Videoradiographic analysis of how carbonated thin liquids and thickened liquids affect the physiology of swallowing in subjects with aspiration on thin liquids.

Bülow, Margareta; Olsson, Rolf; Ekberg, Olle

Published in:
Acta Radiologica

DOI:
10.1080/j.1600-0455.2003.00100.x

2003

Acta Radiologica 44 (2003) 366–372
Printed in Denmark · All rights reserved

ACTA RADIOLOGICA
ISSN 0284-1851

VIDEORADIOGRAPHIC ANALYSIS OF HOW CARBONATED THIN LIQUIDS AND THICKENED LIQUIDS AFFECT THE PHYSIOLOGY OF SWALLOWING IN SUBJECTS WITH ASPIRATION ON THIN LIQUIDS

M. BÜLOW, R. OLSSON and O. EKBERG

Department of Diagnostic Radiology, Malmö University Hospital, Lund University, Malmö, Sweden.

Abstract

Purpose: To analyze how carbonated thin liquids affected the physiology of swallowing in dysphagic patients.

Material and Methods: 40 patients were analyzed; 36 were neurologically impaired. During a therapeutic videoradiographic swallowing examination the patients had to swallow liquids with the following consistencies three times: thin, thickened and carbonated. The liquids were given in doses of 3×5 ml. The swallows were analyzed regarding penetration/aspiration, pharyngeal transit time and pharyngeal retention.

Results: Significant difference was found regarding *penetration/aspiration* when comparisons were made between thin liquid and carbonated thin liquid ($p<0.0001$). Carbonated liquid reduced the penetration to the airways. The comparison between thin liquid and thickened liquid ($p<0.0001$) showed significant less penetration with thickened liquids. *Pharyngeal transit time* was reduced both when comparing thin liquid with thin carbonated liquid ($p<0.0001$) and thickened liquid ($p<0.0001$). *Pharyngeal retention* was significantly reduced ($p<0.0001$) with carbonated thin liquid compared to thickened liquid. The comparison of thin liquids and carbonated thin liquids showed $p = 0.0013$, thin and thickened liquids $p = 0.0097$.

Conclusions: Carbonated liquids reduced penetration/aspiration into the airways, reduced pharyngeal retention and pharyngeal transit time became shorter. Therefore, carbonated liquids are a valuable treatment option for patients with penetration/aspiration. Thickened liquids may still be an option for patients who cannot tolerate carbonated liquids and liquids with this consistency are safer than thin liquids.

Key words: Pharyngeal retention, dysphagia treatment; swallowing therapy; liquids.

Correspondence: Margareta Bülow, Department of Diagnostic Radiology, Malmö University Hospital, SE-205 02 Malmö, Sweden.
FAX +46 40 96 99 77
E-mail: Margareta.Bulow@rontgen.mas.lu.se

Accepted for publication 3 April 2003.

In the management of a patient with impaired swallowing, different treatment strategies are necessary depending on the pathophysiology of the patient's oral and pharyngeal dysfunction. A major problem is patients who suffer from oral and/or pharyngeal impairment leading to misdirected swallowing and/or residue of bolus material. The pharyngeal dysfunction can also lead to insufficient intake of calories and thereby to malnutrition. Defective intake of fluid may cause dehydration. A healthy elderly adult with a body weight of 70 kg has an essential need for 2000 ml of fluid intake per day (30 ml liquid/kg body weight) (3). For patients with impaired swallowing, such an amount can be an almost impossible intake. In particular, thin liquids are difficult to handle by those patients. The best treatment of such dysfunction is head positioning, swallowing maneuvers and/or diet modification. However, due to a more global neurological disease that impairs cognitive capacity and speech, dysphagic patients often have problems understanding and following instructions concerning swallowing maneuvers. Many patients are also too fatigued to participate in swallowing therapy. For those patients, diet modification is essential. Since thin liquids, for example water or coffee, often are the most obvious problem, addition of thickener to thin liquids has so far been an option for treatment (12). Thickened liquids are less prone to pass into the airways. Pharyngeal retention is usually not affected by thickened liquids, but they have a different appearance and palatability than the thin liquids and many patients have problems accepting the intake of thickened liquids. In a study by Jennings et al. the successful use of carbonated beverage swallows in the management of patients with misdirected swallowing due to pharyngeal dysfunction after excision of tumors of the skull base are reported (9). After having used carbonated liquids with good effect in a couple of patients with pharyngeal dysfunction due to neurological disease we attempted to study the effect in a prospective way.

The aim of the present study was to study the effect of carbonated thin liquids compared to thin liquids and thickened liquids on misdirected swallowing, pharyngeal retention and pharyngeal transit time in patients with documented misdirected swallowing.

Material and Methods

Forty patients (22 men and 18 women) ranging in age from 28 to 95 years, mean age 68.7 years, were included in the study, all consecutively submitted for a therapeutic videoradiographic swallowing study (TVSS) according to our routine protocol, from December 2000 to March 2002. Of these patients, 36 were neurologically impaired, 19 having had a cerebral vascular accident. Four patients had no neurological diseases. The routine protocol for the TVSS included the following components.

The examination was performed with digital radiological equipment. An S-VHS videotape recorder with a jog-shuttle and frame lock capabilities to allow analysis frame by frame and in slow motion afterwards was also used. The average fluoroscopy time was about 3 min. This corresponds to a radiation dose of 2–5 mSv. Most patients could perform the examination seated in an upright position, if necessary in their own wheelchair. If that was not possible, they were examined in a recumbent position.

The examination started with the patient in lateral view, i.e., the optimal projection for visualizing penetration or aspiration of bolus material into the airways before, during and after swallowing. If necessary, a frontal projection was obtained as well.

The materials presented were pudding, purée, thickened liquids and thin liquids. If necessary, chopped solid material, either meat or vegetables in sauce, was given. The test material was prepared in the hospital kitchen and stored in a freezer in the radiological department until used. One portion of solid bolus (for example fruit puree or mixed vegetables and meat) consisted of 45 g product and 15 g Mixobar High Density barium contrast (Astra Tech AB, Mölndal, Sweden), giving 60 g ready-mixed material (0.5 dl). One portion of thickened liquid consists of 100 g product (fruit puree) and 30 g Mixobar High Density barium contrast, giving 130 g ready mixed material (1 dl). The thin liquid consisted of Mixobar High Density barium sulfate 40% weight/volume. 5 ml of liquid of each consistency was given three times via a tablespoon. Liquids were measured in a syringe and were first given via a tablespoon and then, if possible, the patients had to practice cup drinking. All materials were given at room temperature (about 22° C). In the present study all liquids were given in doses of 3×5 ml.

A speech language pathologist administered the test materials to the patients. When swallowing the solid boluses and the thin and thickened liquids the patients were told to keep the material in their mouth and not swallow until told to do so.

Patients who aspirated into the airways on thin liquids, were able to sit in an upright position, and could follow instructions were submitted to this study. They were asked whether they would like to try to swallow carbonated thin liquid. The liquid was administered in the same way as the other liquids. However, the patients were told to swallow immediately so that the gas should not disappear. The carbonated thin liquid consisted of Mixobar High Density barium sulfate (40% weight/volume) mixed with sodium bicarbonate (Samarin, Cederroth Int. AB, Sweden). To 100 ml barium contrast we added one package of Samarin (4 g). Sodium bicarbonate is regularly used in our radiological department when performing an ordinary hypopharyngeal–esophageal examination, to make it possible to perform double-contrast radiographs. We wanted to test the carbonated liquid in patients with aspiration into the airways because of the assumption that the carbonated liquids could be a better alternative for a great number of dysphagic patients.

Liquids with different consistencies were analyzed. Each consistency of liquid was given three times. Nine swallows from each subject were analyzed, altogether 360 swallows. Penetration/aspiration, pharyngeal retention and pharyngeal transit time (PTT) were analyzed.

Comparisons were made between thin liquids, carbonated thin liquids and thickened liquids. Penetration–aspiration was defined as a) subepiglottic penetration, b) supraglottic penetration, or c) penetration (aspiration) below the true vocal cords. Pharyngeal retention was defined as a) mild, b) moderate, or c) severe barium pooling into the valleculae or/and accumulation in the pyriform sinuses. The retention was analyzed after the first swallow. PTT was defined as the time (in seconds) from when the apex of the bolus passed the level of the faucial isthmus until the peristaltic wave left the cricopharyngeal muscle. Analyzing the videotape means that the lines in the radiograph updates 50 times every other second, producing 25 pictures/s. This was then converted into seconds when presenting the PTT.

Statistics: The statistical method used was Wilcoxon's signed ranks test. Median values of scores for 40 patients were calculated for every consistency regarding penetration/aspiration, pharyngeal retention and PTT.

Results

The results are presented in Tables 1–9.

Penetration/aspiration (n = 40) (Tables 1–3): Significant differences were found when thin liquids and carbonated thin liquids were compared: p-value < 0.0001 with a 95% confidence interval (CI) of 5.0–7.0. The carbonated liquid reduced the penetration/aspiration into the airways. Significant difference were also found when thin liquids and thickened liquids were compared: p-value < 0.0001 with a 95% CI of 4.5–7.0. The thickened liquid reduced the airway penetration/aspiration compared to the thin liquid.

PTT (n = 40) (Tables 4–6): There was a significantly shorter PTT with the carbonated thin liquids compared with thin liquids: p-value < 0.0001 and 95% CI 4–8.4. The comparison between carbonated thin liquids and thickened liquids also showed a significantly shorter PTT with the carbonated liquids: p-value <0.0001 and 95% CI − 10.1 to −5.7.

Pharyngeal retention (n = 40) (Tables 7–9): Significant differences were found in all three comparisons. There was significantly less pharyngeal retention with the carbonated thin liquids than with the thin liquids: p-value 0.0013 and 95% CI 0.0–1.5. In the comparison between thin liquids and thickened liquids, there was less retention with the thin liquid than with the thickened liquids: p-value 0.0097 and 95% CI –1.5–0. In the comparison between the carbonated thin liquids and thickened liquids, the most obvious difference was found; the carbonated liquids showing significantly less retention: p-value <0.0001 with a 95% CI –3.0–1.0 (Fig. a, b).

Discussion

Many patients with dysphagia have misdirected swallowing even beyond the vocal folds, i.e., into the trachea, of thin liquids. Our hypothesis was that such patients could handle carbonated thin liquids more safely. In order to test our hypothesis we compared three different consistencies. A prior report by Swank Nixon (16) has indicated that carbonated thin liquids could be valuable in the treatment of patients with misdirected swallowing. In a prior pilot study from our own institution we could confirm that finding (2).

In this study we used videoradiography, considered the gold standard, in analyzing in detail the entire swallowing sequence (6). Videoradiography is also the only method that makes it possible to analyze the reaction of the different liquids on swallowing physiology.

Penetration/aspiration: Aspiration into the airways can occur as a result of anatomical and/or physiological disturbances in the oral and/or pharyngeal phases of deglutition (11). A careful evaluation of every dysphagic patient with airway penetration is therefore of great importance in order to clarify the pathophysiology and to achieve a safe oral intake.

We found that carbonated thin liquids significantly reduced tracheal penetration compared to thin liquids as well as thickened liquids. Just one

Table 1

Wilcoxon's signed ranks test. Penetration/aspiration. Comparison of thin liquid with carbonated thin liquid (n = 40)

Difference between pairs	n	Rank sum	Mean rank
Positive	38	771.0	20.29
Negative	1	9.0	9.00
Zero	1		
Difference between medians	6.0		
95.0% CI	5.0–7.0 (normal approximation)		
Wilcoxon's W statistics	771		
Two-tailed p	<0.0001 (normal approximation, corrected for ties)		

Table 2

Wilcoxon's signed ranks test. Comparison of carbonated thin liquid with thickened liquid ($n = 40$)

Difference between pairs	n	Rank sum	Mean rank
Positive	10	166.5	16.65
Negative	18	239.5	13.31
Zero	12		
Difference between medians	−0.5		
95.0% CI	−1.0–0.5 (normal approximation)		
Wilcoxon's W statistics	166.5		
Two-tailed *p*	0.4024 (normal approximation, corrected for ties)		

Table 3

Wilcoxon's signed ranks test. Penetration/aspiration. Comparison of thin liquid with thickened liquid ($n = 40$)

Difference between pairs	n	Rank sum	Mean rank
Positive	37	740.0	20.00
Negative	1	1.0	1.00
Zero	2		
Difference between medians	5.5		
95.0% CI	4.5–7.0 (normal approximation)		
Wilcoxon's W statistics	740		
Two-tailed *p*	<0.0001 (normal approximation, corrected for ties)		

Table 4

Wilcoxon's signed ranks test. Pharyngeal transit time. Comparison of thin liquid with carbonated thin liquid ($n = 40$)

Difference between pairs	n	Rank sum	Mean rank
Positive	34	737.0	21.68
Negative	5	43.0	8.60
Zero	1		
Difference between median	6.2		
95.0% CIs	4.4–8.4 (normal approximation)		
Wilcoxon's W statistics	737		
Two-tailed *p*	<0.0001 (normal approximation, corrected for ties)		

Table 5

Wilcoxon's signed ranks test. Pharyngeal transit time. Comparison of carbonated thin liquid with thickened liquid ($n = 40$)

Difference between pairs	n	Rank sum	Mean rank
Positive	2	34.5	17.25
Negative	35	668.5	19.10
Zero	3		
Difference between medians	−7.6		
95.0% CI	−10.1 to −5.7 (normal approximation)		
Wilcoxon's W statistics	34.5		
Two-tailed *p*	<0.0001 (normal approximation, corrected for ties)		

patient had an increased amount of penetration into the airways with the carbonated liquid. That patient suffered from Parkinson's disease and the increased aspiration could perhaps be due to medication or lack of medication.

In a prior study we found that supraglottic swallow, effortful swallow and chin tuck did not reduce the number of misdirected swallows. However, effortful swallow and chin tuck significantly reduced the depth of contrast penetration into the larynx and trachea (4). Dysphagic patients may also have language disabilities and therefore have difficulties understanding and following instructions for different swallowing techniques, i.e., supraglottic swallow and

Table 6

Wilcoxon's signed ranks test. Pharyngeal transit time. Comparison of thin liquid with thickened liquid (n = 40)

Difference between pairs	n	Rank sum	Mean rank
Positive	12	194.0	16.17
Negative	22	401.0	18.23
Zero	6		
Difference between medians	−1.8		
95.0% CI	−4.7–0 (normal approximation)		
Wilcoxon's W statistics	194		
Two-tailed *p*	0.0768 (normal approximation, corrected for ties)		

Table 7

Wilcoxon's signed ranks test. Pharyngeal retention. Comparison of thin liquid with carbonated thin liquid (n = 40)

Difference between pairs	n	Rank sum	Mean rank
Positive	16	159.0	9.94
Negative	2	12.0	6.00
Zero	22		
Difference between medians	1.0		
95.0% CI	0.0–1.5 (normal approximation)		
Wilcoxon's W statistics	159		
Two-tailed *p*	0.0013 (normal approximation, corrected for ties)		

Table 8

Wilcoxon's signed ranks test. Pharyngeal retention. Comparison of carbonated thin liquid with thickened liquid (n = 40)

Difference between pairs	n	Rank sum	Mean rank
Positive	0	0.0	–
Negative	24	300.0	12.50
Zero	16		
Difference between medians	−2.0		
95.0% CI	−3.0 to −1.0 (normal approximation)		
Wilcoxon's W statistics	0		
Two-tailed *p*	<0.0001 (normal approximation, corrected for ties)		

Table 9

Wilcoxon's signed ranks test. Pharyngeal retention. Comparison of thin liquid with thickened liquid (n = 40)

Difference between pairs	n	Rank sum	Mean rank
Positive	3	26.5	8.83
Negative	15	144.5	9.63
Zero	22		
Difference between medians	−0.5		
95.0% CI	−1.5–0 (normal approximation)		
Wilcoxon's W statistics	26.5		
Two-tailed *p*	0.0097 (normal approximation, corrected for ties)		

effortful swallow. In such patients thickened liquids have for a long time been recommended as a safe alternative for aspirating subjects. However, many patients do not like the thickened liquids.

Nilsson et al. (14) in a study using the Ross test (13) found that the swallowing safety index, which means the ratio between the PTT and the deglutition apnea, was associated with misdirected swallows but not with the PTT or the deglutition apnea. Swallows with a PTT of more than 1.3 s had a greater chance of being misdirected irrespective of the duration of the deglutition apnea. Therefore the

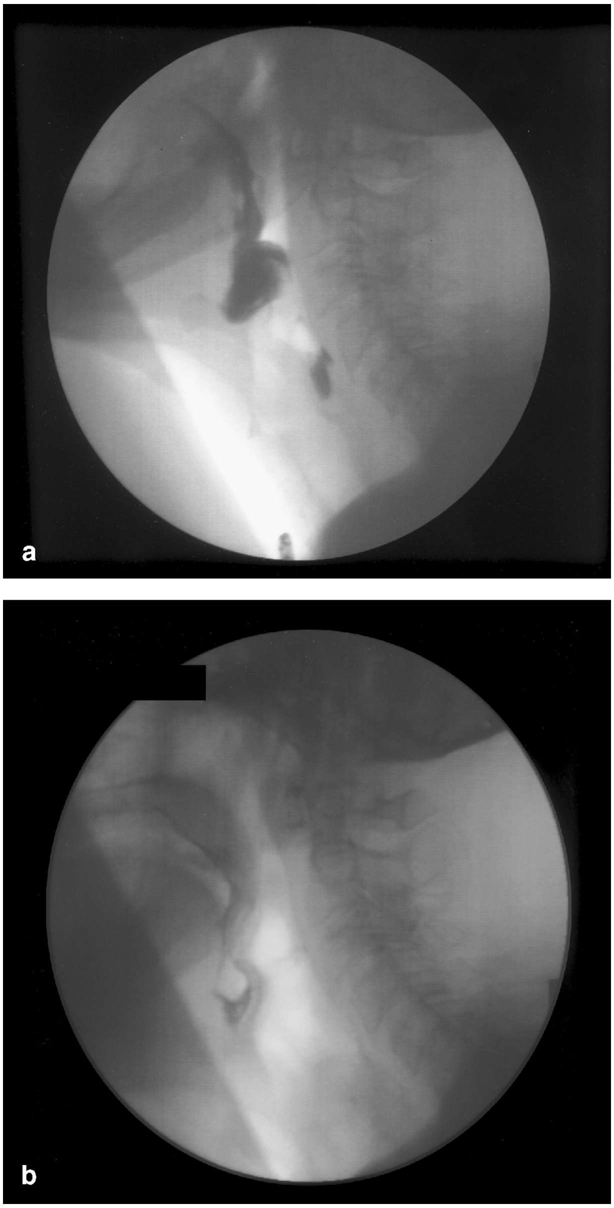

Figure. a) Radiograph of the pharyngeal area in lateral view of a dysphagic 75-year-old man with a cerebral vascular accident and a severe pharyngeal retention after swallowing of thickened liquid. b) The pharyngeal area in lateral view of the same patient after swallowing carbonated liquid. No pharyngeal retention is visible.

shorter PTT of the carbonated liquids could explain their effectiveness compared with the thickened liquids, which have a longer PTT. Hasselbalch et al. (8), comparing the transit times for tablets taken together with 100 ml of cold carbonated water and 100 ml of lukewarm tap water, found that there was a significantly better passage when the tablets were taken with cold carbonated water. Cuomo et al. (5) in a study regarding the effects of carbonated water on functional dyspepsia and constipation, found that in patients who complained of functional dyspepsia and constipation, carbonated water decreased satiety and improved dyspepsia, constipation and gallbladder emptying.

PTT: A significantly shorter PTT was found with carbonated thin liquids compared with both thin liquids and thickened liquids. The laryngeal elevation and the elevation of the hyoid bone started as soon as the carbonated liquid was taken into the mouth. Molecules from the carbonic acid may contact and stimulate the receptors at the faucial isthmus in the mouth more effectively and evoke more afferent impulses (sensory input) to the solitary tract nucleus in the medulla oblongata in the brain stem, eliciting the pharyngeal swallow more rapidly (13). Thermal tactile stimulation has for a long time been used as a specific technique to treat delayed pharyngeal swallow. In a study from 1996, Kaatzke-McDonald et al. (10) studied the effect of cold, touch and chemical stimulation of the anterior faucial pillar on human swallowing. The results from that study suggested that there are thermo-sensitive receptors in the faucial pillars that evoke swallowing when stimulated by cold touch. In another study performed by Ali et al. (1) regarding the influence of cold stimulation on the normal pharyngeal swallow response it was concluded that normal pharyngeal swallow response is neither facilitated nor inhibited by prior cold tactile stimulation or topical anesthesia of the tonsillar pillars. Their observations did not support the hypothesis that elicitation of the pharyngeal swallow response is dependent on stimulation of mucosal receptors in the tonsillar arches.

Pharyngeal retention: In the act of swallowing, the pharyngeal constrictor muscles play an important role. When constrictor activity is impaired, bolus transit from the oral cavity into the esophagus will not work properly. This may lead to pharyngeal retention (7). However, Olsson et al. (15) have shown that in patients with pharyngeal retention the laryngeal elevation is impaired. Their conclusion was that the pharyngeal constrictors are not that important in bolus transport through the pharynx. Instead, the pharyngeal shortening could be the most important mechanism in bolus transport. When we compared carbonated thin liquids and thickened liquids there was significantly less retention with carbonated liquids. This means that the carbonated liquids would be better in clearing the pharynx. That could be of help for patients with pharyngeal residue, which can be due to a generalized dysfunction in pharyngeal pressure generation during swallow (12).

Conclusions: Our results confirmed the hypothesis that carbonated liquids could reduce the number of aspirations into the airways. Carbonated liquids could provide a good option for dysphagic patients with improvement of penetration/aspiration, pharyngeal retention and PTT when compared to thin liquids. However, these encouraging results should not make us forget that the dysphagic patient must be individually evaluated. The dysfunction must be defined according to its etiology. Different anatomical and physiological etiologies require different swallowing management.

REFERENCES

1. Ali GN, Laundl TM, Wallace KL, de Carle DJ, Cook IJS. Influence of cold stimulation on the normal pharyngeal swallow response. Dysphagia 1996; 11: 2–8.
2. Andersson K. Kolsyrad vätskas effekt på sväljningsfunktionen vid amyotrofisk lateral skleros. (In Swedish.) Lund: Faculty of Medicine, the Institution of Logopedics and Phoniatrics, Lund University, 2001.
3. Bidlack W, Wang W. Nutrition requirements of the elderly. In: Morley J, Glick Z, Rubenstein L, eds. Geriatric nutrition, 2nd edn, New York: Raven Press, 1995: 25–49.
4. Bülow M, Olsson R, Ekberg O. Videomanometric analysis of supraglottic swallow, effortful swallow and chin tuck in patients with pharyngeal dysfunction. Dysphagia 2001; 16: 190–5.
5. Cuomo R, Grasso R, Sarnelli G et al. Effects of carbonated water on functional dyspepsia and constipation. Eur. J. Gastroenterol. Hepatol. 2002; 14: 991–9.
6. Ekberg O. The role of radiology in evaluation and treatment of the neurological-impaired patient with dysphagia. J. Neurol. Rehabil. 1990; 4: 65–77.
7. Ekberg O, Nylander G. Pharyngeal constrictor paresis in patients with dysphagia: a cineradiographic study. Clin. Radiol. 1981; 33: 253–8.
8. Hasselbalch H, Jorgensen F, Wamberg T, Hey H. Alternatives to optimal administration of tablets. Acta Med. Scand. 1985; 217: 527–30.
9. Jennings KS, Siroky D, Jackson CG. Swallowing problems after excision of tumors of the skull base: diagnosis and management in 12 patients. Dysphagia 1992; 7: 40–4.
10. Kaatzke-McDonald M, Post E, Davis P. The effects of cold, touch, and chemical stimulation of the anterior faucial pillar on human swallowing. Dysphagia 1996; 11: 198–206.
11. Logemann J. Treatment for aspiration related to dysphagia: An overview. Dysphagia 1986; 1: 34–8.
12. Logemann JA. Evaluation and treatment of swallowing disorders, 2nd edn. Austin, TX: Pro-Ed, 1998.
13. Nilsson H. Quantitative aspects of swallowing – with particular reference to disturbances of swallowing in neurological disorders. Thesis, Lund University, 1998.
14. Nilsson H, Ekberg O, Bülow M, Hindfelt B. Assessment of respiration during video fluoroscopy of dysphagic patients. Acad. Radiol. 1997; 4: 503–7.
15. Olsson R. Castell J, Johnston B, Ekberg O, Castell D. Combined videomanometric identification of abnormalities related to pharyngeal retention. Acad. Radiol. 1997; 4: 349–54.
16. Swank Nixon T. Use of carbonated liquids in the treatment of dysphagia. Network. A newsletter of dietetics in physical medicine and rehabilitation. American Dietetic Association, New York 1997.