Changes in Regional Cerebral Blood Flow During Brain Maturation in Children and Adolescents

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Regional cerebral blood flow (rCBF) was studied by SPECT using ^{133}Xe in 42 children, aged 2 days to 19 years, considered as neurologically normal. rCBF was measured on cortical regions and on the cerebellum and thalamus. Curves for reference values and standard deviation were defined for each region. At birth, cortical rCBFs were lower than those for adults; after birth they increased until 5 or 6 yr of age to values 50%–85% higher than those for adults and thereafter decreased, reaching adult levels between 15 and 19 yr. Neonatal values of rCBF on cerebellum and thalamus were slightly higher than adult level, but not significantly; after age 1, they followed the common pattern for cortical curves. When rCBFs were expressed in percent global CBF, they were lower at birth than adult levels in the cortex, then increased and reached a plateau corresponding to the adult value before the second year of age. The time needed to reach normal adult values differed for each cortical region. The shortest time was found on the primary cortex and the longest on the associative cortex. Cognitive development of the child seems to be related to changes in blood flow of the corresponding brain regions.

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Human brain maturation is incomplete at birth and continues to progress during the first years of life. It has been shown that brain development is associated with regional changes in glucose cerebral metabolic rate (rCMRG) (*1,2*) and cerebral blood flow (rCBF) (*3*). Regional metabolic changes, studied by positron emission tomography (PET), were observed throughout childhood. Regional flow changes, were studied with single-photon emission computed tomography (SPECT) with ^{133}Xe during the two first years of life (*3*). Because measuring rCBF by SPECT is simple and can be used routinely in children, our study covered all ages. The results obtained in 42 neurologically normal children showed rCBF changes observed throughout childhood and represent a first attempt to define rCBF reference values in children.

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MATERIALS AND METHODS

Patients

Forty-two children, 18 girls and 24 boys, were selected a posteriori from 800 children who had rCBF study in our center between 1983 and 1989 for neurological problems retrospectively found to be transient and unaccompanied by cerebral lesion. Neurological examination, EEG and CT scan were normal at the time of the study and psychomotor development studied for at least 2 yr was also normal. Ages ranged from 2 days to 19 years, with 60% of the patients under 2 yr. All studies were performed in accordance with the Ethical Committees of French Public Hospitals and the French Atomic Energy Commission guideline and with informed consent from the parents. The adult reference group consisted of 32 subjects aged 19–29 yr, who were free of cerebral pathology and had normal CT scans.

rCBF Measurement

rCBF was measured in all children with the same brain-dedicated SPECT system, TOMOMATIC 564, using 133-Xe (*4, 5*). This highly sensitive tomographic system provided five contiguous 2-cm thick slices with a spatial resolution of 12 mm. Xenon-133 was administered to children over 5 yr of age by inhalation (as in adults) using a concentration of 740 MBq/liter (20 mCi/liter). Xenon-133 was injected intravenously to the younger and uncooperative children in a dose of 55.5–92.5 MBq/kg (1.5 to 2.5 mCi/kg), and premedication of 4 mg/kg of rectal pentobarbital and of 0.5 mg/kg of intramuscular droperidol was administered to avoid head movement during acquisition. After reconstruction, rCBF was calculated with the algorithms of Celsis et al. (*6*). End-tidal pCO2 was monitored and varied slightly, rCBF values were not corrected for variations. The study was performed in dimmed light and without talking. The subject's head was placed so that SPECT slices were parallel to the orbitomeatal (OM) line. In children ranging in age from newborn to 4 yr, the first slice was centered on the OM line and the five slices were OM, OM + 20, + 40, + 60 and + 80 mm. In children 4 yr or older, the five slices were OM + 20, + 40, + 60, + 80 and + 100 mm. The radiation dose to the lung (the target organ) was 250–450 mrads (*7,8*).

Definition of the Studied Regions

Twenty-five regions of interest (ROIs) were delineated on each slice (Fig. 1). Twenty-one ROIs were positioned in the cortical ribbon; two others were subcortical and corresponded to the thalamus on slice OM + 40 mm. The last two surrounded each half slice. The ROIs were circular except for the thalamic areas and had a diameter larger than 1.5 cm. The set of ROIs was

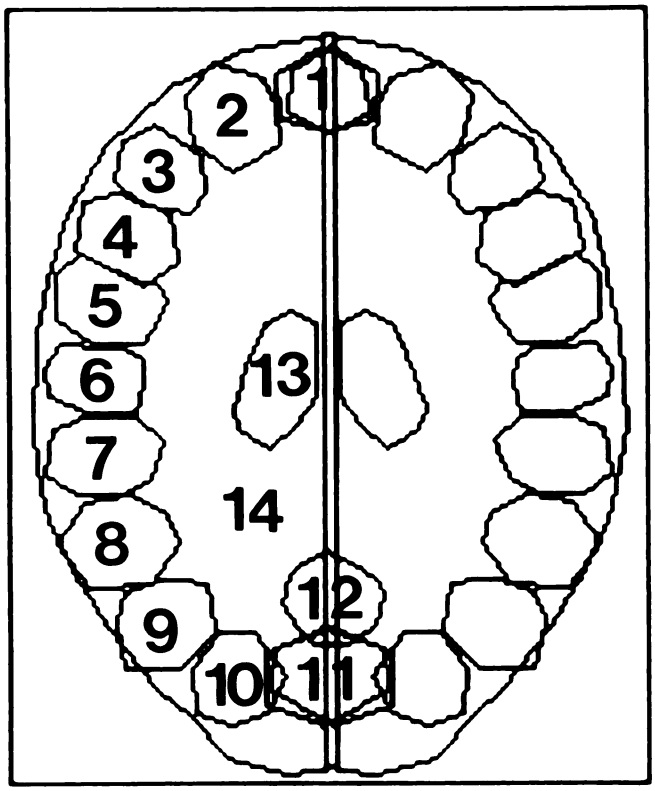

FIGURE 1. Set of 25 ROIs delineated on each SPECT slice. The set size adapted to the dimensions of the brain image of each slice.

adapted by software to the brain size of each SPECT slice. rCBF was calculated for each ROI and the values used were the mean of both sides.

The global or mean CBF (mCBF) was the mean value of the large ROIs surrounding a hemislice on the four upper slices and of an ROI surrounding the cerebellum on the lowest slice.

rCBF was calculated in eleven cerebral regions. Eight cortical regions were defined according to Brodmann's map of the human brain (Fig. 2). Three are involved in primary cognitive functions: SM, the primary motor and somatosensory cortex; VIS; the primary visual cortex; and AU, which contains the primary auditory cortex (*9,10*). Four other regions are involved in associative cognitive functions: the unimodal parieto-temporo-occipital region, (UPTO) implicated in visual associative functions; the polymodal parieto-temporal region (PPT), which is involved in multi-sensorial associative functions; the frontal region (FR), which corresponds to the prefrontal cortex; and the region corresponding to Broca's area (BR) in the left hemisphere (*9,10*). TP corresponded to the temporal pole. Three non-cortical areas were studied: the cerebellar hemisphere (CH); the vermis (VE); and the thalamus (TH). The rCBF of CH was measured on ROI 8 and 9 of slice OM or OM + 20; the rCBF of VE was measured on ROI 12 of OM + 20; and the rCBF of TH was measured on ROI 13 of OM + 40 (Fig. 1).

These regions were localized on SPECT slices with an MRI atlas that provided brain sections parallel to the OM line at various ages of childhood (*11*). Brodmann's areas were previously positioned on the atlas slices (*12*). The set of predefined 25 ROIs delineated on the SPECT slices was enlarged or reduced to fit the brain contour of the corresponding atlas slices. Anatomical structures and Brodmann's areas were transferred from the ROIs of the atlas slices to the ROIs of the SPECT slices. Every region studied included one or several ROIs. The ROIs overlapping two functional regions were discarded and only ROIs entirely included in a functional region were used.

Data Analysis

For the statistical study, six age groups were formed consisting of approximately the same number of children from birth to 1.5 mo, 2 to 7 mo, 9 to 15 mo, 16 to 22 mo, 2 to 4 yr and 6 to 19 yr (Table 1). The mean rCBF for each region of the six groups was tested using ANOVA.

The measured data for each region were plotted against age and a five-point smoothing was used to define running average and standard deviation for every age of childhood. rCBFs presented were read on regional curves obtained after the five-point

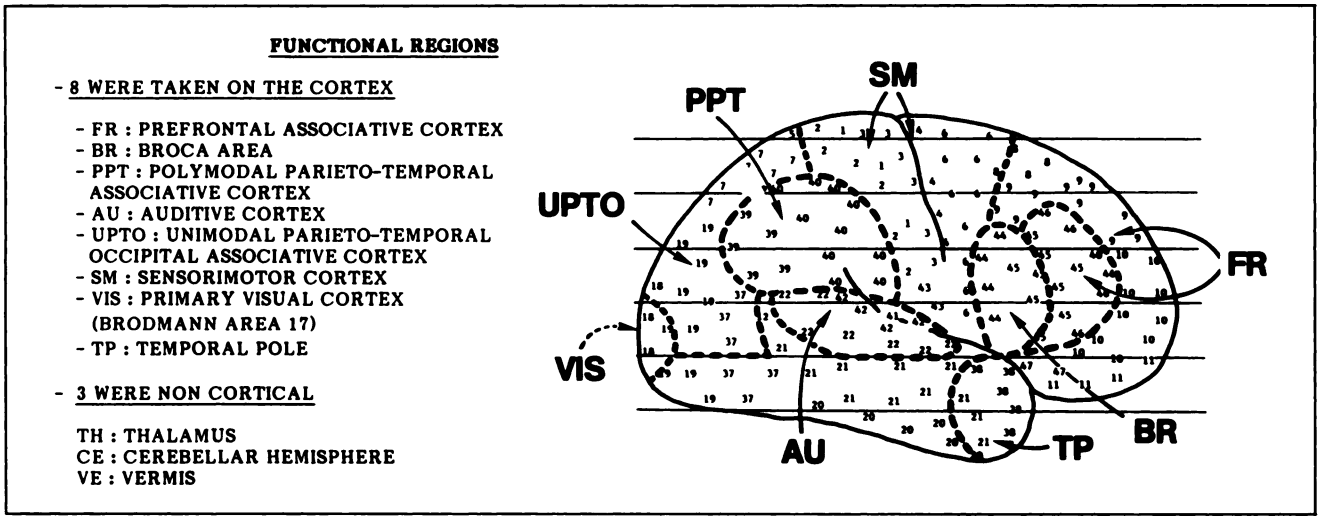

FIGURE 2. Definition of the eight functional cortical regions. Brodmann's areas, represented by numbers, were positioned according to Talairach (*12*). Primary visual cortex (VIS), corresponding to Brodmann's area 17, is mainly located on the medial surface.

TABLE 1
Mean rCBr and Standard Deviation for Children in Six Age Groups and for the Adult Control Group

	n		mCBF	FR	BR	PPT	AU	UPTO	SM	VIS	TP	CH	TH	VE
Group 1		M	50	34	45	39	43	41	43	46	46	75	77	82
(2–45 d)	7	SD	3.4	3.5	3.4	5.8	8.3	6.5	6.0	9.0	3.8	20.7	9.0	15.3
Group 2		M	55	41	53	53	59	52	50	55	51	54	72	74
(2–7 mo)	7	SD	5.3	4.9	6.3	8.5	7.3	7.3	7.0	10.3	6.3	5.5	8.9	9.4
Group 3		M	60	55	63	66	66	63	59	63	61	58	70	67
(9–15 mo)	7	SD	6.7	9.1	11.0	7.5	6.6	7.0	12.2	7.7	5.1	8.1	14.1	6.5
Group 4		M	62	54	63	65	70	62	59	64	63	66	70	71
(16–22 mo)	5	SD	7.6	6.0	10.5	10.3	10.3	5.6	8.1	11.4	8.0	10.7	11.3	3.8
Group 5		M	65	59	67	70	76	67	67	65	65	67	76	70
(2–4 yr)	7	SD	7.8	6.0	9.5	10.0	9.2	10.6	9.4	7.8	6.0	12.8	13.0	14.3
Group 6		M	62	61	67	65	65	64	65	64	66	72	70	74
(6–19 yr)	10	SD	9.6	8.6	11.1	11.4	9.0	11.3	13.1	8.9	12.0	11.9	13.4	12.5
Adults		M	51	47	55	49	55	46	45	51	51	53	61	61
(18–29 yr)	32	SD	7.7	8.1	9.8	7.5	9.2	7.6	7.5	9.4	8.5	10.5	11.6	9.0

M = mean value and SD = standard deviation.

smoothing. rCBFs were expressed in absolute values (ml/mn/100 g of cerebral tissue) (Table 2) and in relative values (%mCBF) defined by the ratio of absolute rCBF to mCBF at a given age.

RESULTS

The rCBF images showed changes related to age. The statistical study of these changes for the six age groups (Table 1) showed an age effect on every cortical region ($p < 0.001$) and on global blood flow ($p < 0.004$).

Absolute rCBF

Entire Brain. Global blood flow at birth averaged 50 ml/min/100 g (Fig. 3), increasing after birth to a maximum of 71 at 5 yr and then decreasing to reach adult levels after 19 yr (Table 2).

TABLE 2
Reference Values of rCBF and Standard Deviation Throughout Childhood Expressed in Absolute Values After a Five-Point Smooth

AGE	mCBF	FR	BR	PPT	AU	UPTO	SM	VIS	TP	CH	TH	VE
0	50/3	33/3	42/3	38/5	40/5	36/4	39/2	44/8	45/3			
1 m	49/2	34/4	46/3	37/4	40/6	41/7	41/3	45/10	46/5	69/10	73/7	79/8
2 m	53/5	38/2	47/3	45/6	55/6	47/5	47/7	53/5	49/6	59/11	74/13	71/5
3 m	53/4	38/3	48/4	48/4	56/5	47/4	48/6	51/4	50/4	53/3	73/12	71/5
4.5 m	53/4	40/4	51/6	51/7	58/7	50/5	49/8	51/7	48/4	51/1	70/9	70/4
6 m	57/4	43/4	55/6	56/7	62/7	55/6	52/6	57/11	51/7	54/7	73/4	75/11
9 m	58/6	48/5	58/9	59/6	62/6	58/4	51/5	62/8	56/7	60/8	68/12	74/12
10 m	59/6	50/5	60/9	62/5	63/6	60/5	53/7	63/9	59/4	61/7	67/12	75/12
12 m	59/6	54/6	63/7	65/7	65/7	64/7	58/7	62/6	61/6	61/8	69/11	70/5
15 m	60/7	57/9	65/11	66/9	67/7	65/7	62/12	62/9	61/6	58/8	71/13	65/5
18 m	64/6	55/5	67/8	68/10	73/10	64/5	63/5	68/10	67/6	68/11	75/12	73/3
22 m	64/6	56/4	65/10	68/9	74/7	63/5	63/5	68/10	67/5	61/10	73/14	71/7
31 m	62/5	58/4	64/7	65/5	72/6	70/11	65/8	61/6	64/6	72/18	70/9	64/10
3 y	70/7	63/5	71/7	75/10	78/9	73/10	75/7	66/7	70/8	76/18	80/10	72/17
4 y	71/6	65/3	73/6	77/9	80/8	73/10	77/6	67/6	74/7	75/18	83/9	75/16
6 y	71/6	67/4	73/6	75/11	78/9	69/5	76/7	68/5	73/7	75/18	84/7	77/13
8 y	71/6	68/2	74/5	77/10	75/11	68/5	75/8	70/5	73/8	81/9	80/14	78/11
11 y	66/4	65/5	74/2	68/7	69/8	69/6	69/5	64/6	70/6	75/6	74/11	72/8
12 y	62/8	59/8	70/11	65/9	64/9	65/11	65/11	66/10	68/5	73/5	69/13	79/13
16 y	56/10	53/9	61/14	58/11	64/9	58/15	58/14	62/11	60/13	64/11	64/15	76/17
19 y	53/10	51/8	57/12	57/11	60/9	54/15	53/14	60/12	56/12	61/11	62/14	71/17
22 y	51/8	47/8	55/10	49/7	55/9	46/7	45/7	51/9	51/8	53/10	61/12	61/9

MCBF = global CBF. See text for regional cortex abbreviations.

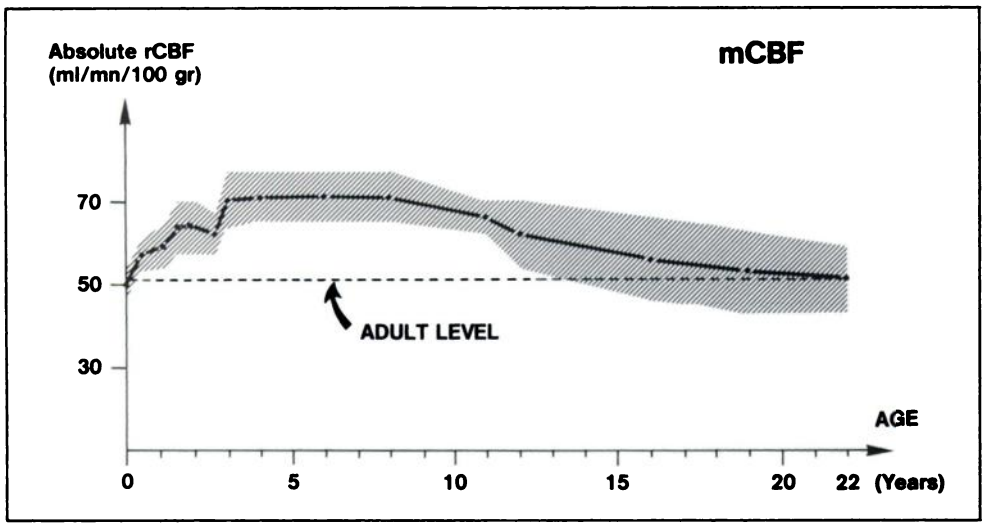

FIGURE 3. Curve for global blood flow against age. The solid line represents the reference values obtained by a five-point smoothing of experimental data and expressed in absolute values. The hatched area corresponds to the interval defined by the reference values plus or minus one standard deviation. The broken line indicates the adult level.

Cortical Regions. All rCBFs at birth were lower than adult levels, ranging from 33 to 45 ml/min/100 g; the highest value was found on TP, followed by VIS, BR, AU, SM, PPT, UPTO and FR (Table 2). After birth, all rCBFs increased, reaching a maximum at 5 or 6 yr, which was 70% higher than adult levels, and then decreasing to attain adult levels after 15 yr (Fig. 4).

Non-cortical Regions. Values for non-cortical regions of two newborn children were discarded because they were extremely high and questionable. Absolute flows were therefore calculated only from 1 mo. rCBF of CH, VE and TH was higher than the adult level in the first months of life, but this increase was not significant (Table 2). After 1 yr, rCBF of CH and TH increased, reaching a maximum at 5 or 6 yr, as in cortical regions, and then progressively decreased to adult values. Vermis rCBF was higher than the adult range and remained approximately at the same level throughout childhood.

Relative rCBF

Relative rCBFs expressed the regional flow as %global CBF and represented a normalization of rCBFs for the mCBF changes.

Cortical Regions. Relative cortical rCBFs were lower at birth than during adulthood, increased in the first two years of life and then remained in plateau during the rest of childhood at approximately the adult level with less than 10% variation (Fig. 5). The plateau values for UPTO and SM remained higher than the adult levels by 10%–20%.

Relative rCBF reached the adult level in the following order: SM between 2 and 4 mo, VIS between 2 and 6 mo, AU at 4 or 5 mo, UPTO at 7 mo, PPT at 10 mo, TP at 12 mo, FR between 13 and 24 mo and BR after 16 mo. For BR, it was difficult to accurately define the age at which the adult level was reached because of scattered data.

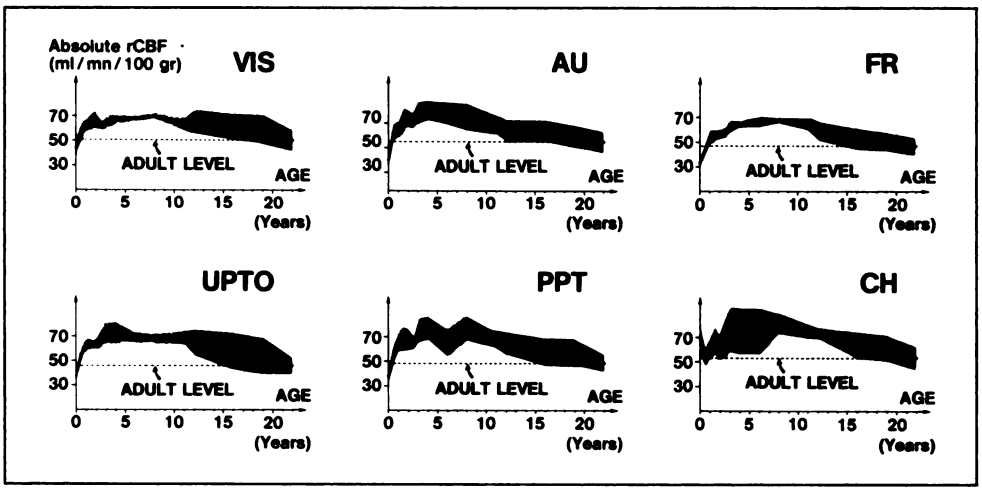

FIGURE 4. Curves for absolute regional blood flow against age, expressed in absolute amounts. For legend see Figures 2 and 3.

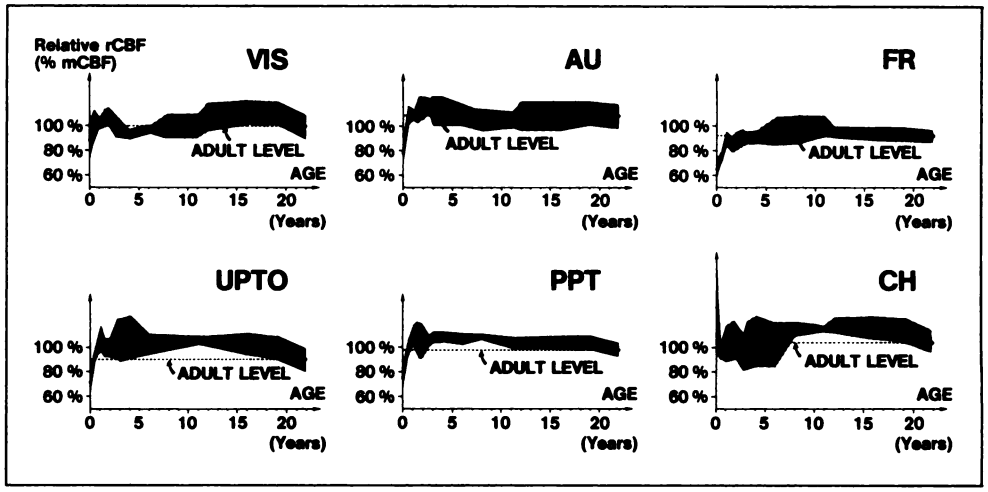

FIGURE 5. Curves for relative regional blood flow against age, expressed as % global blood flow. For legend see Figures 2 and 3.

Non-cortical Regions. Relative rCBF of TH and VE was higher at 1 mo of age than the corresponding adult level by 26% and 33%, respectively. They then decreased, reaching adult levels at about 7 and 12 mo, respectively, and remained approximately in plateau, although they varied more widely than the levels for cortical regions. The relative rCBF of CH remained approximately in plateau in the range of the adult throughout childhood.

DISCUSSION

Our initial CBF studies covered global CBF; this study focused on regional blood flows. Studies in animals indicate that rCBFs increase after birth with regional differences (*13,14*). Volpe was the first to report rCBF data in human newborns with PET, but none of his patients could be considered normal (*15*). Tzourio et al., using ^{133}Xe, showed that cortical rCBFs in infants were low and heterogeneous at birth and gradually increased during the first two years (*3*). This was confirmed by Rubinstein using a semiquantitative method with [^{123}I]IMP (*16*). Ogawa et al. found different results with ^{133}Xe during the first years of life with high values at birth followed by a progressive decrease to adult levels (*17*). Chugani studied the metabolic rates of glucose with 2-deoxy-2(^{18}F)fluoro-d-glucose (FDG) and PET and found that these rates were low at birth, rapidly rising to reach adult values by 2 yr of age, continuing to rise until approximately 9 yr and then declining to reach adult level late in the second decade (*2*). The present study shows that regional blood flows follow a similar pattern, confirming that under normal conditions blood flow and metabolism are closely related in childhood, as demonstrated by Kennedy in a newborn nonhuman primate (*18*). The present work provides rCBF reference values according to age that can be used in pathological situations and shows regional characteristics of brain development.

Methodological Considerations

The SPECT method used for measuring regional blood flow by inhalation of ^{133}Xe (*4,5*) has been validated in adults (*19*) and can be used in cooperative children, generally over 5 yr of age. In the present study, this method was adapted for young and uncooperative children by replacing inhalation of the ^{133}Xe with intravenous injection and by adding premedication. The effect of the tracer administration mode was checked in 10 children and found not to be statistically significant on global CBF (Table 3). The effect of premedication was studied in two other groups of children: one given only pentobarbital and the other given both pentobarbital and droperidol. No statistically significant differences in mCBF was found in the groups before or after premedication (Table 3). Similar results obtained with pentobarbital were previously reported by Kety et al. (*20*). Because the ^{133}Xe administration mode and the premedication used did not induce significant modification of CBF, results obtained with inhalation without sedation and by injection with premedication could be processed together. The overall reproductibility of the SPECT method was studied in 37 children, and rCBF measurement accuracy, i.e., residual error, was 7.5% (*21*).

Running averages and standard deviation of regional blood flows proposed as reference values were calculated from experimental data with a five-point smooth. To control the reliability of the fitting procedure, experimental data were also fitted with a third-degree polynomial function and a gamma function. The results obtained did not differ significantly from those of the five-point smooth, with differences smaller than 6%, except between 3 and 8 yr of age. During this period, results differed by 7%–11%, but only when the third polynomial function was used.

As a result of partial volume averaging, it was shown that the use of regions 1.5 cm or smaller in diameter may result in a 25%–50% error when using a 12-mm resolution collimator (*22*). In our study, all regions were larger than 1.5 cm in diameter except for AU, VIS and BR in the two youngest subjects. This potential error should have minor effects on our findings.

TABLE 3
Methodological Aspects

Age (yr)	Inhalation*	Injection*	Age (yr)	Injection*	Injection*+ pentobarbital
13	43	44	12	53	53
16	49	63	15	42	39
8	62	74	13	44	45
6	70	76	16	47	53
16	58	48	13	63	62
4.5	75	88	8	74	62
8	71	61	12	60	61
10	69	61	15	48	48
11	45	33	11	59	70
62	61	59	19	41	42
mean	60.3 (±11.4)	60.7 (±16.2)	mean	53.1 (±10.7)	53.5 (±10.1)

With 12-mm axial resolution and 20-mm slice thickness, the performance of our SPECT system is well below those of recent PET systems, but is now the best means for measuring rCBF with SPECT and its performance conforms to that obtained by PET in the mid 1980s. Despite its limitations, this SPECT method is the only quantitative method that can be routinely used in children because it needs no arterial or arterialized blood sampling, takes 5 min to perform and delivers a low radiation dose to the target organ.

Contours of the regions selected on SPECT slices were defined using a new MRI atlas of a child's brain (*11*). The regions studied were previously defined by referring to adult atlases, assuming that a child's brain was a small adult brain. The localization procedure used in the present study accounts for anatomical brain changes with age and is more accurate.

Significance of Absolute Values

The pattern of the cortical rCBF curves, an increasing phase followed by a decreasing phase and maximum values observed between ages 5 and 8 yr, has already been found in metabolic studies (*1*). The increasing phase may correspond to the period of postnatal brain growth (*23*), mainly supported by myelination (*24,25*) and dendritic growth (*26*). The decreasing phase may be related to selective synaptic stabilization corresponding to a dramatic decrease in the number of synapses (*27,28*). Such a transient postnatal overshoot has been described for most synaptic markers, including synaptic density (*29*), enzymatic activity (*30*) and receptor density (*31*). The relationship with postnatal angiogenesis, which has not been extensively studied, is not as clear. In the first months of life, capillary density increases in the cortex, whereas the density of the radially oriented primitive vessels decreases throughout development (*32*).

High rCBF values found in the cerebellum at birth were not reported in the rCMRGlu study, but results obtained between birth and 12 mo were pooled (*2*). The early high blood flow may be related to the intense proliferation of the granular cells of the external layer described at this age. During the first months of life, these cells migrate to the deep layers and their activity decreases. Migration is completed at approximately age 10 mo (*33*).

Usefulness of Relative Values

The expression mode in relative flows that normalizes regional values for global changes facilitates the interpretation of regional changes. Relative cortical rCBF increased to reach a plateau after birth and does not show a decreasing phase as absolute values do. The absence of a decreasing phase may mean that postnatal synaptic regression involves the entire brain without any regional predominance.

A primary cortex such as VIS, AU and SM shows higher relative rCBFs at birth and requires a shorter time to reach normal adult values than such associative cortices as UPTO, PPT, FR and BR, suggesting a more advanced maturation of the sensorial and motor regions. Such data agree with metabolic, morphological and histoenzymological findings already reported (*1,2,30,33*).

PET and SPECT stimulation studies provide additional data for neuropsychology in localizing mental operations (*34–37*). The development of cognitive functions in children has been related to a regional metabolic increase and should also be related to an increase in rCBF. Our results seem to support the existence of such a relationship for visual, auditory and frontal functions. Visual function, which takes place in the first 6 mo of life (*38*), is partly sustained by VIS and UPTO. The relative rCBF of these areas similarly reach adult levels at approximately 6 and 7 mo. Integration of visual modalities dependent on PPT appears a few months later; relative rCBF similarly reaches adult levels by 10 mo in this area. Auditive function also develops during the first year of life. Differentiation of phonemes sustained by AU precedes the recognition of sounds and sentences dependent on PPT (*39*). Relative AU and PPT rCBF reach adult levels in the same sequence at 5 and 10 mo, respectively. Frontal functions sustained by frontal cortex include higher cognitive abilities (*40*) which appear after 2 yr of age. The relative FR rCBF similarly reaches adult values by 2 or 3 yr of age. These examples suggest that the development of cognitive functions is related to an rCBF increase in the corresponding cortical regions. The time needed to reach relative normal adult rCBFs may be considered an index of regional maturation.

CONCLUSION

This study defines the reference values of rCBF for the main functional regions of the brain at various ages in childhood. It describes the characteristics of cerebral developmental changes and confirms that the first year of life is a decisive moment for human brain maturation.

APPENDIX

Age, Sex and Measured rCBF Values for 42 Neurologically Normal Children

AGE	SEX	mCBF	FR	BR	PPT	AU	UPTO	SM	VIS	TP	CH	TH	VE
2d	F	50	36	40	44	43	36	39	46	46	56	91	112
18d	F	48	29	44	34	37	31	36	49	45	80	67	83
27d	M	52	33	41	35	37	40	42	36	44	117	75	89
30d	F	45	35	48	34	34	39	40	33	50	66	73	80
45d	M	50	32	47	44	44	47	44	46	50	67	67	66
45d	F	49	39	49	37	49	50	43	59	39	78	83	77
45d	M	56	3	44	48	58	43	55	52	46	59	83	69
2m	M	56	40	52	49	58	51	53	56	54	54	83	76
3m	F	46	34	44	40	49	41	39	45	48	52	55	67
3.5m	F	56	38	47	51	62	50	46	54	55	50	68	66
4.5m	F	53	41	51	50	51	49	47	48	48	51	78	75
6m	M	56	44	59	61	67	55	60	48	44	53	75	71
7m	F	55	45	54	52	60	54	54	62	46	51	72	71
7m	M	64	49	62	66	68	65	55	75	62	66	74	94
9m	M	54	46	50	61	62	57	45	56	58	54	56	66
10m	F	66	56	73	63	67	58	57	64	63	70	84	76
11m	M	51	43	53	53	54	54	46	53	52	60	56	65
12m	M	58	54	62	67	65	67	62	67	59	56	67	74
13m	M	63	59	63	70	72	69	65	65	68	51	74	70
14.5m	M	59	57	62	70	67	71	59	59	62	68	63	64
15m	M	70	71	82	76	74	69	81	76	64	49	93	57
16m	M	53	49	50	57	62	57	47	52	53	65	62	65
16m	M	55	47	66	56	58	57	58	56	58	55	62	69
17m	F	64	62	71	79	84	69	67	68	74	66	89	72
18m	F	71	56	74	59	75	61	57	81	64	59	72	75
22m	F	66	55	54	72	70	67	66	62	66	83	66	72
27m	M	66	53	72	73	78	66	66	74	71	75	85	77
30m	M	54	52	55	59	65	56	57	55	60	56	54	60
30m	F	61	58	57	61	67	64	56	69	57	62	71	81
31m	F	65	57	66	69	71	63	68	59	60	63	73	58
33m	M	65	64	71	72	81	89	76	58	69	71	72	56
3y	M	65	61	69	65	76	61	68	65	72	45	79	64
3.9y	F	80	69	83	89	92	89	82	74	67	86	96	94
6y	M	74	66	68	82	69	69	83	72	81	91	81	87
8y	F	72	7	74	78	80	77	77	67	81	84	86	73
10y	M	61	71	72	63	72	67	71	62	66	67	78	69
11y	M	64	65	73	71	62	64	63	74	68	76	57	69
11y	F	64	61	77	65	71	67	69	57	67	75	75	64
12y	M	62	59	74	61	61	66	67	62	69	71	73	85
12y	M	71	65	78	76	73	80	78	80	76	79	86	98
16y	F	50	45	50	52	51	50	48	59	61	65	54	79
19y	M	47	49	50	53	60	51	52	58	45	56	50	60
22y		51	47	55	50	55	46	45	51	51	53	61	61

See text for regional abbreviations.

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