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Swallow apnea – Rhinomanometric manifestation and classification

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SUMMARY

Swallow apnea designates the oropharyngeal phase of swallowing during which respiration ceases. Abnormal swallowing in this phase is caused by a disturbance of the food transport and/or a disturbance of the closures of the lower airway. Respiratory movements during swallowing leave the lower respiratory tract vulnerable to invasion by food. The respiratory inactivity of swallowing and its disturbance can be demonstrated by rhinomanometric tests. These tests produce characteristic responses, which are reproducible and are not caused by other events. Three types of responses and three subgroups have been found in 639 examinations of 120 subjects. Thirty subjects had actually experienced aspiration. This event was of life-threatening nature in 11 of the subjects. The combination of multiple swallows and prolonged transport, associated with abnormal positioning and release movements points to a serious disturbance. This method has been a good screening test to detect pathologic swallow and to monitor results of treatment.

INTRODUCTION

In the course of clinical rhinomanometric examination, we observed changes that we identified as swallow apnea. This stimulated our interest to study rhinomanometric manifestions of voluntary swallowing.

Swallow apnea is the brief period in which respiration ceases during the oropharyngeal phase of swallowing. This is expressed in rhinomanometric recording as a straight line at zero, indicating respiratory inactivity. Disturbances in this phase will either interfere with the transport or the airway closure or both. Interference with the transport will prolong this phase of swallowing. Interference with airway closure will be expressed as vertical deviation from the zero line. This indicates that active air movements have occured while swallowing was still in progress. This will leave the lower respiratory tract vulnerable to invasion by food. The rhinomanometric testing produces characteristic responses that are reproducible and were not caused by other events. The oropharyngeal phase of swal-

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Dedicated to the memory of Maurice H. Cottle

lowing depends on the intricate interplay of the larynx, the esophageal sphincter and the oropharyngeal structures. Examination of the swallowing mechanism has primarily relied on x-ray examinations (Mosher, 1927; Barclay, 1930 and others), high-speed radiography (Saunders, et al., 1951; Donner and Siegel, 1965), image intensification (Donner and Siegel, 1965; Hüpscher, 1977) and electromyography (Dotty and Bosma, 1956). Rhinomanometric examination provides an additional method to record and analyse this rapid and complex process.

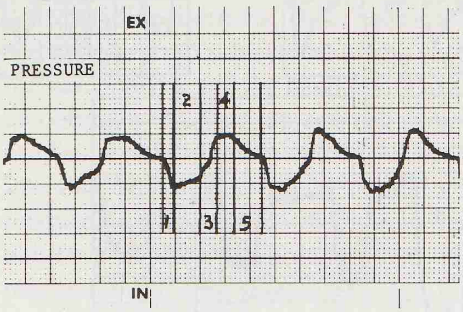
MATERIAL AND METHODS

All subjects were informed volunteers. During a 4 year period a total of 639 observations in 120 subjects were submitted to this study. The age varied from 8 to 72 years. The subjects were divided according to their history of swallowing difficulty into a symptomatic and an asymptomatic group. Seventy-one subjects were symptomatic and 49 were asymptomatic. (Table 1). In the symptomatic group 43 (60.6%) were female, and 28 (39.4%) were male. In the asymptomatic group 40 (81.6%) were female and 9 (18.4%) were male. There were no cases of tumor in this material. One subject had Parkinson's Syndrome, one had scleroderma, one had Sjögren's Syndrome. In addition, one suffered from sleep apnea and wore a tracheotomy tube, one had had surgery for a retropharyngeal abscess and tracheotomy, one had had surgery for Hashimoto thyroiditis, one had no gag reflex, 3 had cleft palate repair and one had an extensive defect of the soft and hard palate and wore an obturator.

The procedure was explained to the subjects. A general history with special reference to swallow difficulty was obtained and a detailed ENT examination was

Table 1. Distribution of subjects.

symptomatic		asymptomatic	
individuals (predominant response)		individuals (predominant response)	
Type I	25	Type I	30
Type II	10	Type II	4
Type III	36	Type III	7
		Mixed	8
Total	71	Total	49
Double or multiple swallows: 42			
Single observations		single observations	
Type I	130	Type I	154
Type II	121	Type II	64
Type III	130	Type III	40
Total	381	Total	258
Double or multiple swallows: 100			



EXPIRATION ▲
1 large square horizontally = 1 second
INSPIRATION ▼
1 large square vertically =
10 mm of water pressure

Figure 1. Elements of the single breath (according to Cottle).

carried out. A baseline of the rhinomanometric pattern was obtained, using the Cottle Rhinomanometer, dual channel*, in the standard manner as described by Cottle, 1968. All recordings were made at a speed of 5 mm/sec. One large square horizontally equals 1 second. One large square vertically equals 10 mm of water pressure (Figure 1). In swallow tests either pressure or flow recordings alone will be sufficient ($P < 0.05$). At times the changes are more clearly visible in the flow recording (Figure 4, 5). In our illustrations (except in Figure 4, 5) only the pressure recordings are presented, to save space. The recordings were made in sitting position while the subject swallowed on command either "empty" or swallowed water. The time required for a spontaneous swallow in our asymptomatic group varied between 0.3 and 1 second. We used, therefore, one second as the upper limit for the normal swallow.

RESULTS

The rhinomanometric manifestions of swallow apnea show characteristic reproducible patterns that can be classified into 3 main types (Figure 2) and 3 subgroups (Figure 2 + 3).

Type I In the asymptomatic subjects of this type (Table 1) (Figure 2.1 and 2.3), the respiratory inactivity of swallow apnea is expressed as a straight line at zero of not more than one second duration. There is usually noticeable uniformity of the response in the same individual on repeat testing. The swallow may occur at any phase of the individual breath (Figure 1), and is usually followed by resumption of the breathing cycle. Swallowing on command requires slightly more time than the spontaneous swallow ($P < 0.05$). The subjects in this category had clinically normal velopharyngeal function and were able to produce good closure of the nasopharynx. The pharyngeal mucosa was moist. Some had mild changes in the configuration of the velum palatinum secondary to scar traction. Four subjects

* Instrumentation and Control Systems, Addison, Illinois 60101.

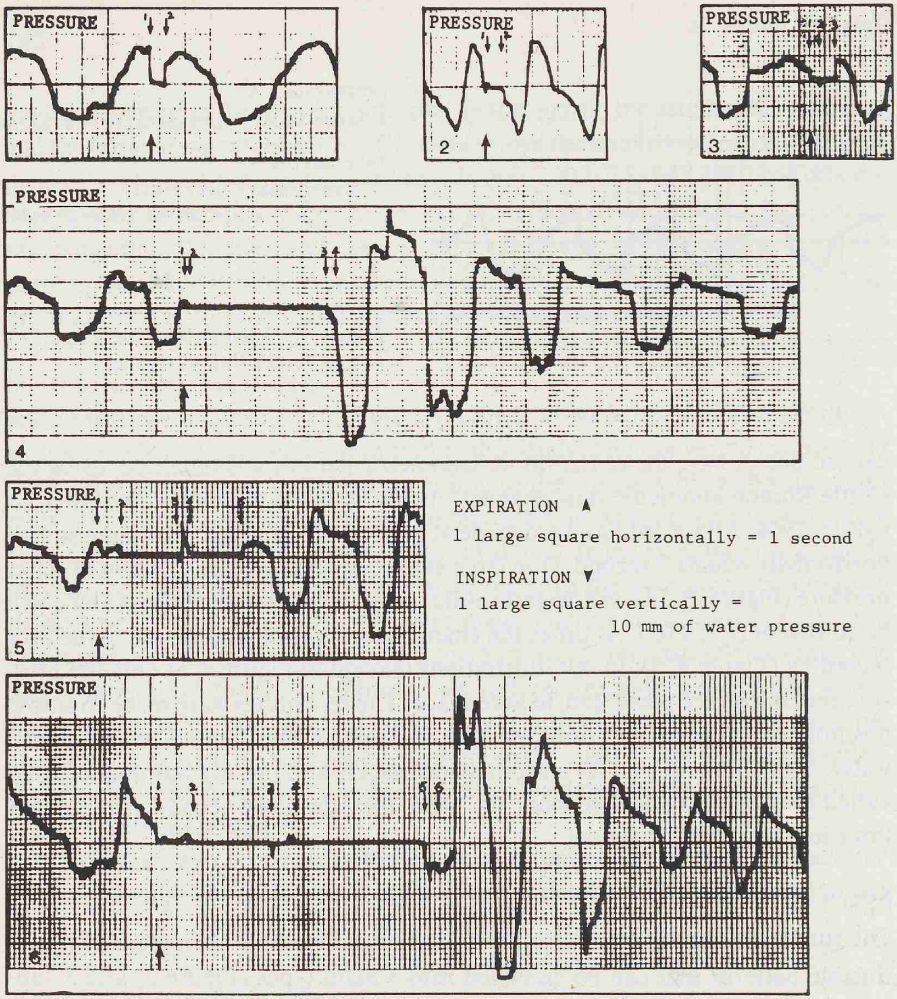


Figure 2. Different types of swallow recordings. The arrows below the zero-line indicate the beginning of the swallow. The numbered arrows above the zero-line mark the different elements of the swallow.

1 and 2. Type I. Arrow 1 marks the positioning movement (A_1). Arrow 2 marks the release movement (A_2).

3. Variant of Type I. Arrows 1 to 3 mark the beginning and the end of the swallow. Arrow 2 points to a minimal vertical movement.

4. Type II. Prolongation of transport and increase of respiratory excursions after swallow. Arrow 1 to 4 – total length of swallow. Arrow 1 to 2 – positioning movement (A_1). Arrow 3 to 4 – release movement; this is slightly more than normal (B_2). Arrow 2 to 3 – prolonged transport of bolus. Beyond 4 – increase of respiratory movement.

5. Type III. Double swallow and prolonged transport. Arrow 1 to 6 – total length of swallow. Arrow 1 to 2 – prolonged and abnormal positioning movement (B_1). Arrow 2 to 3 – first swallow. Arrow 3 to 4 – spike directly before the second swallow (4 to 5) (C_1). At arrow 6 – normal release movement (A_2).

6. Type III. Prolonged transport, double swallow, increased respiratory excursions (air hunger). Arrow 1 to 6 – total length of swallow. Arrow 1 to 2 – abnormal positioning movement. Arrow 2 to 3 – first swallow. Arrow 3 – release movements. Arrow 4 – positioning movements. Arrow 4 to 5 – second swallow. Arrow 5 to 6 – abnormal release movement. Beyond 6 – increased respiratory movement.

were notable exceptions. Three had cleft lip and cleft palate repair with the usual scarring. A fourth subject had a large defect of the soft and hard palate exposing the nasopharynx and the nasal cavity to a large extent. The defect was closed by an obturator. All four subjects had some speech impediment. They each produced a normal swallow recording, except when swallowing was repeated in short intervals. The subject with the obturator was remarkable in that she was able to produce a normal swallow recording when swallowing water without having the obturator in place. She accomplished this without getting water into the nasopharynx or the nose (Figure 5).

The pharyngeal reflex was prompt in all but one subject whose gag reflex was absent. She was symptom-free and had a normal swallow record. A normal swallow was also obtained in several subjects after application of 2% Xylocaine to the pharynx.

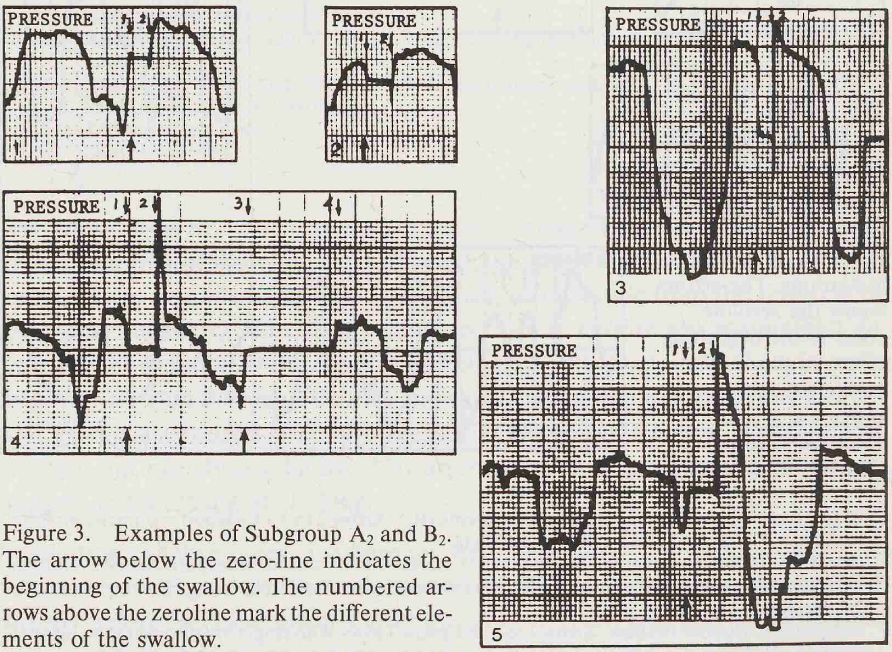


Figure 3. Examples of Subgroup A_2 and B_2. The arrow below the zero-line indicates the beginning of the swallow. The numbered arrows above the zeroline mark the different elements of the swallow.

1. Normal swallow. Arrow 1 - normal positioning movement (A_1). Arrow 2 - normal release movement (A_2).
2. Arrow 1 - normal positioning movement (A_1). Arrow 2 - release movement, beyond normal range (B_2).
3. Arrow 1 - normal positioning movement (A_1). Arrow 2 - abnormal release movement (B_2).
4. Arrow 1 - normal positioning movement. Arrow 2 -abnormal release movement. Arrow 1 to 2 - time of first swallow minimally prolonged (1.2 sec). Arrow 3 to 4 - second swallow prolonged to 3.2 seconds.
5. Abnormal release movements with increased movements after swallow.

In the symptomatic group of Type I, there were 25 subjects (Table 1). All had some degree of dryness of the pharynx and 21 showed significant nervous tension. They noticed the swallowing difficulty especially when swallowing "dry". They found it helpful to prime the pharynx with liquids prior to swallowing and preferred moist food or liquids. They became asymptomatic with appropriate care. In three instances we found in asymptomatic subjects a minor deviation from the zero-line. This was not observed in the symptomatic group, which lead us to think that this is probably only a variant of Type I rather than a separate type (Figure 2.3).

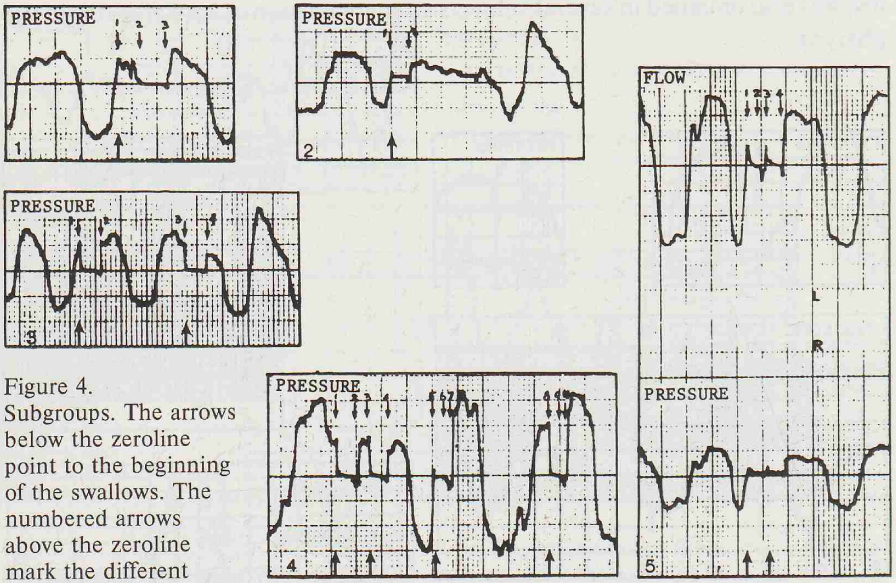


Figure 4.
Subgroups. The arrows below the zeroline point to the beginning of the swallows. The numbered arrows above the zeroline mark the different elements of the swallow.

1. Arrow 1 to 2 - abnormal positioning movements (B_1). Arrow 2 to 3 - transport minimally prolonged. Arrow 2 - normal release movement (A_2).
2. Arrow 1 - normal positioning movement (A_1). Arrow 1 to 2 - normal transport. Arrow 2 - normal immediate release movement (A_2), which is followed by waves of irregular release movements for 2.3 seconds.
3. Subgroup C. Double swallow. Arrow 1 to 2 and arrow 3 to 4 - with single breath separation (arrow 2 to 3).
4. Subgroup C. Multiple swallows. Arrow 1 to 2 - first swallow (voluntary). Arrow 2 - slight abnormal release movement (B_2). Arrow 2 to 3 - spike before involuntary second swallow (arrow 3 to 4). Arrow 4 - normal release. Arrow 4 to 5 - respiratory movement. Arrow 5 to 7 - third spontaneous swallow. Arrow 6 to 7 - mild abnormal release (B_2). Arrow 7 to 8 - respiratory movement. Arrow 8 to 10 - fourth spontaneous swallow. Arrow 9 to 10 - mild abnormal release (B_2). It can be seen that the involuntary swallows are slightly shorter than the voluntary swallow.
5. Pressure and flow curves are presented to show that at times the flow tracing will reveal the double swallow better than the pressure tracing. The positioning movement and the release movement (arrow 1 and 3) are greater than normal. This is not apparent in the pressure curve.

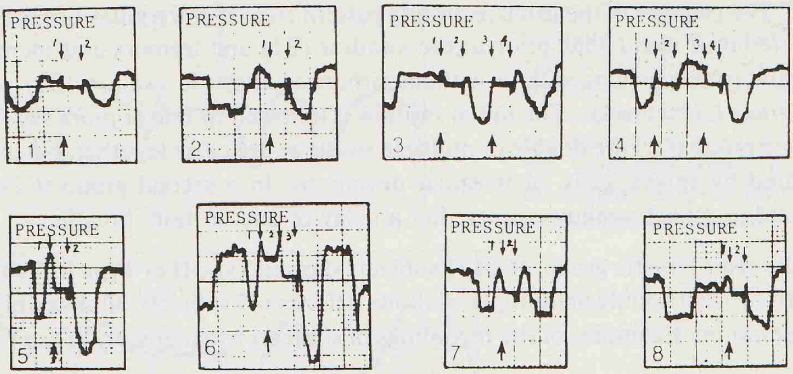


Figure 5. Recordings from a subject with a large defect of the soft and the hard palate with wide exposure of the nasopharynx and the nose. The arrow below the zeroline indicates the beginning of the swallow. The numbered arrows above the zeroline mark the different elements of the swallow.

1 to 4. Swallow with the obturator in place.
1 and 2. Represent a "dry" swallow. Arrow 1 – positioning movements. Arrow 2 – release movements.
3 and 4. Swallowing water. Attention is called to the double swallow.
5 to 8. Swallows without the obturator.
5 and 6. Represent swallows.
7 and 8. Swallowing water.

Type II and Type III The response in these 2 categories are obvious deviations from the normal swallow pattern. In Type II, the swallow apnea is prolonged indicating a delay in transport. There is, however, no deviation from the zero-line of respiratory inactivity. This shows that good airway closure was maintained. In Type III, the duration of the swallow is prolonged, and in addition, there is vertical deviation from the zero-line. This indicates a disturbance of the airway protection, as well as a disturbance of the transport. The swallow apnea of Type II and III is often, but not always, followed by an increase in respiratory excursion, air-hunger, and a feeling of choking.

In addition to these types, 3 subgroups were identified.

Subgroup A (Figure 3) Vertical excursions of the recording were observed directly before (A1) and directly after the swallow (A2). Limited, single vertical excursion at the beginning and the end of the swallow apnea are normal. They represent positioning and release movements. They are produced by movements of the larynx, the pharynx, and the velum palatinum. They can be simulated experimentally.

Subgroup B (Figure 4) When these movements are extensive or multiple, they express overreaction, delay or an indecisive repetition of an ordinarily smooth movement and are pathologic. This indecisiveness can be an invitation to aspira-

tion. The changes of the usual recording pattern consist of irregularities, tremors and reduced excursions prior to the swallow (B1) and tremors and increased respiratory excursions with or without airhunger after the swallow (B2).
Subgroup C (Figure 4) The initial swallow is followed by one or more swallows. In one group (C1) the double or multiple swallows are close together, but are separated by spikes, gaps, or irregular deviations. In a second group (C2), the second or repeat swallow occurs after a delay of one or more breaths.

In the symptomatic group, 46 of 71 subjects showed Type II or Type III swallow. Forty-two had double or multiple swallows. Of these 42 subjects, 30 gave a history of aspiration. Examples of the recordings of subjects with a history of aspiration

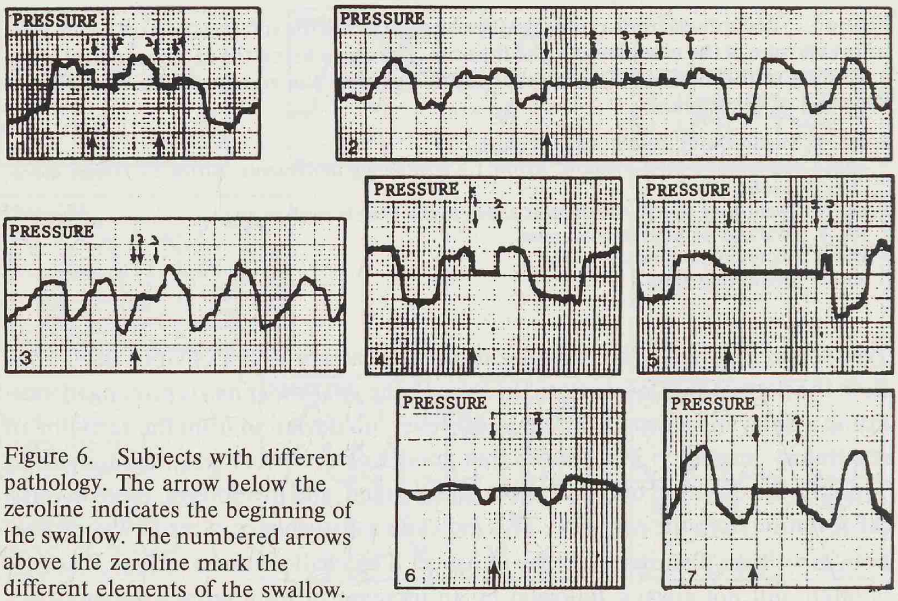
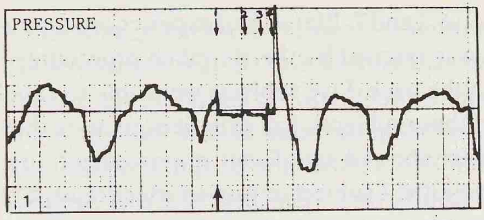
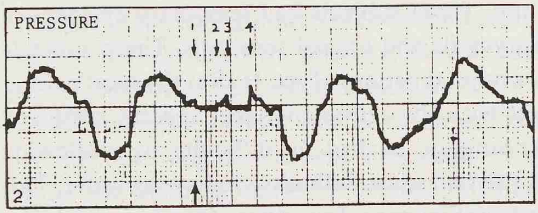
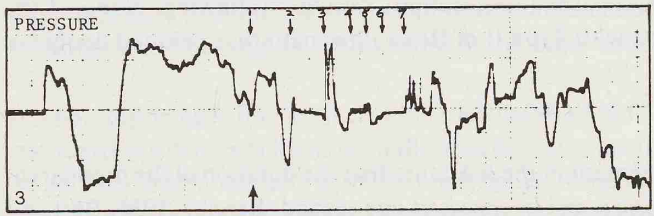


Figure 6. Subjects with different pathology. The arrow below the zeroline indicates the beginning of the swallow. The numbered arrows above the zeroline mark the different elements of the swallow.

1. Subject with Sjögren's Syndrome. Arrow 1 to 2 - voluntary dry swallow. Arrow 2 to 3 - respiratory movement. Arrow 3 to 4 - second (involuntary) swallow.
2. Subject with Scleroderma. Arrow 1 to 2 - voluntary dry swallow. Arrow 2 to 3 - 2nd swallow (involuntary). Arrow 2 to 4 - 3rd swallow (involuntary). Arrow 4 to 5 - 4th swallow (involuntary). Arrow 5 to 6 - 5th swallow (involuntary). At arrow 5 - irregular positioning movements (B_1).
   Both subjects had experienced aspiration. They improved when priming the throat with liquids.
3. Swallow after the subject with scleroderma drank liquids. Arrow 1 to 2 - minimal change in the positioning movement.
4 and 5. This subject had had incision and drainage of a retropharyngeal abscess and had had tracheotomy.
4. Arrow 1 to 2 - dry swallow.
5. Swallowing water. Arrow 1 to 2 - significantly prolonged transport. Arrow 2 to 3 - abnormal release movements.
6 and 7. This subject suffers from sleep apnea and wears a tracheotomy tube.
6. Dry swallow with the tracheotomy tube closed.
7. Dry swallow with the tracheotomy tube open. The transport (arrow 1 to 2) is lightly prolonged in both tests.







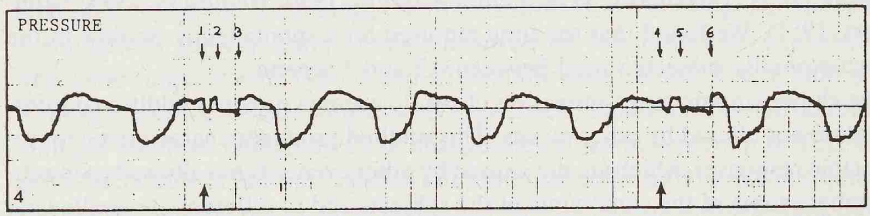


Figure 7. Examples of swallow recordings of subjects who experienced life-threatening aspirations. The arrows below the zeroline indicate the beginning of the swallow. The numbered arrows above the zeroline mark the different elements of the swallow.

1. Subject with cerebral arteriosclerosis. Frequent and serious episodes of aspiration. Was rescued by slap on back.
   Arrow 1 to 2 – voluntary swallow. Arrow 2 to 3 – second (involuntary) swallow.
   Arrow 3 to 4 – abnormal release movements.
2. Subjects with general debility. Frequent and serious episodes of aspiration. Rescued with slap on back.
   Arrow 1 to 2 – voluntary swallow. Arrow 2 to 3 – abnormal release movements. Arrow 3 to 4 – second (involuntary) swallow.
3. Subject with Parkinson's Disease. Frequent and serious episodes of aspiration. Responded to slap on back.
   Arrow 1 to 2 – abnormal positioning movements. Arrow 2 to 3 – voluntary swallow. Arrow 3 to 4 – irregular release movements. Arrow 4 to 5 – involuntary swallow. Arrow 5 to 6 – release and positioning movements. Arrow 6 to 7 – involuntary swallow. Beyond arrow 7 – irregular movement that can not be analysed.
4. This subject had had one serious attack of aspiration and was rescued by the Heimlich procedure. There is a persistant disturbance of the positioning movement (B_1), Arrows 1 to 2 and 4 to 5. So far, she has responded well to changes of the swallowing technique and to guidance.

are given in Figures: 2.4, 2.6, 3.6, 4, 6.1, 6.2 and 7. Eleven had experienced aspiration of life-threatening nature. One was rescued by the Heimlich procedure; 5 were rescued by determined slaps on the back. Five subjects were able to expel the food without help. All, but one of these subjects, had experienced more than one episode of aspiration. One subject showed significant improvement after thyroid operation for Hashimoto thyroiditis; 1 subject improved after drainage of a retropharyngeal abscess. Nine other subjects had a history of occasional aspiration, not of life-threatening nature. Three subjects had temporary episodes of aspiration secondary to hypopharyngitis and lingual tonsillitis. These subjects changed from Type II and III to a normal pattern (Type I) after the local pathology had cleared up. The subject with the retropharyngeal abscess improved steadily. At three months after surgery, he had no difficulty in swallowing "empty" or swallowing food, but still had some difficulty swallowing water. This was substantiated by the swallow test (Figure 6). Two other subjects gave a history of recurrent laryngospasm (? aspiration) during swallowing. None of the asymptomatic subjects with Type II of III swallow pattern, exhibited double or multiple swallows.

DISCUSSION

There is a general agreement in the literature that the duration of the oropharyngeal phase of swallowing is not in excess of one second (Barclay, 1936; Best and Taylor, 1939; Davenport, 1978; Fenton-Cowgill, 1950; Hendricks, 1974; Saunders, 1951). We found that the time required for a spontaneous swallow in the asymptomatic subjects varied between 0.3 and 1 second.

The rhinomanometric examination of swallow apnea provides additional information not offered by other means. This method produces characteristic reproducible responses, which are not caused by other events. It has allowed us to substantiate some of the complaints of the subjects and to differentiate swallowing disturbances of physical nature from psychological problems. It also points to subjects with a potential to aspiration and has been helpful in monitoring progress of treatment. The graphic recording allows comparison of the swallow mechanism on different occasions and under different circumstances.

When a temporary disturbance clears up, the swallow recording will return to a normal pattern (Type I). We observed this in three subjects with lingual tonsillitis and inflammation of the aryepiglottic region and in one subject with a retropharyngeal abscess.

In the double swallow, inadequate clearing of the pharynx of food from the first swallow is apparently a responsible factor, as could be seen in x-ray examinations with contrast media. The subjects who experienced aspiration had prolonged or multiple swallows with disturbance of airway protection (Type II and III: Subgroup B and C). Also increased respiration after swallowing or pathologic

positioning or release movements represent a serious disturbance of swallowing. These changes may be due to muscular or nerve impulse dysfunction (hypertonic-atonic dysphagia of Catel; 1936) or may be of local nature. Shortwindedness of any etiology was an aggravating factor.
Application of topical anesthetic (2% Xylocaine) did not interfer with a normal swallow. This is in agreement with clinical experience and was also observed experimentally with topical Cocaine by Dotty and Bosma (1956).
Changes in the configuration of the velum palatinum had less influence on swallowing than scarring of the pharynx. Even an extensive defect of the soft and hard palate could be compensated to such an extent that a normal swallow was possible without reflux of fluid into the nasopharynx or the nose (Figure 5). This is apparently not a singular incident. Freystadtl (1928) reported a similar observation. Miller and Sherrington (1916) demonstrated normal swallowing in decerebrate cats after resection of the soft palate, proving that the velum palatinum is not always necessary to allow a normal swallow. Zwaardemaker and Eijkman (quoted by Miller and Sherrington, 1916) came to the same conclusion.

It is not surprising to find subjects with a normal swallow recording in the symptomatic group since complaints of swallowing difficulty are frequently found in tense patients and in subjects with dry pharyngitis. None of the symptomatic subjects with Type I swallow experienced aspiration. While there has been good correlation between the complaints, the rhinomanometric recordings and the other examinations, some questions remain unanswered. What is not yet explained is why some subjects with Type II and III swallow were entirely free of difficulty. None of the asymptomatic subject with Type II or III swallow exhibited double or multiple swallows (subgroup C) or changes described in subgroup B. This suggests that double or multiple swallows in combination with abnormal positioning and release movements are more consequential factors than the prolonged transport.
In symptomatic subjects of Type II and III swallow, search for underlying pathology revealed one or a combination of several of the following problems: contraction of the cricopharyngeal muscle, arthritis and spurring of the cervical and thoraric spine, hiatus hernia, tendency to gastro-intestinal spasm, dryness of the pharynx, inflammation of the lingual tonsil and the aryepiglottic region, elongation of the styloid process, intraesophageal webbing, scarring of the pharynx, iron deficiency anemia and ill-fitting dentures. These problems were common and became a routine consideration in the search for underlying pathology. However, there were some patients without any demonstrable cause. To what extent each of these problems individually influence the swallow act can not yet be said.

ZUSAMMENFASSUNG

Schluckapnea ist ein Zeidren der oropharyngeal Phase des Schluckens, wenn die Atmung zum Stillstand kommt. Pathologisches Schlucken in dieser Phase wird durch Verstörung des Transportes oder/und Verstörung des Verschlusses der unteren Luftwege bedingt. Respiratorische Bewegungen während des Schluckens bringen die unteren Luftwege in Gefahr der Aspiration. Die respiratorische Inaktivität des Schluckens und ihrer Störungen kann mit rhinomanometrischen Untersuchungen dargestellt werden . Diese Untersuchungen verursachten charakteristische Aufzeichnungen die reproduzierbar sind und die nicht von anderen Ereignissen bedingt waren. Drei Typen und drei Unterabteilungen wurden in 639 Untersuchungen von 120 Personen gefunden. Dreissig Personen hatten eine Aspiration erlebt. In 11 Personen war dieses Ereignis von lebensgefährlicher Nature. Das Zusammentreffen des mehrfachen Schlucken und des verlängerten Transport mit abnormalen Einstellung und Auflösung Bewegungen weisen auf eine ernsthafte Störung hin. Diese Methode hat sich als gutes Untersuchungsmittel bewährt um Schluckstörungen aufzufinden. Es war auch nützlich um die Resultate der Behandung zu folgen.

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