SUMMARY

The development and use of frontal and base-view fluorography have increased the value of cinefluorography in the evaluation of velopharyngeal closure. This paper discusses problems in the fluorographic examination of the closure mechanism, the need for other measures of velopharyngeal closure, and the validation of closure measures. Reliability data are needed for measurements made from frontal and base-view films and tapes. Measures in addition to those of a fluorographic nature are needed for the identification of persons with questionable velopharyngeal closure and for use in the evaluation of training procedures that may contribute to improved use of the velopharyngeal closure mechanism. A pattern of relationships among fluorographic and nonfluorograph measures of velopharyngeal closure can be studied in the validation of both classes of measures.

Issues Involved in the Evaluation of Velopharyngeal Closure

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A preoccupation with certain issues is reflected in the annual scientific meeting and publication programs of the American Cleft Palate Association. Repeated discussion of a given issue sometimes generates complaints. However, the continuing search for better solutions to abiding problems is more to be commended than criticized if it is well performed. One abiding issue concerns methods for evaluating velopharyngeal closure—both the closure that is performed by an individual at a given time and his potential to improve incompetent velopharyngeal performance without surgery or prosthesis. A viewpoint is developed in this paper that evaluation of velopharyngeal closure for speech requires consideration of patterns among a number of variables.

For some years, velopharyngeal closure has been assessed directly by sagittal fluorography and indirectly by measurement of variables that are influenced by velopharyngeal closure. Indirect phenomena studied include articulation, air pressure and flow, and oral and nasal sound pressure level. Attempts have been made to correlate fluorographic measures with indirect closure measures in order to decrease need for x-ray observation. Improvements in radiation pulsing and image intensification and also availability of videofluorographic recording

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procedures have reduced radiation exposure associated with fluorographic examination of the closure mechanism (McWilliams and Girdany, 1964; Skolnick, 1970). Since the introduction of videofluorography, more frequent application has been made of frontal fluorographic examinations, and Skolnick (1970) has introduced the ingenious base-view examination. With some persons now advocating multiview fluorographic examination for all potential candidates for secondary velopharyngeal surgery, clinicians must decide whether these examinations are required and if so whether a need continues to exist for other methods of evaluating velopharyngeal closure. This article is addressed to three topics: (1) procedural issues involved in the fluorographic examination of the velopharyngeal closure mechanism, (2) the need for non-fluorographic measures of closure, and (3) the validation of measures of velopharyngeal closure.

Procedural Issues Involved in the Fluorographic Examination of the Velopharyngeal Closure Mechanism.

Recently, persons concerned with the fluorographic assessment of velopharyngeal closure have focused their attention on the use of frontal and base views. Clearly those views supplement the sagittal view in the evaluation of velopharyngeal function. Nevertheless, the study of speech production by motion x-ray techniques (Subtelny, et al., 1957; Bzoch, 1970) has demonstrated that factors in addition to view must be considered by persons using x-ray to study speech mechanisms.

Camera Speed and Loss of Information. Investigatiors have learned that some articulatory movements occur so quickly that information is lost between motion picture film frames exposed at 24 frames per second (Moll, 1960). Consequently, investigators seeking to develop theories that will economically account for as much articulatory behavior as possible have used cinefluorographic apparatus that will expose film frames at a rate of 100 frames per second (Kent and Moll, 1972). The 24-frame-per second camera speed has proven to be satisfactory for the clinical assessment of velopharyngeal closure sufficiency (Shelton, et al., 1963; Bzoch, 1970). However, for the investigation of many basic questions that relate to articulation behavior, use of high speed instrumentation is essential, and views other than sagittal may be unnecessary. A case in point is McClean's (1973) use of sagittal x-ray views and a 100-frame-per-second camera to explore the relationship between onset of velar movement and presence of a junctural boundary in the utterance studied. This investigation was directed not to the clinical assessment of velopharyngeal closure but to testing and developing a theory of speech production.

Television cameras rather than motion picture cameras are now often used in motion x-ray studies. While a television camera does not have a film-frame advance mechanism, a phenomenon analogous to film-frame rate does exist in the television mechanism. The pickup tube of a television camera houses a photoconductive layer that is scanned at a rate of 1050 lines per second in a high resolution camera or at 525 lines per second in many cameras that are in clinical use. The camera lens focuses an image on the photoconductive layer, and the

layer forms voltages corresponding to the image. The layer is scanned line by line by an electron beam much as a person reads a newspaper. The beam scans every other line and completes its scan of a set of half the lines in 1/60 of a second. The beam then retraces to the top of the screen and again scans down the field filling in the intervening lines. Thus, it takes 1/30 of a second to complete the process of scanning the photoconductive layer. A set of half the lines or scans is called a visual field, and two fields correspond to one film frame in a motion picture camera. During this process, information is lost as the beam returns horizontally to the start of each line and as the vertical retrace is made between visual fields. Thus, a video camera and recorder with a 1/60 of a second scanning rate may be considered analogous to a motion picture camera operating at 30 frames per second.

The information obtained by the television camera may be displayed on a television screen by a process that is the reverse of the process just described, or it may be recorded on videotape for later transmission to the television screen. Some videorecorders are constructed with only one head. These recorders may be used to display visual fields individually in stop-frame projection. Since one of the two visual fields that constitute a frame is recorded ahead of the other in time, stop-frame projection of sequential visual fields displays information recorded at a rate analogous to 60 film frames per second. However, motion may not be displayed at that rate, and the quality of the stopped image is reduced. If a videotape recording is converted to motion picture film, typically the film is exposed at 24 frames per second. We know of no laboratory that converts videotaped images to film in such a way that each visual field is recorded on a separate film frame. We conclude that, so far as information loss is concerned, a videotape system displaying 60 visual fields (30 frames) per second is a little better than a motion picture system operating at a standard speed of 24 frames per second. Thus, a video system of this type is satisfactory for clinical examinations of velopharyngeal closure but may miss information needed for some research purposes. Information loss is an important consideration for persons taping or filming fluorographic information.

TISSUE DEFINITION. Definition of tissue margins has long been a problem in cinefluorographic speech studies. This issue includes concern about oral placement of objects or substances that might facilitate viewing but at the expense of naturalness of movement. Tissue definition is frequently resolved by using radiopaque material to outline structures of interest. Furthermore, use of radiopaque fluid may intrude on the speech act in a manner analogous to oral placement of an endoscope shaft. At least one individual studied by the first author gagged in response to taking a spoonful of barium into the mouth. His speech was cinefluorographed soon after he placed the barium in his mouth, and we conjecture that his response to the barium may have influenced the oral gestures that he used as he talked during the filming. Indeed, even in the absence of a readily observed response to radiopaque media, an individual may respond to fluorographic equipment in a way that would influence the speech studied. That is, we differentiate between voluntary and automatic speech acts (Shelton,

et al., 1963; Wright, et al., 1969), and the presence of equipment cues may result in the production of velopharyngeal performance that would not have occurred spontaneously.

A tissue marking system is needed to facilitate interpretation of base-view observations. A weakness of the base-view examination is difficulty in determining the level at which the velopharyngeal port is observed. That is, base-view may provide information about velopharyngeal relationships at a level outside the region of juncture between the velum and the pharyngeal walls. If so, velopharyngeal closure would be overlooked. Some investigators glue radiopaque markers to structures of interest in order to facilitate study of movements of particular points within the speech mechanism (Kent, 1972; Lifschiz, 1963). Use of a technique of this kind—intrusive though it may be—seems needed in the further development of base-view techniques. Difficulty in placing markers would prevent their use in clinical examinations, but perhaps their experimental use would allow the radiologist to devise a procedure for locating the transverse level at which base observations are made.

Cervical Posture. Posture is known to influence relationships among oropharyngeal structures (Shelton and Bosma, 1962), and McWilliams, Musgrave, and Crozier (1968) have demonstrated that persons with marginal velopharyngeal closure may appear to close while producing phones or syllables in an upright posture but present a velopharyngeal opening while producing the same utterance in an extension posture. That distinction is diagnostically useful. Since base-view fluorography requires adjustments of cervical posture, it is possible that the closure phenomena observed during base-view are different from those which occur when the patient is upright as during taping for sagittal and frontal views. Some—probably most—of this variability could be eliminated by maintaining a standard posture throughout base, sagittal, and frontal recording. However, the "sphinx" posture used in the base view examination would not be the posture of choice if closure during that posture differs from that observed in the upright individual. Simultaneous filming or taping of base and sagittal views followed by repeated recording of sagittal performance in an upright posture might resolve this problem. However, such a procedure seems unrealistic in terms of cost and radiation exposure.

MATTERS OF MEASUREMENT. The opportunity for bias as an error factor in research is well known (Rosenthal, 1968). Persons studying cinefluorographic records, project films with stop-frame projectors, and film frames are traced and measured (Fletcher, et al., 1960; Moll, 1960; Smith, et al., 1960; Diedrich and Youngstrom, 1966). Similarly, counters may be used with a videotape system to allow an investigator to identify visual fields and to display them in stop-projection, or videorecorded information can be transferred to film via a kinescope procedure (Shprintzen, 1975). To reduce the influence of observer bias and to evaluate error in making measurements from projected fluorographic images, investigators often engage in the repeated measurement of a film. Measurements made by different observers are compared statistically to obtain information about measurement reliability. Other statistical procedures are used

to estimate measurement error. Reliability may be a greater problem for frontal and base views than for sagittal views since velopharyngeal tissues can be less clear in those views.

Recent research by Shprintzen, McCall, Lencione, and Skolnick (1974, 1975a, 1975b) utilized tracings and measurements from projected frontal, lateral, and base images. Reliability data were not reported; however, if measurement reliability may be inferred from an orderly pattern of results, then measurement reliability was probably satisfactory. Earlier multiview research by Skolnick and his associates (1970, 1972, 1973) relied on description and reproduction of film frames to support inferences. While those papers constituted a substantial contribution to the study of velopharyngeal closure, they would have been stronger had reliability estimates been reported for independent observers. Reliability procedures that have been used in measuring sagittal fluorographic views need to be applied more extensively in the utilization of frontal and base-views.

Measurement problems may also arise when fluorographic films or tapes are projected for description or scaling. Certainly data obtained by scaling need to be checked for reliability. Also, more articulatory phenomena are recorded on a fluorographic film or tape than an observer can process simultaneously. Lacking an organized procedure for studying the projected image, an observer may overlook important information. McWilliams and Bradley (1965) devised a procedure for scaling sagittal videofluorographic tapes of velopharyngeal closure, and Schulz et al., (1973) devised a somewhat similar schema for evaluating videopanendoscopic tapes of velopharyngeal closure in patients who had undergone pharyngeal flap surgery. Regarding the extraction of data from videotape, Shelton et al., (1975) noted that, in the absence of an outline to guide his or her observations, an observer was likely to shift attention from one phenomenon to another as successive performance trials were studied.

In conclusion, Skolnick and McCall and their associates have made a substantial contribution in their development of multiview fluorographic procedures and in their publications and oral presentations of information about velopharyngeal closure. In spite of the progress made, some questions of reliability and validity remain unanswered.

Is There Need for Velopharyngeal Closure Measures in Addition to Those Based on Multiview Fluorography?

Velopharyngeal closure is evaluated for different purposes. The first of two purposes which we will consider here is clinical evaluation of the adequacy of an individual's velopharyngeal mechanism. A clinician may wish to determine whether an individual demonstrates adequate closure or whether he is a candidate for surgery or prosthesis. Are closure measures in addition to those based on fluorography needed for this purpose?

Our second issue concerns velopharyngeal training. Some individuals will be found whose closure status is borderline. An attempt may be made to improve the velopharyngeal function of these individuals through training or other procedures such as reduction of prosthetic speech appliances. Persons in this

category include cleft palate individuals who have had primary surgery but who may be candidates for secondary surgery or prosthesis. Also included are individuals who have had secondary surgical procedures but who continue to emit air through the nose during consonant production. We assume that some of the latter individuals have failed to learn to use mechanisms that are structurally capable of supporting normal speech. Others may continue to present anatomically insufficient velopharyngeal mechanisms. Are closure measures in addition to those based on fluorography needed to evaluate an individual's response to training intended to improve his or her velopharyngeal function?

EVALUATION OF CLOSURE STATUS. Just as a decision must be made to provide a child with secondary velopharyngeal surgery, so must a decision be made to conduct a fluorographic evaluation of an individual's speech mechanism. The decision to refer a patient for fluorographic examination often proceeds from observations of articulation and nasal resonance. If the speech pathologist is the first person to identify a person who appears to present poor velopharyngeal closure, he or she will refer the patient to someone else—preferably to a multidisciplinary cleft palate team. Before making the referral, the speech clinician will want to be certain that it is warranted. Since articulatory errors in cleft palate patients can result from factors other than poor closure (Van Demark, 1966), any errors observed must be analyzed to determine if they present a pattern that may reflect poor closure. Errors may vary in severity and consistency of occurrence. These factors too must be considered in deciding to pursue further valuation and possible treatment. Observations of articulation and resonance may be supplemented by use of a number of simple tools which serve as indirect indices of velopharyngeal closure. For example, a listening tube (Blakeley, 1972, p. 149) may help experienced observers to identify clinically significant nasality and audible nasal escape, and Fox and Johns (1970) have described a tongue-anchor technique for screening velopharyngeal closure. Other available tools include manometers to measure nasal escape of air associated with sound production or differences in oral air pressure as an individual blows with modest but constant effort with the nares open and again with nares pinched closed (Morris, 1966; Shelton, et al., 1965). More elaborate instrumentation permits simultaneous measurement of pressures and flows by means of pressure transducers, pneumotachographs, and electronic recorders (Hardy, 1965; Lubker, 1970; Warren, 1973). Also, instrumentation that responds to oral and nasal sound pressure levels (Shelton, et al., 1967; Fletcher, 1972) may be used. Again, the various measures obtained are studied for a pattern that suggests poor velopharyngeal closure. The speech pathologist does need tools in addition to fluorography in order to make suitable referrals.

After a patient has been referred to a cleft palate team, the team members must decide whether indirect measures regarding velopharyngeal closure must be supplemented by direct evidence. Often treatment decisions are made on the basis of indirect evidence such as articulation or pressure-flow observations. If direct evidence is needed, consideration can be given to the use of endoscopes, nasopharyngoscopes, and ultrasound apparatus, as well as to multiview

fluorography. Whatever decision is made, indirect measures of velopharyngeal closure do play a role in the evaluation process.

EVALUATION OF A PATIENT'S RESPONSE TO TRAINING. Speech pathologists have a long-standing interest in the improvement of velopharyngeal closure through training or therapeutic exercise (Shelton, 1963; Shelton, et al., 1973). Recently Shprintzen, McCall, and Skolnick (1975a) described the results of a training procedure used with patients who presented closure during blowing and whistling but not during speech. Feedback of information about nasal escape of air was used to encourage transfer of closure performance from blowing and whistling to speech. Shelton, et al., (1975) used a panendoscope and a closed circuit television system to display to normal subjects their own velopharyngeal movements. The feedback information was used to teach non-speech voluntary movements. While we consider velopharyngeal closure training to be an experimental procedure in need of further investigation and development, clearly work of this kind requires information about closure other than that which can be provided by fluorography. Even with reduction in radiation brought about by improved technology, the number of x-ray examinations that can be conducted on a given person is limited. Training procedures for the development of velopharyngeal closure or for effective use of a speech mechanism newly treated by surgery or prosthesis require trial-by-trial assessment of the patient's velopharyngeal performance during a learning task. This requires use of devices that will permit reliable observation of closure related phenomena and valid inference of velopharyngeal closure. Shprintzen et al. (1975a) used a "scape scope" to assess closure during training trials. The scope consists of tubing, a portion of which houses a lightweight chip of plastic that can easily be displaced by air escaping from a patient's nose. The device functions similarly to a water manometer. While the scope has received little attention in the literature, it apparently served a useful purpose in a treatment program designed to teach improved velopharyngeal function. Hixon (1975) recommended use of a two-channel recorder for observation and measurement of nasal air flow and oral air pressure in investigations of this type. The oral pressure observations can be used to keep respiratory phenomena constant concurrent with attempts to reduce nasal air flow.

We conclude this section by noting that none of the measures discussed—including fluorography—will tell an examiner what a patient can do. Rather, they tell what he did do during a given assessment. Also, no measure will provide an absolute index of the need a person has for velopharyngeal treatment because that decision must involve the personal taste and preference of the patient.

Validation of Velopharyngeal Closure Assessment Procedures.

Various kinds of validity are defined in the psychological literature (Shontz, 1965). Here we are concerned with predictive validity[1] which concerns the

[1] We would prefer to refer to construct validity which involves empirically testing theory-based predictions. However, the extensive information that is available regarding velopharyngeal closure and speech has not been stated in suitable theoretical form.

accuracy of predictions based on a given measure. Some tests and measures for sale to professional workers have no established validity of any kind. Other measures are satisfactory for sorting persons into groups but will support only crude predictions expressed in terms of percentages of group members who are likely to behave in a given way in the future. An example of such a measure is the Predictive Screening Test of Articulation (Van Riper and Erickson, 1968). Tests of this kind are useful to persons who must make administrative decisions regarding large groups, but they are not very useful to the worker who must plan services for an individual. Establishment of clinical prognoses for a specific patient requires tests and measures that are so well developed that they will support precise predictions about future behavior. That is, the measures require a high order of validity.

Various measures of velopharyngeal closure including fluorographic measures have validity of sorts supported by clinical research. However, little systematic work has been done to establish the validity of those measures in constructing precise prognostic statements regarding the likely outcome of surgical, prosthetic, or training treatments provided to individuals with cleft palate (Van Demark, et al., 1975). Reliable measurement of fluorographic images either by frame-by-frame measurement or by psychophysical scaling is a first step in achieving this measurement goal. However, impressionistic viewing of projected images is not likely to provide information suitable for making precise predictions. Development of predictive validity information for a measure of velopharyngeal adequacy for speech requires measurement of speech as well as measurement of velopharyngeal closure. We sometimes forget that, while speech measures and velopharyngeal closure measures share some common variance, they are also to a considerable extent independent of one another (Brandt and Morris, 1965; Shelton, et al., 1965).

Two classes of experimental methodology described by Shontz (1965) may help us to consider in greater detail matters involved in the validation of velopharyngeal closure measures. Shontz differentiated between what he termed direct and remote control of research variables. Direct control involves direct observation or measurement of a phenomenon of interest whereas remote control requires inference of a construct from something that is directly observed. For example, an examiner concerned with tongue tie may directly observe and measure the lingual frenum and adjacent tissue thus engaging in direct control. Another examiner engages in remote control when he makes a physiological measurement in an attempt to learn something about a feeling state such as anxiety. The second examiner attempts to infer a phenomenon from the observation of something else. Shontz states that to use remote control a scientist must establish the rules of correspondence between the thing he observed and the thing he inferred. Evaluation of articulation and of speech sound discrimination provides another example of the distinction between direct and remote control. We may directly observe one or another aspect of articulatory behavior by eye or ear. However, we infer speech sound discrimination from observation of an individual's gestural or verbal responses that are made to auditory stimuli.

Fluorographic, endoscopic, and ultrasonic procedures for the evaluation of velopharyngeal closure appear to provide direct information whereas other means of studying closure, such as pressure-flow instrumentation, are remote means. If so, rules of correspondence should be established between the pressure-flow phenomena observed and the velopharyngeal closure that interests us. Warren (1967) and Warren and associates (1967), have done exemplary work of this type.

In a sense, fluorographic, endoscopic, and ultrasonic procedures may be considered as remote indices to velopharyngeal closure. We have already indicated that intrusion of instrumentation or radiopaque media may alter the behavior studied. During an examination, the patient may deliver velopharyngeal performance different from that which he would use more automatically. Certainly the speech studied by instrumentation constitutes a small sample of an individual's total speaking behavior. Thus, we are not assured that observations made during a fluorographic examination represent the individual's speech behavior under other circumstances. We do not know whether a speech sample studied fluorographically is representative of the individual's population of speaking behaviors. Therefore, even though we often attempt to validate indirect measures of velopharyngeal closure by cinefluorographic measurement, it may also be necessary to validate fluorographic observations against other indices of velopharyngeal function. Data regarding relationships among speech measures obtained in different environments—including the fluorographic laboratory—would be helpful.

The circularity of a situation wherein each of two measures is used to validate the other may be distressing to the reader. However, we are drawn to the conclusion that evaluation of velopharyngeal closure for speech requires consideration of patterns among a number of variables. This conclusion is compatible with a philosophy of science concerned with relationships among phenomena (Deese, 1972; Arndt, 1974). Deese (1972) describes a conceptualization of science that is concerned with "relationships among the parts and components of a larger system." This conceptualization may be contrasted with a more traditional concern with causal relationships that developed in physics early in the 20th century. Arndt (1974) discusses a similar concept with reference to a holistic psychologist who " . . . rejects the notion of cause and effect as he rejects all other dichotomies and isolated classes. Instead, he maintains that events are related dynamically in such a way that events can be both causes and effects at the same time."

The notion of cause and effect is sometimes useful, but it becomes a liability when it directs a clinician to a search for causes that can't be cound or that can't be remedied if found. At present no one technique provides an entirely satisfactory measure of the adequacy of velopharyngeal closure for speech production. The clinician concerned with the evaluation of velopharyngeal closure must base clinical decisions on a pattern of relationships rather than on an established cause. He needs to look at a pattern that involves speech in and outside the clinic. A variety of tools are required, and each tool needs sound

development. We contend that management decisions based on study of patterns of behavior will be more satisfactory than those based on use of a single measurement tool.

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