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A Computer-Assisted Method for Semi-Quantitative Assessment of Salivary Gland Diseases

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Abstract. The authors report on a computer-assisted method that allows a semi-quantitative assessment of salivary gland function under normal and pathologic conditions. They illustrate some mathematical procedures suitable for this purpose and the results achieved in various salivary gland diseases.

Introduction

Radioisotope methods are regarded at present as an indispensable diagnostic tool in various fields of Ear, Nose and Throat pathology, including salivary glands [1–4, 10–15, 17].

In some previous studies [5–9] we reported the results of radioisotopic and thermographic research on salivary gland diseases. The aim of this paper is to illustrate the possibility of a semi-quantitative assessment of these results.

Material and Methods

Our technique, previously [5–9] reported in detail, is here summarized: after 2 mCi $^{99m}TcO_4$ i.v., sequential scintiphotos were taken by a 29 × 1.3 cm Anger scintillation camera with a pin-hole collimator and an exposure time of 2 min, at 5, 10, 20, 25 and 40 min respectively. Simultaneously the data were collected on magnetic tape in 2 min frames from 0 to 44 min; after 0.25 mg carbaminoylcholine chloride s.c. at the 22nd min, a rapid and intense sialorrhea followed.

The stored data were recalled from the magnetic tape and displayed; four regions of interest (R.O.I.) were then selected, corresponding to the major salivary glands (Fig. 1). For each R.O.I. the computer (Laben 70) displayed a counts/time curve that we called "functional" (Fig. 2).

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Mathematical elaboration of the curves obtained in some of the subjects previously [7] examined was then performed.

Results

Parotid and submandibular curves under normal conditions are shown in Fig. 2. After an initial steep rise of radioactivity in the first 4–6 min (gland perfusion) the concentration of $^{99m}TcO_4$ steadily increases until the 12th-22nd min as reported by many Authors [2, 3, 10, 13, 15, 17] and confirmed by our experience in 12 patients with no salivary pathology undergoing radioisotope examination for 90 min without carbaminoylcholine stimulus. At 2–4 minutes after carbaminoylcholine a rapid and intense sialorrhea follows.

We first considered *T*max, i.e. the "peak-time" of the curve that under normal conditions ranged from the 12th up to 16th min for submandibular glands and from the 16th up to the 22nd min for parotid glands.

Furthermore we evaluated the slope of the segment of the curve ranging from the 2nd-4th min up to *T*max, i.e. the rate of accumulation of activity in the stated time interval. To this purpose we feel it worthwhile to use the power function reported by Rosenthal and Kaye [16] for ^{99m}Tc-Pyrophosphate kinetics:

$$C = Kt^m$$

where C is the counts, K a constant, t the time in minutes and m the slope of the logC versus logt plot. Fitting this curve to the considered segment of the functional curve, the correlation coefficient always exceeded 0.97.

It was more difficult to find a suitable mathematical parameter for a satisfactory semi-quantitative assessment of the descending segment since it represents a complex curve that cannot be reduced to a simple

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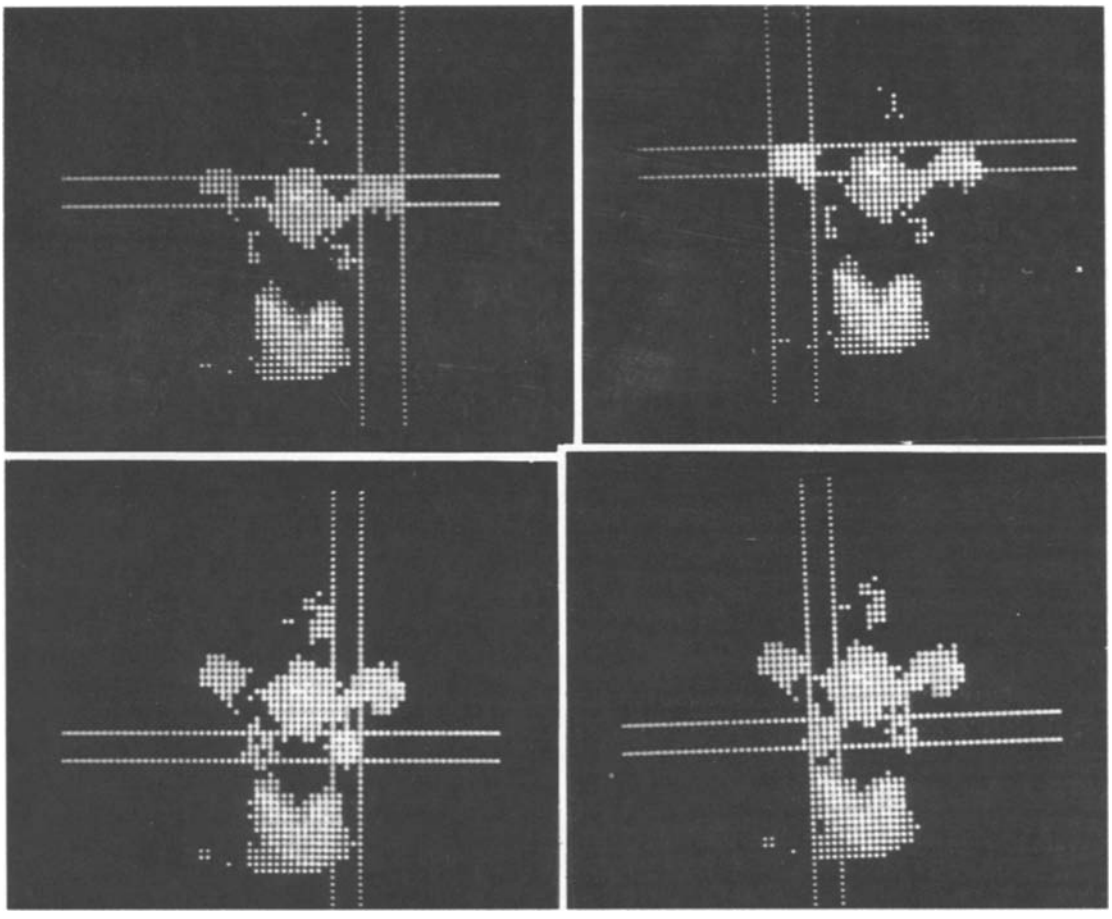

Fig. 1. Regions of interest selected by the computer for each major salivary gland

exponential function. We assumed that a practical index of $^{99m}TcO_4$ excretion rate would be the $t^1/_2$ obtained by graphic interpolation of the points from 2 up to 10 min after the "peak" of the functional curve.

Laben 70 computer in "off-line" mode was able to give us all the mathematical results using a suitable program in Basic language: an example is shown in Fig. 4.

The results obtained in 32 normal subjects are reported in Table 1. Mean values of accumulation and excretion parameters showed a close symmetry between right and left side for parotid and submandibular glands as well, as reported in the previous studies [5–9] and shown by Fig. 3.

As far as pathologic conditions are concerned (Table 2) the usefulness of radioisotope methods in facial paralysis "a frigore" was clearly shown in our previous studies [5–7], the difference between the affected and the normal submandibular curve being an important criterion for deciding on surgical management. Three out of fourteen patients showed in the affected side a *T*max that was prolonged by more than 20% as well as a decreased slope on the accumulation curve. Moreover the excretory $t^1/_2$ was between 45% and 73% higher than in the contralateral gland. These subjects underwent surgical operation with good results, while in the remainder of the cases with side asymmetry of mathematical parameters of less than 20% or no variation, the drug therapy was preferred (Table 3).

Chronic inflammation of salivary glands is characterized by a slower $^{99m}TcO_4$ uptake: *m* is 39% lower than the normal value with a decreased excretion as well.

In acute inflammation the excretion is markedly slowed but on the contrary $^{99m}TcO_4$ accumulation in the involved gland is 28% higher than in the normal one.

Obstructive disorders (i.e. calculi and duct stenosis) "flattened" the excretory segment and thus $t^1/_2$ was so prolonged that it was undeterminable in most

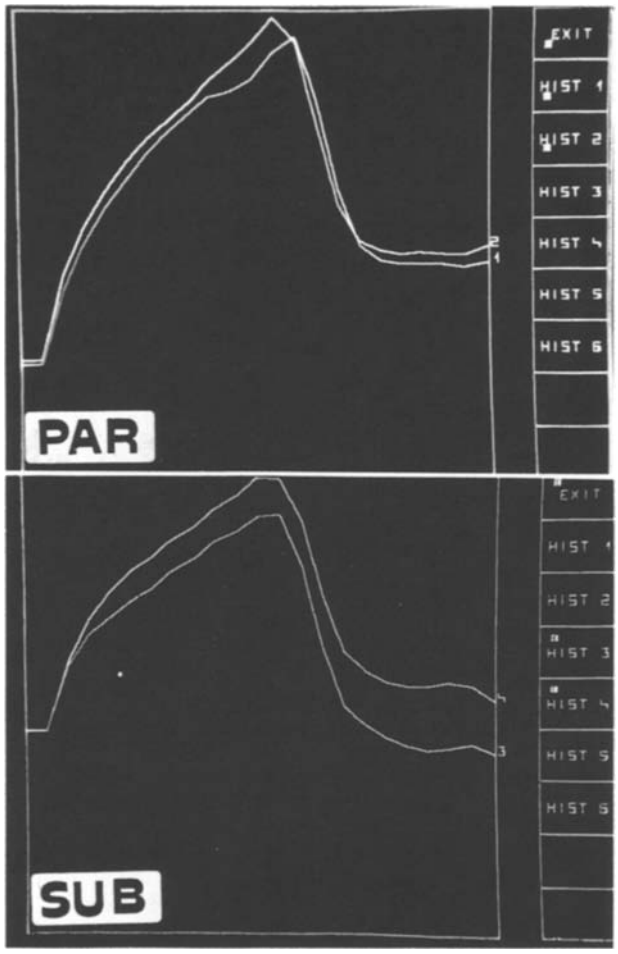

Fig. 2. Functional curves of parotid and submandibular glands under normal conditions

Table 1. Normal Subjects

	Mean ± SD	Mean ± SD
*T*max	19 ± 3	14 ± 2
m[a]	37.5 ± 5	32.6 ± 5
$t^1/_2$	8.5 ± 2.7	12 ± 2
	Parotid glands	Submandibular glands

[a] For practical purposes the values printed out by the computer were multiplied by 100 before calculating mean and standard deviation

cases. Accumulation rate was decreased as much as 37% and *T*max very prolonged.

Mathematical parameters in Sjogren's syndrome clearly "reflected" scintigraphic and functional patterns, all being markedly altered.

Finally no significant change was found in systemic diseases.

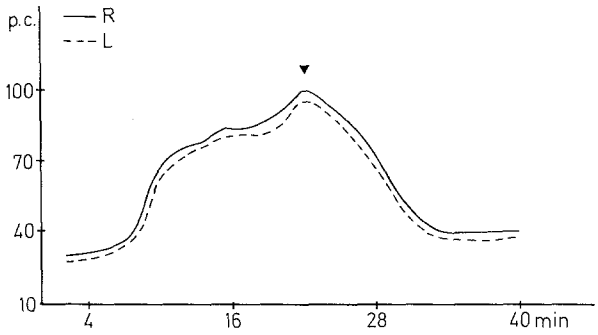

Fig. 3. Parotid curves are graphically represented as the percentage of the maximum radioactivity reached within the *T*max

Discussion

Semi-quantitative measurement of functional curves substantially confirms what we reported in the previous studies and at the same time gives some additional useful data.

In this connection let us take into account Table 1.

The range of normality is narrow enough to allow an exact differentiation between normal and pathologic cases. This is clearly confirmed from the values of *P* which were always >0.001.

In chronic inflammation both *T*max and *m* values support the hypotesis of a prevalent involvement of the accumulation segment. In sub-acute and especially acute diseases on the other hand, hyperemia is the cause of a shortened *T*max with a steeper slope of the curve. In both cases $t^1/_2$ of the descending segment is more or less prolonged in connection with the degree of duct involvement, i.e. according to the higher or lower resistance to the transit of saliva flow towards the mouth. Once this situation reaches the "acme" such as in the occlusion of the duct either by a large calculus or by a stone plus stenosis, $t^1/_2$ becomes undeterminable because of the "flatness" of the descending segment.

The value of radioisotope method instead of Blatt's test – i.e. the separate catheterisation of Wharton's ducts, as described by Bernard et al. [3] – in order to decide on surgical management in facial paralysis is more and more confirmed by mathematical parameters that also allow for a higher diagnostic accuracy. *P* values in Table 2 are obviously insignificant for the submandibular glands too, since only 3 out of 14 patients showed appreciable changes of the parameters.

Finally it is easy to realize the usefulness of semi-quantitative measurements to follow-up the effects of surgery, drugs or radiotherapy.

Table 2. Abnormal subjects

	*T*max				*m*[a]				$t^1/_2$				Number of subjects
	Parotid glands		Submandibular glands		Parotid glands		Submandibular glands		Parotid glands		Submandibular glands		
	Mean ±SD	*P*	Mean ±SD	*P*	Mean ±SD	*P*	Mean ±SD	*P*	Mean ±SD	*P*	Mean ±SD	*P*	
Chronic inflammation	22 ±2.2	<0.001	18 ±3.7	<0.001	22.8 ±9.5	<0.001	19.9 ±9	<0.001	13.8 ±5.8	<0.001	19.6 ±9.9	<0.001	37
Acute or sub-acute inflammation	16 ±1.9	<0.001	10 ±4	<0.001	48 ±11	<0.001	41.7 ±9.5	<0.001	22.1 ±9.6	<0.001	31.2 ±12	<0.001	18
Facial paralysis	18.9 ±1.3	n.s.	15 ±3.5	n.s.	37 ±2	n.s.	31.7 ±1.5	n.s.	8 ±1.7	n.s.	11.2 ±1	n.s.	14
Calculi	39.1 ±14	<0.001	29.9 ±13	<0.001	23.6 ±10	<0.001	20.5 ±8.8	<0.001	n.d.	–	n.d.	–	6
Systemic diseases	18.8 ±2	n.s.	13.7 ±1	n.s.	37.6 ±1.9	n.s.	32.4 ±1.4	n.s.	8.2 ±1.4	n.s.	11.8 ±1.8	n.s.	6
Sjögren's syndrome	11 ±4.8	<0.001	21 ±5.3	<0.001	0.12 ±0.2	<0.001	0.14 ±0.4	<0.001	57.5 ±0.5	<0.001	75 ±0.7	<0.001	3

[a] As in Table 1

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QUANTI PUNTI?
?11
DAI X,Y
?2,476
?4,599
?6,691
?8,763
?10,829
?12,886
?14,934
?16,982
?18,996
?20,1026
?22,1097
K 374.165466 M .343768 R2 .998574 R .999286

M    E.S.    D
2 21.817420 1.158874
4 24.474475 3.605346
6 26.286876 1.736206
8 27.622451 1.747314
10 28.792358 3.280395
12 29.765750 6.870849
14 30.561412 7.027587
16 31.336875 11.484008
18 31.559467 14.618652
20 32.031234 21.893798
22 33.120986 14.203857
ESCR.:DAI 5 COPPIE
?26,983
?28,747
?30,590
?32,558
?34,548
K ESC. -.073007 T1/2 -9.492111

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Fig. 4. Printout of the computer with mathematical elaboration of a parotid curve showing from up-side to down-side: the inputs (minutes and respective integral values of the selected area) for accumulation curves in 2 min frames; the values of: accumulation constant (*K*), m (*M*), determination coefficient (*R2*), correlation coefficient (*R*), standard error (*ES*), difference between experimental and calculated curve (*D*); inputs (same parameters as for accumulation) for excretion curve in 2 min frames; excretion constant (*K ESC*); excretion $t^1/_2$ ($T^1/_2$)

Table 3. Variation of quantitative parameters of involved submandibular gland in facial paralysis

	No variation	Up to 20%	21–40%	41–60%	>60%
*T*max	6 cases	↑ 5 cases	↑ 1 case	↑ 1 case	↑ 1 case
m	6 cases	↓ 5 cases	↓ 1 case	↓ 1 case	↓ 1 case
$t^1/_2$	4 cases	↑ 7 cases		↑ 2 cases	↑ 1 case
	Drug therapy			Surgery	

↑ = Increased value; ↓ = Decreased value

In our opinion the introduction of mathematical methods in order to semi-quantitatively assess the "functional" curves is a real "step forward" in the diagnosis of salivary gland diseases, taking into account the possibility of extending this method to other fields of radioisotope studies following the example of Rosenthal and Kaye [16].

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