Assessment and Remediation of Intractable Articulation Disorders using EPG

W. Hardcastle*, F. Gibbon*, and H Dent+

* Department of Speech Pathology and Therapy,
Queen Margaret College, Edinburgh, Scotland

+ Department of Linguistic Science,
University of Reading, England

Introduction

The technique of Electropalatography is designed to record temporal and spatial details of tongue contacts with the hard palate during continuous speech. Three commercial systems are currently in use - a Japanese system developed by Rion Corporation (Fujimura, Tatsumi and Kagaya, 1973), a system developed at the University of Reading, U.K. (Hardcastle, Gibbon and Jones, 1991) and an American system (Fletcher, McCutcheon and Wolf, 1975, now marketed by Kay Elemetrics). Recently the results of a number of major research projects carried out in Britain, Japan and USA have established the system as a useful tool in the assessment, diagnosis and rehabilitation of a wide variety of speech disorders in both children and adults (see review in Nicolaidis, Hardcastle and Gibbon, 1993).

The time seems ripe to review the contribution the technique has made to the field of clinical phonetics and to point to future directions. It seems particularly appropriate to review the technique in the context of a Festschrift for Professor Hirose as it was in his Research Department of Logopedics and Phoniatrics that much of the pioneering work on EPG took place.

The EPG Technique and Data Reduction

EPG records contact between the tongue and hard palate during connected speech. All three commercial systems use an artificial palate moulded to fit an individual's palate and teeth. Important differences between the systems lie in the placement of electrodes. For example, the Reading EPG3 system places electrodes according to well-defined anatomical landmarks, such as the junction between the hard and soft palates, while the Rion system uses the best fit from a set of standard-sized palate shapes (Fig 1). Most systems have some facility for correlating the EPG patterns with data from other channels such as the microphone, laryngograph,pneumotach etc. In the Reading EPG 3 system the acoustic signal is sampled at 10k Hz along with the EPG signal (100 Hz) and one other channel (Fig 2). A full print-out of contact patterns is available (eg Fig 3) and from this full print-out a number of measures have been found to be clinically useful. These measures include area of contact (overall or in different regions of the palate), centre of gravity of contacts across the palate, long-term frequency of activation of individual electrodes, duration of contact, a variability index, co-articulation index and asymmetry index (for further details of data reduction techniques see Hardcastle, Gibbon and Nicolaidis, 1991).

As a clinical tool EPG has been useful in three areas: in assessment of speech disorders, in therapy and in evaluating the efficacy of therapeutic techniques. In assessment, comparisons can be made, for example, between a normal child's tongue-palate contact patterns and those of a speech disordered child's (eg a child with a repaired cleft palate as in Fig 4). In therapy, the technique is used to provide a visual real-time display of contact patterns and, under the supervision of a speech and language therapist, a speech disordered subject can learn to change existing abnormal patterns (eg Gibbon and Hardcastle, 1989, Michi, Yamashita, Imai, Suzuki and Yoshida, 1993; Fletcher, Dagenais and Critz-Crosby, 1991). In the efficacy studies the technique has been used to provide quantitative measures of differences along various parameters before and after therapy for a number of speech disorders (see below).

To illustrate the clinical applications of EPG the following is a summary of some of the results of a recent Medical Research Council (MRC) project which involved the assessment and remediation of intractable articulation disorders using EPG which was carried out at the University of Reading, 1990-1992.

Case Studies from MRC Project

The project carried out controlled clinical trials with EPG on 25 children aged 8-17 years. All the children had intractable speech problems which had been resistant to conventional therapy. They were all assessed using EPG prior to therapy and on two separate occasions afterwards to identify any changes in articulatory patterns that took place. On the basis of the experience gained with these children we were able to divide the types and aims of therapy into three main groups:

- Group 1: establish new articulatory patterns;
- Group 2: modify existing patterns (primarily for fricatives and stops),
- Group 3: inhibit specific abnormal contact

These three groups will be illustrated by means of brief case studies:

Group 1: Case Study TG (establish new patterns)

TG was diagnosed as having velopharyngeal incompetence at 3;6 years and a pharyngoplasty was performed at 6;1 years. He had a unilateral sensori-neural hearing loss. Initial speech and language assessments carried out at 2;11 years revealed language skills within normal limits but a severely reduced phonological system with no lingual plosives or fricatives. No significant progress was recorded despite regular periods of treatment prior to referral to the MRC project at 9;00 years.

His initial EPG assessment showed minimal tongue-palate contact for all lingual obstruents with /s/ and /ʃ/ targets sounding like pharyngeal fricatives (see Fig 5). Therapy aimed at developing a whole new range of motor patterns to produce lingual plosives and fricatives. The success of therapy is reflected in Fig 6 where patterns for a number of words pre- and post-therapy are shown. Good carry-over was recorded in an assessment carried out three months later; the newly learned patterns had obviously been mastered with dramatic improvement in overall intelligibility. In this case a number of significant factors were revealed in therapy: (a) TG was able to achieve and use new contact patterns with the associated new motor gestures. Therefore we can assume there was no structural or neuromuscular deficit; (b) he was able to deploy the newly acquired gestures without phonological "errors" eg neutralisation. Therefore we can deduce there was no phonological deficit; and (c) he had been unable to exploit articulatory possibilities available for obstruent production following surgery. Therefore his problem could be construed as an initial deficit in the specification of articulatory parameters for specific phonological classes. (For further details see Hardcastle, Dent and Gibbon, 1992).

Group 2: Case Study EJ (modify existing patterns)

EJ had a history of normal development, normal hearing and normal auditory perceptual skills, but a specific "phonetic" disorder involving "backing" of alveolar stops at 9;0 years which persisted until her referral to the EPG project. The phonological system was otherwise normal. There was no identifiable etiology for this specific speech defect. Despite long periods of conventional therapy the problem remained.

Initial EPG assessment revealed a general tendency towards velar contact during target alveolar stops (Fig 7). Listeners' impressions of these target alveolars varied widely - from unmistakable velars to acceptable alveolars (see listeners' results in Fig 7). The EPG patterns, however, revealed an important consistent pattern: namely a general tendency towards complete velar closure. There was some indication also of forward movement of the tongue during the closure phase of the stop. This forward movement was thought to account for a measurable increase in stop duration for these target alveolar stops when compared with target velars (see Gibbon, Dent and Hardcastle, 1993). The evidence suggested that the "backing" was not a motor problem as EJ produced the more complex sibilants and laterals perfectly normally. Also there was no evidence of a perception problem; she was able to distinguish normal contrasts. The hypothesis was that this was a high level problem affecting a specific group of sounds, namely alveolar stops. Consequently therapy was aimed at modifying her abnormal tongue placements for these alveolar targets. Post-therapy records (Fig 8) show a clear reduction of the velar constriction and consequently more normal sounding alvelolar stops. In addition, measurements of stop duration made after therapy showed no significant difference in duration between target alveolars and velars. This suggests that the differences in duration noted before therapy could be accounted for by the abnormal forward movement of the tongue during the target alveolar stop production.

This case study is interesting because it illustrates how EPG can reveal fine-grained abnormalities of tongue gesture (the full velar closure, the anterior tongue movement during closure) that remain undetected by an auditory based analysis.

<u>Group 3: Case Study PB (inhibit specific abnormal contact)</u>

PB was born with a unilateral cleft lip and palate. The lip was repaired at 3 months and the palate at 6 months with a further lip revision at 4;6 years. He had a history of bilateral conductive hearing loss. He presented with delayed speech and expressive language at 2;0 years with a retracted place of articulation for many speech sound classes including alveolar stops and fricatives. There was also audible nasal emission during obstruent production. Video-fluoscopic investigation showed good palatal and pharyngeal movement at 9;0 years when he was referred to the project. Initial EPG assessment revealed extensive velar contact accompanying all anterior lingual obstruent sounds including / s / but also during bilateral and labio-dental stops and fricatives. Fig 9 shows clear evidence of full velar closure accompanying the / b / in "biscuit". This simultaneous velar closure certainly was consistent with the general tendency to raise the back of the tongue for all anterior obstruent sounds. The interesting fact was that this abnormal velar tongue movement was not detected by an auditory impressionistic analysis, presumably because this velar gesture was released prior to the release of the anterior stop.

EPG therapy focussed on reducing the velar closure component in these anterior obstruent sounds and, after a few clinical sessions, PB was able to monitor his own production of these sounds and produce at will the anterior stop with and without accompanying velar closure. (See Fig 10 for illustrations of some sound productions after therapy).

Therapy was thus successful in inhibiting an abnormal lingual gesture, the raising of the back of the tongue towards the velar region. A noticeable side benefit of the modified gestures was an improvement in nasal emission as the velar contact was inhibited. (For further details of this case see Dent, Gibbon & Hardcastle, 1992).

Future Directions

These case studies illustrate one important advantage of EPG as a clinical tool, the identification of abnormal patterns of contact undetected by an auditory analysis. This has important theoretical consequences. For example, some children diagnosed as phonologically disordered on the basis of absence of audible contrasts may in fact be making consistent sub-phonemic gestures. There is increasing EPG evidence of this (Gibbon, 1990).

The technique is of course limited to data on tongue-palate contact only. It is not possible to track individual parts of the tongue or to determine proximity of the tongue to the palate. Ideally, in order to obtain overall tongue shape and configuration, EPG needs to be used in conjunction with other techniques, eg Electromagnetic transduction (Hoole, Nguyen, Hardcastle and Marchal, 1993) and ultrasound (Stone, Faber, Raphael and Shawker, 1992).

It is also important when interpreting EPG contact patterns, to take into account the actual shape of the subject's palate. A reflex microscope linked to a PC (eg Speculand, Butcher and Stephens, 1988) can be used to obtain XYZ co-ordinates for all palatal electrodes and contact patterns can be displayed with reference to actual palatal dimensions (Hardcastle, Gibbon, Dent and Nixon, 1991). In this way it will be possible to determine the ways in which palatal anatomy can influence tongue-palate contact patterns.

As a therapeutic tool in the treatment of specific types of speech abnormalities such as those described in this paper, EPG has been shown to be an efficient adjunct to conventional methods.

Acknowledgement

The work described in this paper was supported by the British Medical Research Council (Project grant number G8912970N).

References

Dent, H., Gibbon, F. and Hardcastle, W. (1992). Inhibiting an abnormal lingual pattern in a cleft palate child using Electropalatography (EPG). In M. Leahy and J. Kallen (eds) *Interdisciplinary Perspectives in Speech and Language Pathology* (pp 211-221). Trinity College, Dublin: School of Clinical Speech and Language Studies

Fletcher, S. G., Dagenais, P. A. and Critz-Crosby, P. (1991). Teaching consonants to profoundly hearing-impaired speakers using palatometry. *Journal of Speech & Hearing Research* 34, 929-942

Fletcher, S. G., McCutcheon, M. J. and Wolf, M. B. (1975). Dynamic palatometry. *Journal of Speech and Hearing Research* 18, 812-819.

Fujimura, O., Tatsumi, I.F. and Kagaya, R. (1973). Computational processing of palatographic patterns. *Journal of Phonetics* 1, 47-54.

Gibbon, F. (1990) Lingual activity in two speech-disordered children's attempts to produce velar and alveolar stop consonants: evidence from electropalatographic (EPG) data. *British Journal Disorders of Communication*, 25, 329-340.

Gibbon, F. and Hardcastle, W. (1989). Deviant articulation in a cleft palate child following late repair of the hard palate: a description and remediation procedure using electropalatography. *Clinical Linguistics and Phonetics* 3, 93-110.

Gibbon, F., Dent, H. and Hardcastle, W., (1993) Diagnosis and therapy of abnormal alveolar stops in a speech disordered child using EPG. *Clinical Linguistics and Phonetics.* 7, 247-268.

Hardcastle, W. J., Gibbon, F. E. and Jones, W. (1991). Visual display of tongue-palate contact: Electropalatography in the assessment and remediation of speech disorders. *British Journal of Disorders of Communication*, 26, 41-74.

Hardcastle, W J., Dent, H. and Gibbon, F. (1992). Diagnostic therapy: a case study using Electropalatography (EPG). In E. Loebell (ed) *Proceedings 22nd World Congress of the International Association of Logopedics and Phoniatrics*, Hanover, Germany.

Hoole, P., Nguyen, N., Hardcastle, W. and Marchal, A. (1993). Reduction and parametrization of EPG and EMA data for the investigation of articulatory/acoustic correlations. *Language and Speech* (in press).

Michi, K., Yamashita, Y., Imai, S., Suzuki, N. and Yoshida, H. (1993).Role of visual feedback treatment for defective / s / sounds in patients with cleft palate. *Journal of Speech and Hearing Research* 36, 277-285.

Nicolaidis, K., Hardcastle, W., and Gibbon, F. (1993). Bibliography of electropalatographic studies in English (1957-1992) Part I: Full list of references. *Speech Research Laboratory, University of Reading, Work in Progress*, 7, 28-43.

Speculand, B., Butcher, G., and Stephens, C. (1988). Three-dimensional measurement: The accuracy and precision of the Relex Microscope *British Journal Oral and Maxillofacial Surgery* 26, 276-283.

Stone, M., Faber, A., Raphael, L.J. and Shawker, T. H. (1992). Cross-sectional tongue shape and linguopalatal contact patterns in [s], [ʃ], and [l]. *Journal of Phonetics* 20, 253-270.

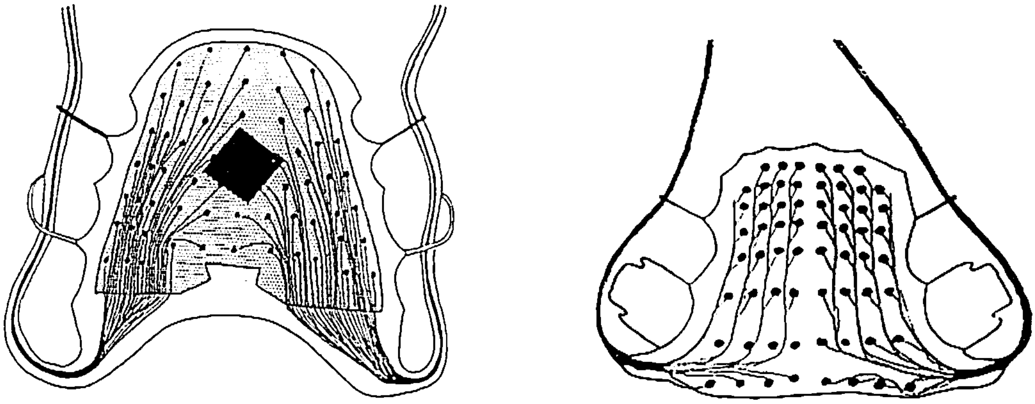

Fig 1. Illustrations showing the placement of electrodes in the Reading EPG 3 system (right) and the Rion system (left).

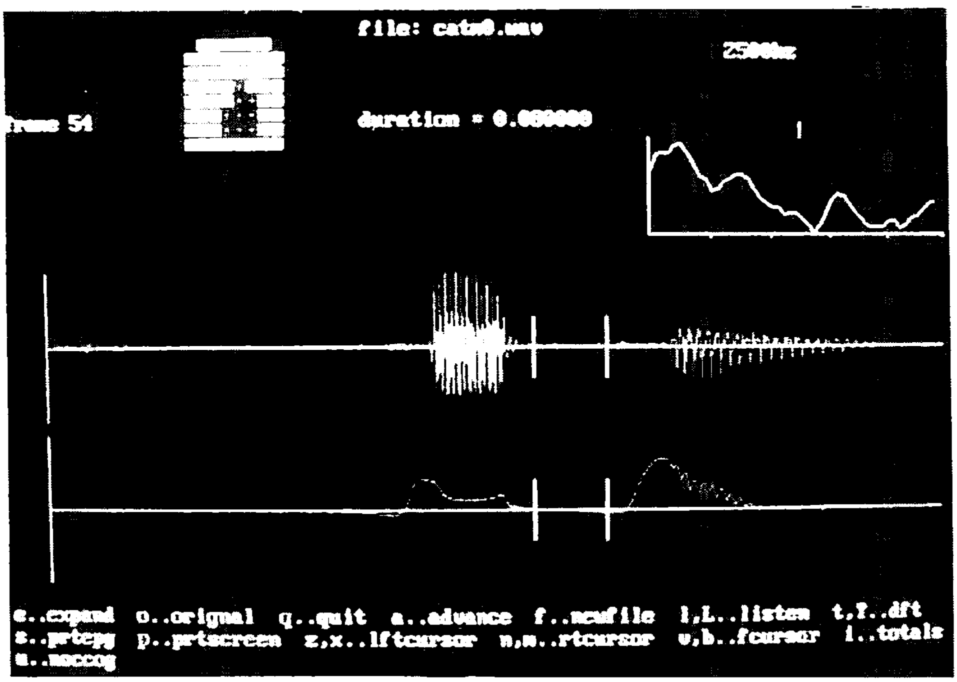

Fig 2. EPG 3 screen display of the word "catkin" showing acoustic wave form, oral air-flow (bottom trace) EPG contact pattern at left hand cursor, and DFT analysis at position of right-hand cursor (upper right).

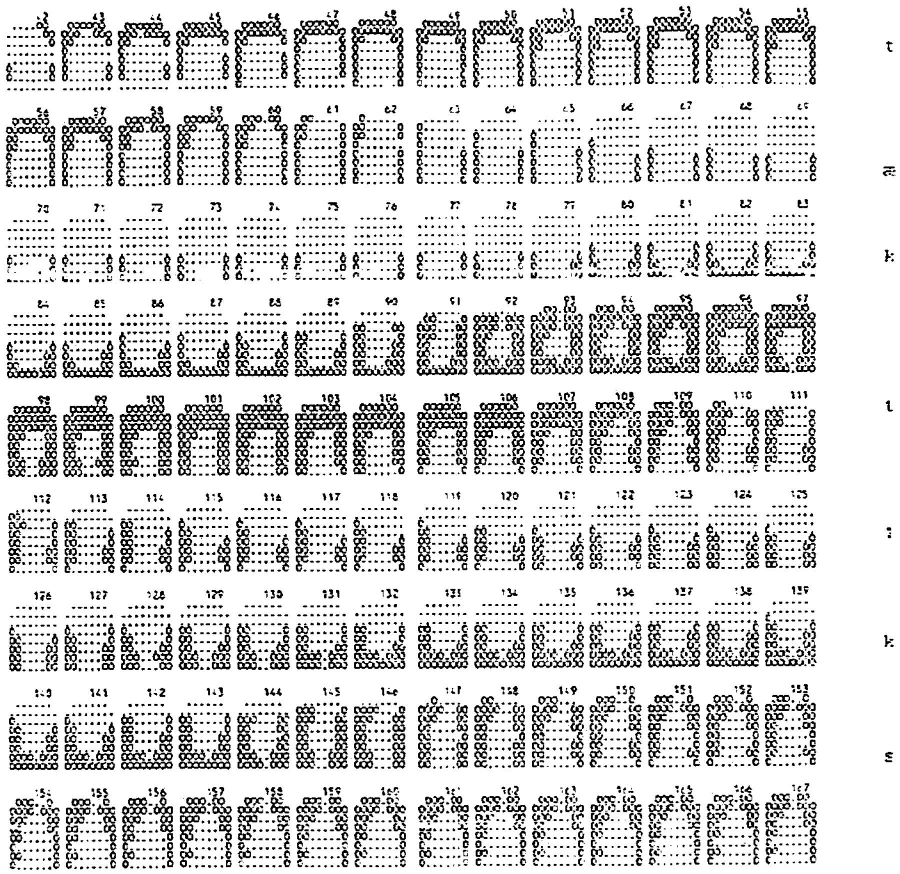

Fig 3. Full EPG print-out for the word "tactics". Contacts are shown by zeros and the sampling interval between succesive palatal frames in 10 ms.

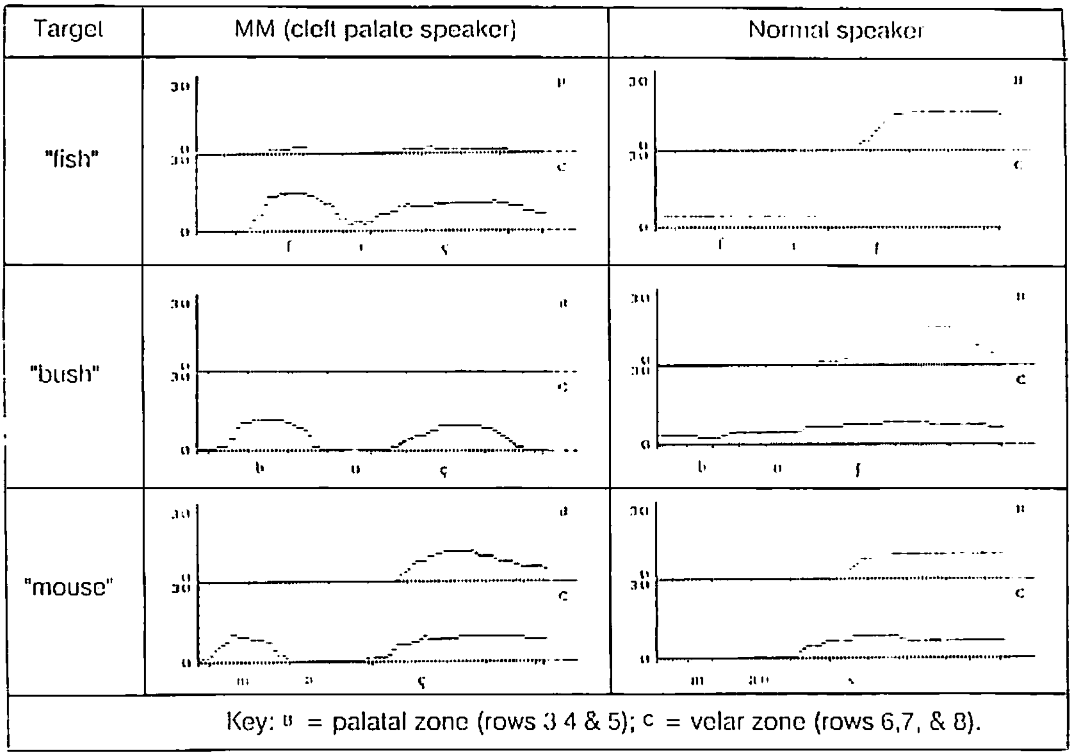

Fig 4. Graphs showing differences between the area of tongue-palate contact (expressed as total number of activated electrodes, vertical axes) in two different regions of the palate for a normal and cleft palate child.

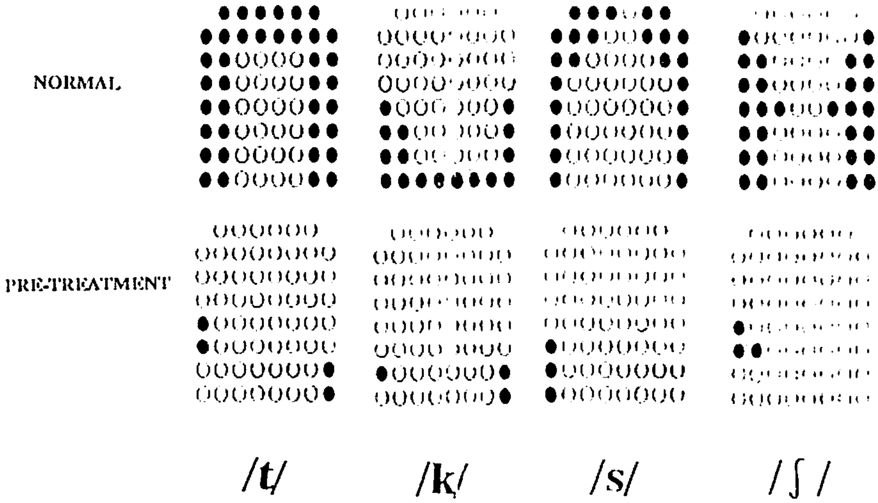

Fig 5. EPG patterns at the point of maximum constriction for a number of obstruent sounds spoken by a normal speaker (above) and TG (below)

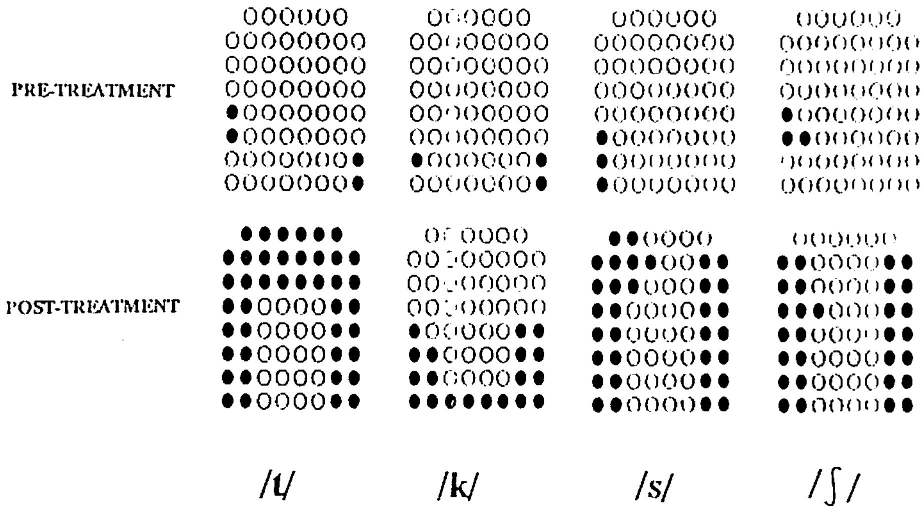

Fig 6. EPG patterns for TG pre- and post-therapy.

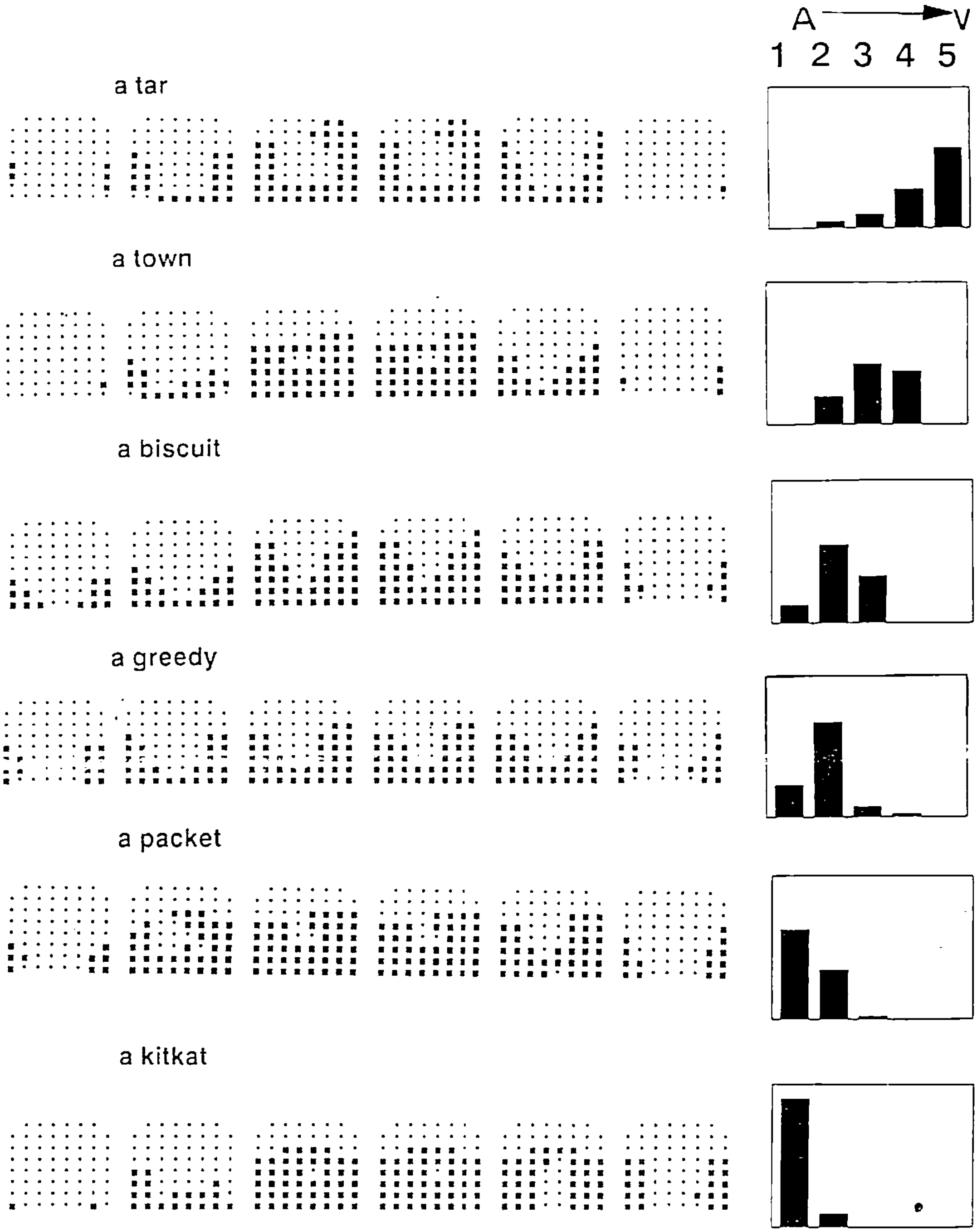

Fig 7. EPG patterns at six different points during production of target alveolar stops in a number of words spoken by EJ before therapy. Histograms of listeners responses from alveolar to velar stops are shown on the right. (For description of the six annotations points used in the EPG print-outs see Gibbon Dent and Hardcastle, 1993).

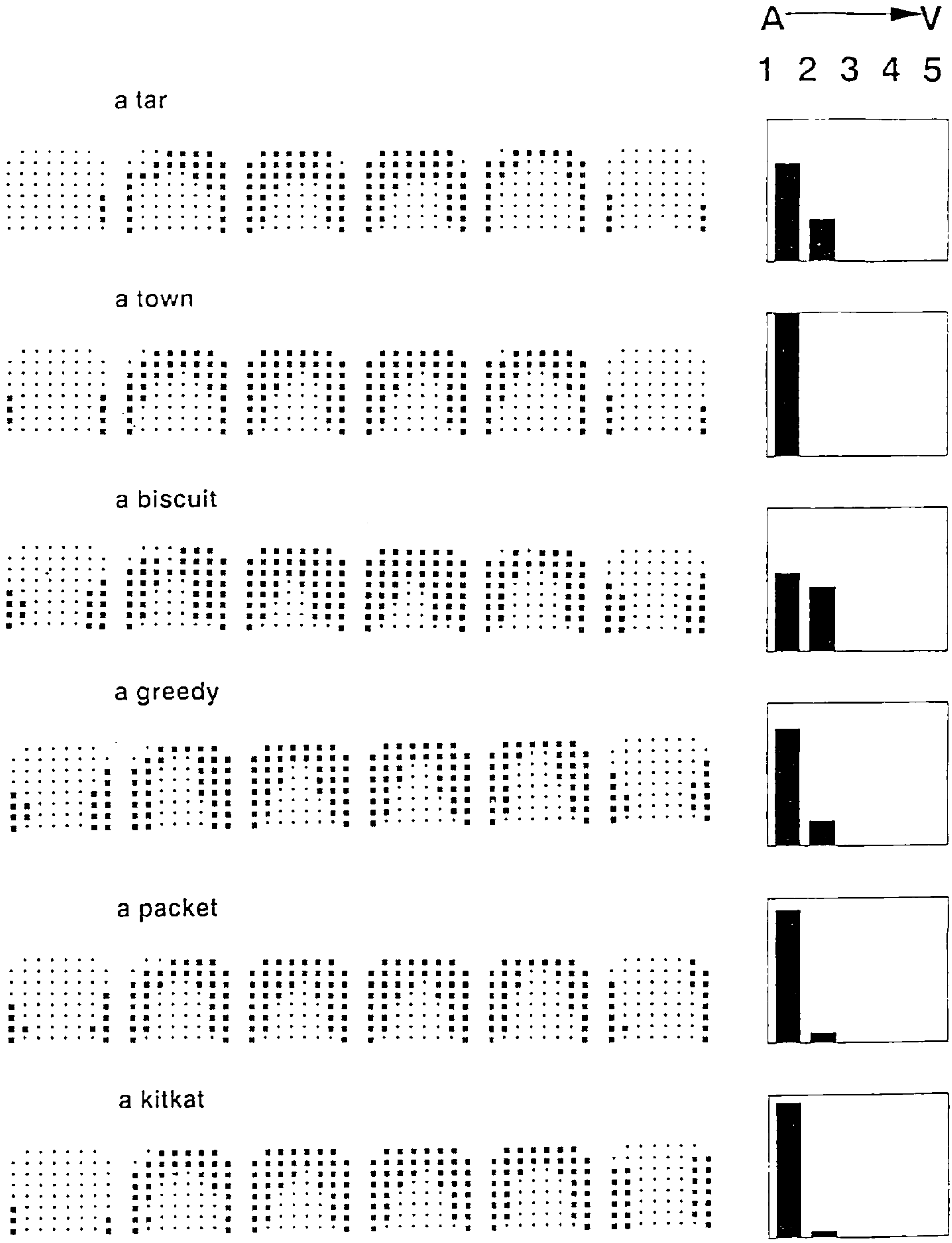

Fig 8. EPG patterns for a number of words spoken by EJ after therapy. Listeners responses from alveolar to velar are shown as histograms on the right.

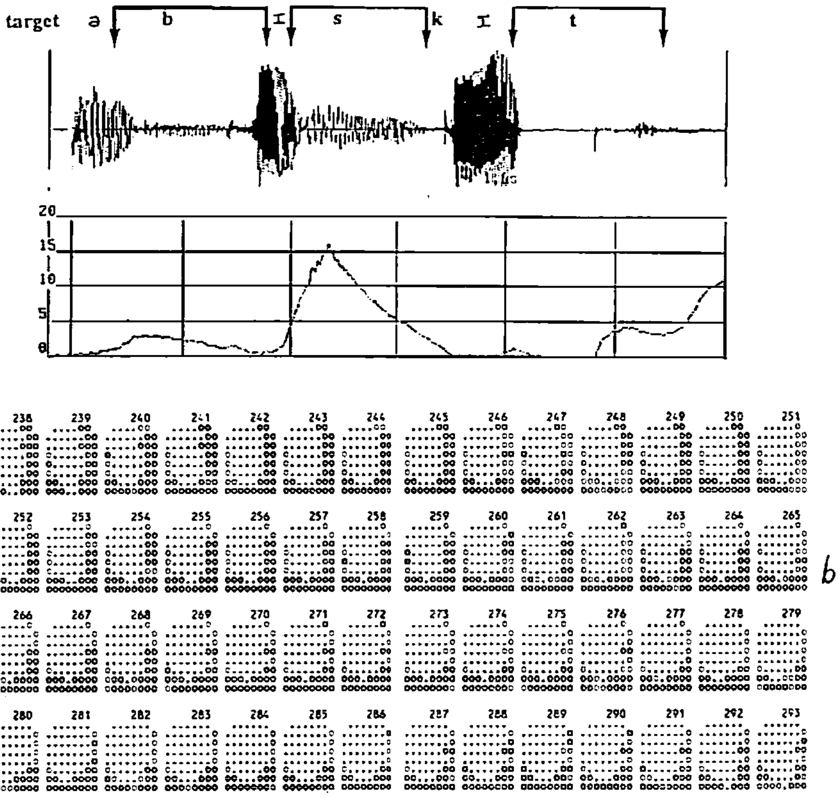

Fig 9. Full EPG print-out of /b/ in the utterance"a biscuit" showing complete velar closure. The lower trace in the screen display is nasal air-flow.

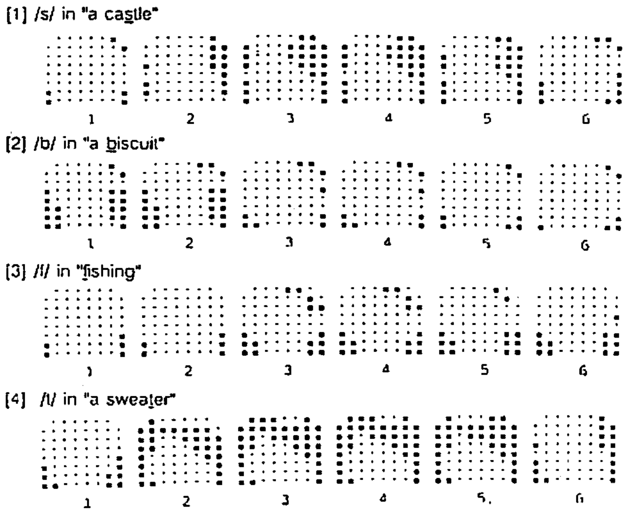

Fig 10. EPG patterns for PB at six different reference points during production of four words after therapy.