious neuromuscular electrical stimulation can improve swallowing function in patients with dysphagia caused by non stroke diesases: a meta-analysis. J Oral Rehabil. 2013;40:472–80.
53. Langmore SE, et al. Efficacy of electrical stimulation and exercise for dysphagia in patients with head and neck cancer: a randomized clinical trial. Head Neck. 2015;38:E1221–31.
54. Krisciunas GP, Castellano K, McCulloch TM, Lazarus CL, Pauloski BR, Meyer TK, Craner D, VanDaele DJ, Silbergleit AK, Crujido LR, Rybin D, Doros G, Kotz SE, Langmore T. Impact of compliance on dysphagia rehabilitation in head and neck cancer patients: results from a multi-center clinical trial. Dysphagia. 2016. doi:10.1007/s00455-016-9760-4.
55. Martin-Harris B, McFarland D, Hill EG, Strange CB, Focht KL, Wan Z, Blair J, McGrattan K. Respiratory-swallow training in patients with head and neck cancer. 2015. Arch Phys Med Rehabil. 2015;96(5):885–93.
56. Shaker R, Sanvanson P, Balasubramanian G, Kern M, Wuerl A, Hyngstrom A. Effects of laryngeal restriction on pharyngeal peristalsis and biomechanics: clinical implications. Am J Physiol Gastrointest Liver Physiol. 2016;310:G1036–43.

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