CEREBRAL BLOOD FLOW AND METABOLISM EVALUATION IN COMATOSE PATIENTS BY DYNAMIC SPECT

Alessandro Giordano, Maria Lucia Calcagni, Francesco Della Corte* ,
Mariano Alberto Pennisi* , Guido Galli

*(Institute of Nuclear Medicine and * Institute of Anaesthesiology and Intensive Care of the Catholic University of the Sacred Heart, Roma, Italy)*

Wang Fengqin (王凤琴) and Zhao Huiyang (赵惠杨)

(Zhongshan Hospital, Shanghai Medical University, Shanghai 200032, China)

(Received April 1992)

ABSTRACT

Thirty patients in coma state underwent dynamic SPECT with ^{133}Xe, a validated technique for the quantitation of CBF by SPECT, using a new brain dedicated tomograph: CERTO-96. $CMRO_2$ was computed by multiplying the mean CBF by $AVDO_2$ according to the Fick's principle. The mean values of CBF, $AVDO_2$ and $CMRO_2$ in patients with good outcome were significantly different from those with worse outcome. On the basis of the best "discriminant threshold", CBF and $AVDO_2$ demonstrated an intermediate accuracy in separating the two groups, while $CMRO_2$ showed a satisfactory accuracy.

Keywords: Dynamic SPECT Cerebral blood flow Cerebral metabolic rate of oxygen Comatose patients

1 INTRODUCTION

The prediction of outcome is an important significance for the management of coma patients in Intensive Care Units. The computation of cerebral blood flow (CBF) and of cerebral metabolic rate of oxygen ($CMRO_2$) as well as the imaging of their regional distribution is supposed to be useful in risk stratification and in monitoring the effects of therapy; however the data published in the literature on this topic are few and often contradictory.[1,6-10] An additional problem is the lack of standardization of techniques and instrumentations.

We are currently employing brain dynamic SPECT (DSPECT) with ^{133}Xe to obtain tridimentional mappings of regional CBF in a quantitative format; the device used is CERTO-96, a new brain dedicated tomograph[3]. The aim of this paper is to study whether CBF and $CMRO_2$ are of value in predicting the outcome of patients in coma state.

2 MATERIAL AND METHODS

Thirty comatose patients (19 men, 11 women, aged 48± 13 y) admitted in the General Intensive Care Unit of Catholic University of Roma were studied, 14 due to head trauma (postraumatic coma), 7 due to a cardiac arrest (postanoxic coma), and 9 due to cerebrovascular diseases. All patients were treated with traditional therapy (mechanical ventilation aimed to maintain a over 13.3 kPa for O_2 and 4.0—4.7 kPa for CO_2, moderate hypertension, parenteral nutrition, control of seizures with low-dose barbiturates, moderate dehydration).

In all patients the bulb of the right internal jugular vein was cannulated to measure the arteriovenous difference of oxygen. ($AVDO_2$ = Arterial oxygen content-Jugular oxygen content; Oxygen content $= 1.24 \times Hb \times Sat$ in $O_2 + 0.0031 \times p_{O_2}$). This value was then correlated with DSPECT determination of mean CBF to obtain $CMRO_2$ based on Fick equation ($CMRO_2 = CBF \times AVDO_2$). All patients underwent mean CBF determination by DSPECT using CERTO-96[3].

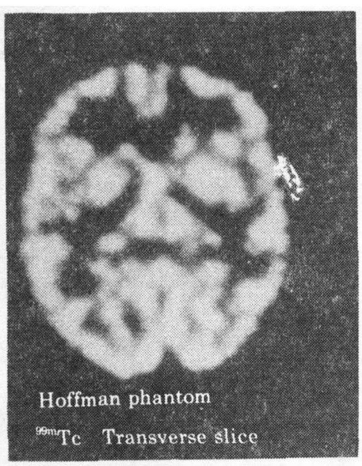

Fig.1 Reconstructed transverse slice of an Hoffmann phantom filled with ^{99m}Tc pertechnetate using CERTO—96 with high resolution collimators

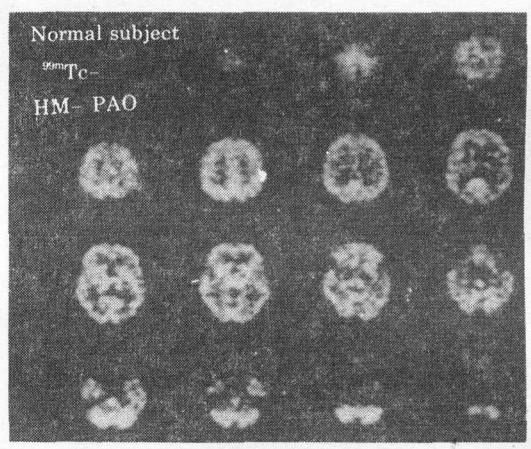

Fig.2 16 transverse slices of a normal subject studied with ^{99m}Tc—HM—PAO using CERTO—96 with high resolution collimators

Certo-96 (S.E.L.O, Italy) is a new cerebral tomograph capable of performing two SPECT approaches to CBF evaluation: high resolution qualitative SPECT with ^{99m}Tc labelled tracers and low resolution quantitative SPECT with ^{133}Xe. The device consists of 4 small field-of-view gamma-cameras assembled in a circular gantry rapidly rotating around patient's head. The use of high resolution collimators permits the performance of high quality SPECT in 15—30 min after injecting 370—740 MBq of ^{99m}Tc-HM-PAO. In such configuration the achieved maximal tomographic resolution

FWHM is 8 mm.

Fig.1 shows a transverse slice of an Hoffman phantom filled with ^{99m}Tc pertechnetate. Fig.2 shows a set of transverse slices of a normal subject using ^{99m}Tc–HM–PAO, and high image quality is obtained.

A quantitative assessment of CBF in ml/(100g · min) can be performed by CERTO 96, using ^{133}Xe inhalation technique and a DSPECT acquisition (4 consecutive SPECT lasting 1 min each) with high sensitivity collimators[3,4]. For the first time it is possible to obtain a tridimensional quantitative CBF mapping in up to 28 transverse, coronal and sagittal slices with a SPECT technique.

In this study all patients underwent ^{133}Xe DSPECT. The dose for each patient was 3700 MBq diluted in 10 L of air. Inhalation was performed by a properly adapted mechanical ventilator (Angstrom 300).

A semiautomatic program computed the mean flow of the whole brain (mCBF), utilized for determination of $CMRO_2$. The significance of the differences among the mean values of mCBF, $AVDO_2$ and $CMRO_2$ was computed using the Mann–Whitney *U*–test.

3 RESULTS

The results of mCBF, $AVDO_2$ and $CMRO_2$ for all patients as well as the clinical

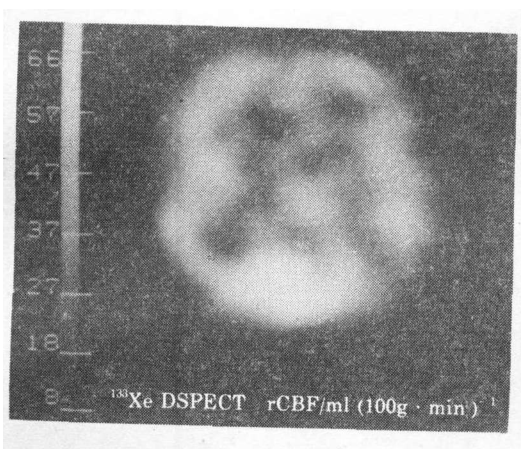

Fig.3 Representative transverse slice of a ^{133}Xe DSPECT study in a patient with postanoxic coma (pt. n.30)

The regional CBF distribution is rather homogeneous and mean CBF is normal: 34.5 ml/(100g · min). The patient survived and is now in good health.

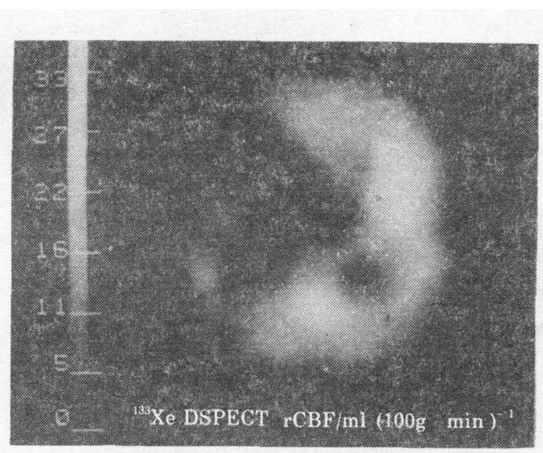

Fig.4 Representative transverse slice of a ^{133}Xe DSPECT study in a patients with post—traumatic coma (pt. n.3)

The regional CBF distribution is severely impaired in the right temporo–parietal cortex and the mean CBF is very low: 18.7ml/(100g · min). The patient died 2 weeks after the examination

outcome expressed by the GOS index[4] are tabulated in Table 1. The mean values of mCBF, $AVDO_2$ and $CMRO_2$ in patients with severe outcome (GOS 1—2) were 28.8± 13.6, 3.1±1.2, 0.92±0.52 expressed in ml/(100g · min), respectively. In patients with a more satisfactory outcome (GOS 3—5) the mean values of mCBF, $AVDO_2$ and $CMRO_2$ were 42.8± 7.1, 4.6± 1.4, 1.98± 0.79, respectively. The differences among the mean values of each parameter were statistically significant: mCBF = $P<0.01$; $AVDO_2 = P<0.05$; $CMRO_2 = P<0.001$.

Table 1

Results obtained in 30 patients in coma

Patient	Coma type	mCBF/ ml · (100 g · min)$^{-1}$	$AVDO_2$/ ml · (100 g)$^{-1}$	$CMRO_2$/ ml · (100 g)$^{-1}$	GOS
1–FE	PT	34.2	2.7	0.92	1
2–CI	PT	60	3.1	1.82	1
3–SE	PT	18.7	2.3	0.43	1
4–BE	PT	32.9	1.9	0.62	1
5–PR	PT	39.2	2.9	1.13	1
6–DE	PT	25	5.4	1.35	1
7–MA	PT	43.4	3.9	1.69	1
8–PA	PT	52.9	2.6	1.37	3
9–IA	PT	38.4	4.9	1.88	3
10–TA	PT	31.2	2.5	0.78	3
11–MA	PT	3.54	4.0	1.41	3
12–DEL	PT	49	6.2	3.03	4
13–CO	PT	40.7	4.1	1.66	4
14–LI	PT	44.7	3.9	1.74	5
15–MI	PA	0	1.8	0	1
16–AM	PA	21.7	2.2	0.48	2
17–ME	PA	15.5	2.8	0.43	2
18–MEL	PA	18.1	2.9	0.52	2
19–VA	PA	31.6	3.6	1.13	2
20–PO	PA	46.1	3.5	1.61	3
21–MAR	PA	49.6	6.3	3.21	5
22–RI	CV	28.6	4.6	1.31	1
23–PE	CV	33.9	2.8	0.94	1
24–SE	CV	43	4.6	1.55	1
25–RO	CV	28.6	4.7	1.34	1
26–SH	CV	9.3	1.5	0.14	1
27–LE	CV	25.6	4.4	1.12	1
28–OR	CV	38.4	1.4	0.53	2
29–MO	CV	47.9	6.4	3.06	4
30–AM	CV	34.5	5.8	2.00	5

Legend: PT = Post–traumatic coma PA = Post–anoxic coma CV = Cerebrovascular coma
GOS (Glasgow outcome scale): 1 = death 2 = apallic coma 3 = survival with severe symptoms
4 = survival with mild symptoms 5 = healing

The "discriminant threshold" allowing to optimally distinguish patients with severe outcome (GOS 1–2) from patients with rather good outcome (GOS 3–5) have been computed to be as following: mCBF = 38.17; $AVDO_2$ = 3.77; $CMRO_2$ = 1.36.

The data of patient No.15 who was in brain death (mCBF = 0) were excluded from computations of the discriminant threshold.

On the basis of such values the sensitivity and specificity of mCBF and of $AVDO_2$ in predicting the outcome in single patient (GOS 1— 2 vs. 3— 5) is only moderate: sensitivity = 72.5 %, specificity = 72.5 %; conversely a satisfactory sensitivity and specificity were obtained with $CMRO_2$: sensitivity = 91 %; specificity = 83.3 %.

Fig.3 and 4 show two representative transverse slices obtained by DSPECT in a comatose patient with a normal flow pattern (pt n.30) and in a comatose patient with an extended defect due to a temporo–parietal hematoma (pt n.3).

4 DISCUSSION AND CONCLUSION

At present brain SPECT can be performed by rotating gamma–cameras and by dedicated tomographs. Both systems have some limitations: rotating gamma–cameras are not suitable for dynamic SPECT which is presently the only validated SPECT technique capable of quantitating CBF; on the other hand brain dedicated tomographs are capable of performing DSPECT but can only generate one or few transverse slices due to design constraints; therefore small lesions may be missed and coronal/sagittal/oblique slices can not be obtained. Moreover no re–orientation on the orbito–meatal line can be performed in case of non perpendicular head position (frequent in neurological patients). The new brain dedicated tomograph CERTO–96, presently used in our institute, is designed to perform both ^{99m}Tc–HM–PAO SPECT and ^{133}Xe DSPECT for detecting the full brain volume by means of 28 contiguous slices.

Comatose patients are seldom studied in nuclear medicine departments mainly due to logistic difficulties in moving such patients from the ward and in performing scintigraphic procedures while the patient is mechanically ventilated. The use of a dedicated tomograph, like CERTO–96, is of great help in performing the SPECT studies. The ^{133}Xe DSPECT procedure lasts only 4 min; adding the time required for preparing the examination and for a complete washout of the residual gas from the patient, a CBF study requires less than 30 min.

The evaluation of prognosis represents a major clue in the treatment of comatose patients. Electrophysiological, metabolic and clinical evaluation, by themselves, may only partly define outcome.

On the basis of our results the computation of CBF, $AVDO_2$ and $CMRO_2$ should be of value in distinguishing patients with a severe outcome (GOS 1— 2) from patients with a rather good one (GOS 3— 5): in fact we obtained a statistically significant difference between the mean values of each parameter in the two groups (mCBF $= P < 0.01$, $AVDO_2 = P < 0.05$, $CMRO_2 = P < 0.001$). Nevertheless the computation of the best "discriminant threshold" for each parameter showed that CBF and $AVDO_2$ cannot predict the outcome of comatose patients with sufficient accuracy; conversely $CMRO_2$, having 91.2 % sensitivity and 83.3 % specificity, is demonstrated to be a useful prognostic index.

From our results it can be concluded that the quantitation of CBF by ^{133}Xe DSPECT should be suggested when the outcome of a comatose patient is to be determined; the procedure employed by our group using CERTO–96 brain dedicated tomograph, is rather easy to be accomplished and cost–effective compared to the more complex techniques requiring positron emitting tracers.

REFERENCES

[1]Abdel Dayem H, Sadek S A, Kouris K *et al.* Radiology, 1987, 165:221.
[2] Celsis P, Goldman T, Henrikens L *et al.* J Comput Assist Tomogr, 1981, 5:641.
[3] Giordano A, Calcagni M L, Di Fazio P *et al.* Eur J Nucl Med, 1991, 18:524.
[4] Jennet B, Bond M. Lancet, 1975, 1:480.
[5] Kanno I, Lassen N A. J Comput Assist Tomogr, 1979, 3:71.
[6] Obrist W D, Langfitt T W, Jaggi J L *et al.* J Neurosurg, 1984, 61:241.
[7] Order W, Goldenberg G, Podreka I *et al.* Intensive Care Med, 1991, 17:149.
[8] Overgaard J, Tweed W A. J Neurosurg, 1974, 41:500.
[9] Reid R, Gulenchyn K Y, Ballinger J R *et al.* Clin Nucl Med, 1990, 15:383.
[10] Uzell B P, Obrist W D, Dolinskas C A *et al.* J Neurosurg, 1985, 65:630.
